Chapter 2
Soil Characteristics That Affect Productivity and Influence Best Management Practices

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Soil profile and master horizons

Douglas-fir forests occupy a wide range of soils. Having a conceptual understanding of how soils are formed and positioned on the landscape and how soil characteristics affect forest productivity will help forest managers maintain healthy, productive forests. If you dig a pit in any forest soil, you will see different layers in the profile. These layers are called master horizons. These horizons are distinguished by differences in composition and color as well as soil structure and texture. In a typical forest soil, you are likely to see some or all of master horizons O, A, E, B, C, and rock (figure 2.1).

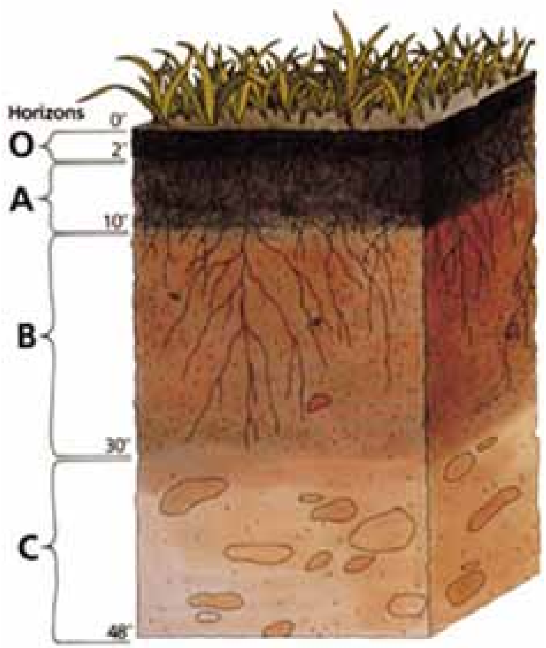

Figure 2.1. Soil profile diagram showing master horizons.

Image courtesy of USDA-NRCS.

Description of master horizons

The following descriptions can help you identify which master horizons your soil may have:

- **O Horizon**: organic horizon or forest floor; composed mostly of leaves, needles, and other organic matter; usually above mineral horizons
- **A Horizon**: a surface mineral horizon; mixture of organic matter and mineral material; usually darker in color than horizons below because of higher organic matter content
- **E Horizon**: can be a surface mineral horizon directly beneath an O or A horizon; light in color (usually off-white or gray); common in undisturbed forest soils and develops this color after loss of clay, iron, aluminum, or organic matter
- **B Horizon**: mineral horizon with
  - an increase in clay, iron, aluminum, and organic matter that has been deposited from the E horizon above; or
  - substantial alteration of the original parent material that eliminated original rock structure and formed clays or oxides with a resultant change in color and structure; or
  - both of these characteristics
- **C Horizon**: mineral horizon little altered from its parent material and lacking properties of an A, E, or B horizon
- **Rock**: parent rock relatively unchanged or with some signs of weathering

If you have used a soil survey map, you might have noticed some small letters that accompany the master horizons, such as O*i*, O*e*, or O*a*. These letters are called subordinate horizon designations and are used to indicate some specific distinctive properties of a master horizon that help you identify and understand why one soil might be different from another soil on your property. For example,

- *i* stands for organic matter that is slightly decomposed but still recognizable in its original form (e.g., needle fragments),
- *e* stands for organic matter that is intermediate in decomposition, and
- *a* stands for organic matter that is highly decomposed and not recognizable.

Basic soil physical properties

Understanding the following physical properties of a soil will help you interpret what you see in the field.

Color

Horizon color offers clues about the nutritional status, type of horizon, and processes occurring in that horizon. You will find three basic colors in horizons:

- Organic matter—usually black or brown
- Free iron oxides—usually reddish (in well-drained soils), yellowish brown or orange (in less drained or oxidized soil), or gray to bluish gray (in poorly drained soils)
- Uncoated mineral grains—usually gray but may be any color depending on the minerals present

Soil color can also be described using color charts and noted by horizon on soil profile descriptions. For example, the 10YR4/3 soil color can be interpreted as follows:

- Hue (10YR) is the dominant primary color (yellow-red).
- Value (4) describes the lightness or darkness (0 = black and 10 = white).
- Chroma (3) describes the intensity and brightness of the colors.

Texture

Soil texture describes the proportion of various mineral-size particles in the soil that are less than 2 mm in diameter:

- Sand particles are smaller than 2 mm but larger than 0.05 mm in diameter.
- Silt particles are smaller than 0.05 mm but larger than 0.002 mm in diameter.
- Clay particles are smaller than 0.002 mm in diameter.

After the particle size distribution is determined with tests in a soil lab, texture is determined according to the percentages of sand, silt, and clay by using the soil textural triangle (figure 2.2) or the two-axis Canadian soil texture triangle (figure 2.3). This method yields common terms such as clay loam, sandy loam, and silty clay loam. The textural class of a soil directly affects water-holding capacity, water movement, aeration or porosity, bonding of soil particles into stable aggregates, soil microorganisms, root growth, and soil temperature dynamics.

Stones, cobbles, and gravel are larger than 2 mm in diameter, and their presence is used to modify a soil texture (e.g., a gravelly sandy loam). These coarse materials can affect soil trafficability, water-storage capacity, and forest productivity. For example, if you have more than 80% stone in your soil, the volume of fine soil is greatly reduced; this, in turn, greatly limits forest productivity.

The USDA Natural Resources Conservation Service provides a useful field guide for determining soil texture on this website: *http://soils.usda.gov/education/resources/lessons/texture/*.

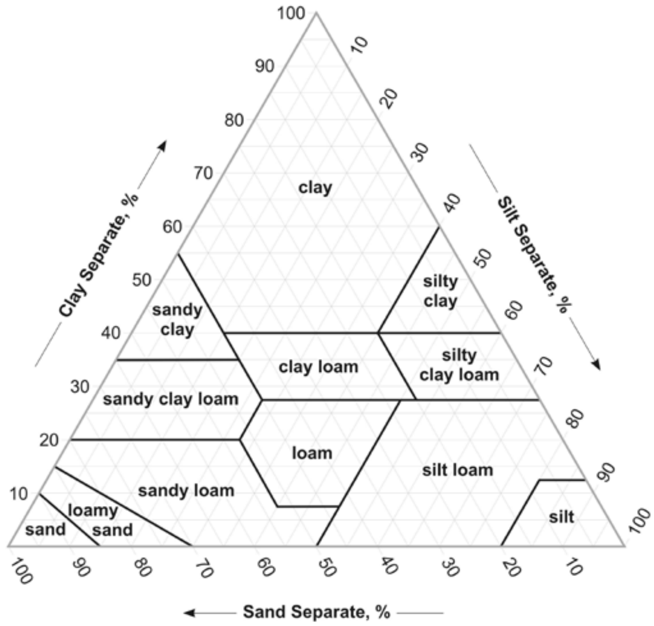

Figure 2.2. Soil textural triangle used for determining soil texture.

Image courtesy of USDA-NRCS.

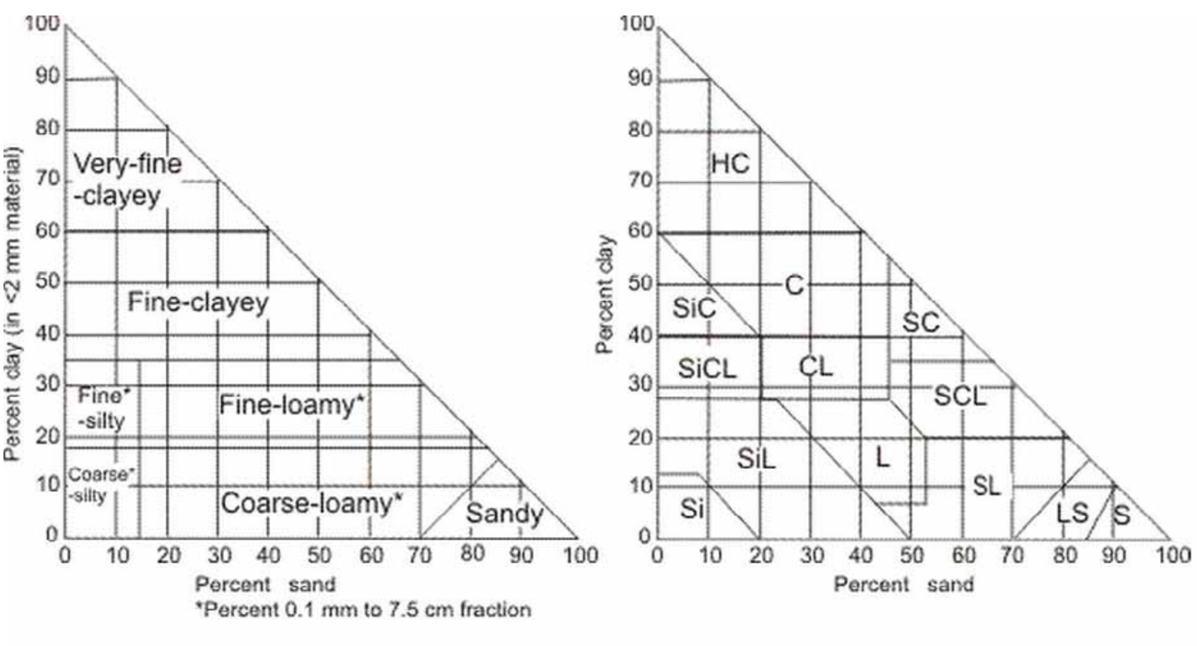

Figure 2.3. Canadian soil texture triangle that uses only two axes to determine soil texture from percentages of sand and clay. Abbreviations for the texture classes: HC, heavy clay; C, clay; SiC, silty clay; SiCL, silty clay loam; CL, clay loam; SC, sandy clay; SiL, silt loam; L, loam; SCL, sandy clay loam; SL, sandy loam; Si, silt; LS, loamy sand; S, sand.

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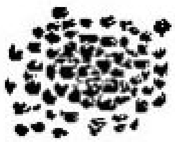
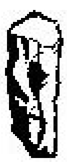


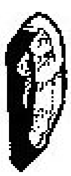
Granular. Roughly spherical, like grape nuts. Usually 1–10 mm in diamteter. Most common in A horizons, where plant roots, microorganisms, and sticky products of organic matter decomposition bind soil grains into granular aggregates.

Platy. Flat peds that lie horizontally in the soil. Platy structure can be found in A, B, and C horizons. It commonly occurs in an A horizon as the result of compaction.

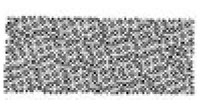
Blocky. Roughly cube shaped with more or less flat surfaces. If edges and corners remain sharp, we call it angular blocky. If they are rounded, we call it subangular blocky. Sizes commonly range from 5–50 mm across. Blocky structures are typical of B horizons, especially those with a high clay content. They form by repeated expansion and contraction of clay minerals.



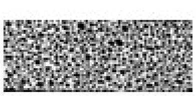
Prismatic. Larger, vertically elongated blocks, often with five sides. Sizes are commonly 10–100 mm across. Prismatic structures commonly occur in fragipans.



Columnar. The units are similar to prisms and are bounded by flat or slightly rounded vertical faces. The tops of columns, in contrast to those of prisms, are very distinct and normally rounded.



Massive. Compact, coherent soil not separated into peds of any kind. Massive structures in clayey soils usually have very small pores, slow permeability, and poor aeration.



Single grain. In some very sandy soils, every grain acts independently, and there is no binding agent to hold the grains together into peds. Permeability is rapid, but fertility and water holding capacity are low.

Figure 2.4. Types of soil structures.

Images and descriptions courtesy of USDA-NRCS.

Structure

Soil structure is the arrangement of soil particles into clumps or aggregates. The degree of aggregation varies in different soils and ranges from single grained (each particle acts independently) to massive (particles are completely stuck together; figure 2.4). Soil strength, root penetration, soil air and water movement, and ease of erosion are significantly dependent on soil structure.

Though soil texture is not easily changed in any given soil, soil structure is especially vulnerable to management activities. For example, a granular structure can quickly change to a platy structure if equipment compacts moist or wet soil. Such changes can increase soil strength (restricting root elongation), reduce large or macropore space (lessening aeration), and restrict water infiltration (increasing water runoff potential).

Bulk density and porosity

If you took a cup of undisturbed soil (void of rocks), weighed it (oven-dry weight) to get its mass, and then divided this mass by the volume of the cup, you would get its bulk density in units of g/cm^3. The higher the bulk density, the more compacted (massive) the soil. Texture, organic matter content, and amount of volcanic material can affect soil bulk density. Soils high in organic matter or volcanic ash content can have relatively low bulk densities. Typically, a good range for bulk density is 0.75 to 1.0 g/cm^3 for surface soils in high-productivity sites. At a soil bulk density of 1.6 g/cm^3, root penetration is seriously impeded. If you suspect you have compacted soils, it would be wise to check the soil's bulk density.

Porosity refers to the void space occupied by air and water in soils. Porosity is important for gas exchange and drainage of water. Larger macropores (diameter larger than about 0.05 mm) are particularly important for adequate oxygen supply to plant roots, diffusion of carbon dioxide produced by respiring organisms and plant roots, and water infiltration and drainage.

Water-holding capacity

Water is a very important soil component that is required for plant growth and adequate nutrient supply. Small pores (micropores) in the soil are responsible for capillary action that draws water from wet areas to dry areas in the soil. These small pores are more prevalent in clayey soils than sandy soils; therefore, these two types of soils have different water-retention capabilities (clayey soils will have a greater water-holding capacity than sandy soils).

Soil water-holding capacity is important in the Pacific Northwest, where a relatively low percentage of the annual rainfall occurs during the growing season. This limitation is particularly important for young trees during summer months as their roots are not fully developed and may not be deep enough to obtain the water necessary for growth. Soil depth is an important factor in tree growth. In general, deeper soil means better potential for tree growth because the volume of soil that can be occupied by plant roots has a direct effect on soil water supply and the capability of that soil to supply nutrients for plant growth. Soil water content also affects soil strength. With the exception of sandy soils, dry soils usually have higher soil strength than moist soils. Impedance of root growth is greatest in high-strength soils with poor soil structure.

Temperature

Dry soils warm faster than wet soils, especially in the spring. This is because the heat capacity and ability to conduct heat is higher for water than soil solids. In physics terms, a higher moisture content in surface soil reduces the increase in temperature per absorption of a unit quantity of heat and increases the soil's thermal conductivity and downward conduction of heat rather than its retention in the surface zone (Hillel 1998).

Douglas-fir root growth is temperature sensitive. Minimal root growth occurs at temperatures of 5°C to 10°C (41°F to 50°F), and maximum root growth occurs at about 20°C (68°F). Water uptake by Douglas-fir roots ceases at about 5°C (41°F). Soil temperature also affects microorganism activities and, therefore, the speed of nutrient and organic matter cycling. Organic matter cycling generally increases with increasing soil temperature as long as moisture is available.

Certain forest management practices can affect soil temperature. Reducing stand density and crown cover during thinning or final harvest will increase soil temperature during the growing season, as will removal of harvest residuals (slash) and surface organic matter. Weeds shade the soil from sunlight, so weed control may hasten soil warming.

Key references and other resources

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