Oregon Envirothon Soils and Land Use Manual

About This Guide

This publication was created by Marissa Theve, soil scientist at the Bureau of Land Management (BLM) and Garrett Duyck, soil conservationist at the Natural Resources Conservation Service (NRCS) in 2020. It is inspired by the Oregon State University (OSU) publication Manual for Judging Oregon Soils from 2006 and the NRCS's Connecticut Envirothon Soil Manual which Marissa helped update in 2014. The manual is intended as a starting point for Oregon Envirothon teams to study for the soils test. For more resources, see the Oregon Envirothon website. Special thanks to reviewers: Amy Meredith (BLM), Taylor Cullum-Muyres (NRCS), Pam Keller, Mark Keller (retired BLM and NRCS), Sarah Hash (Forest Service), and Emily Parent (Salem-Keiser School District).

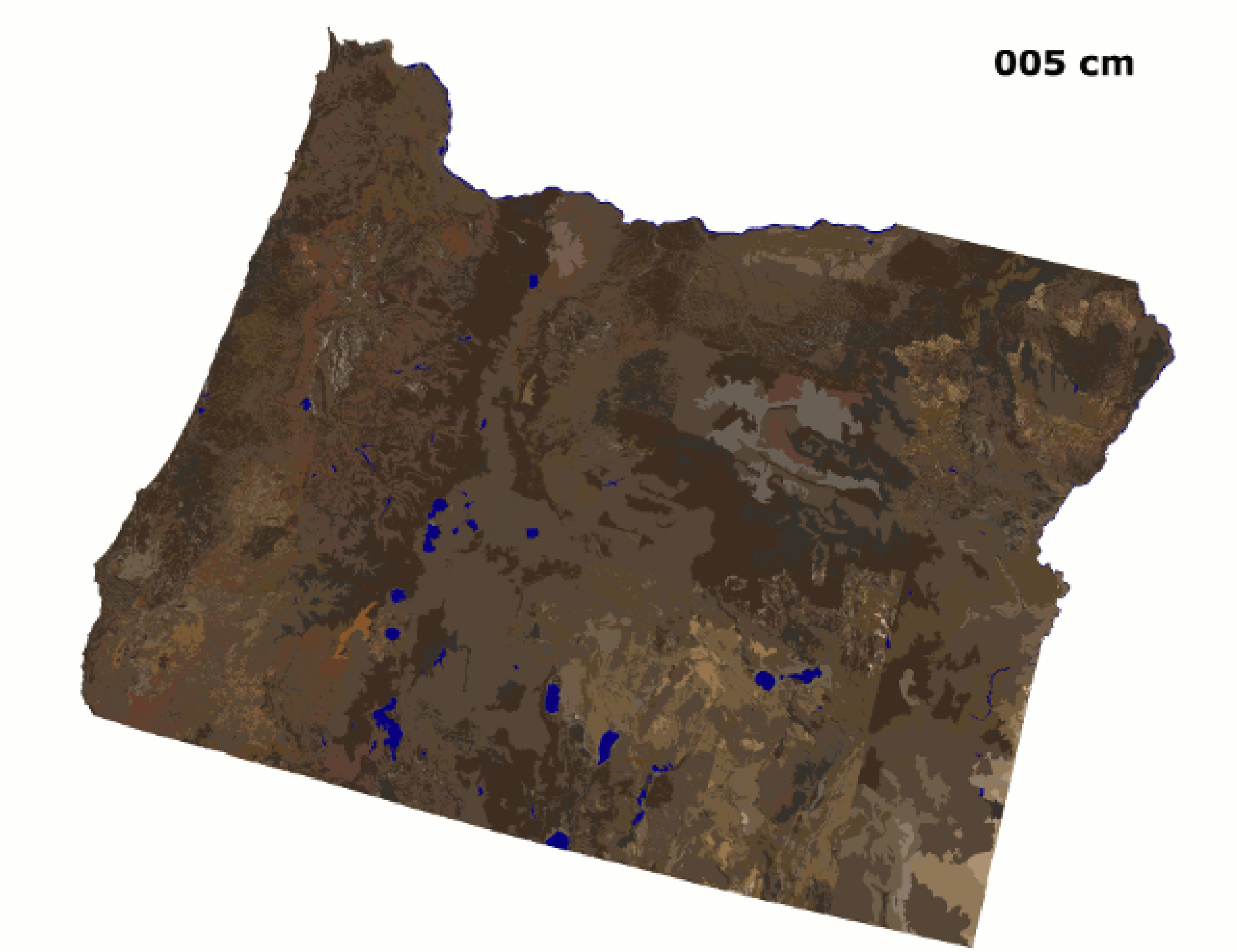


Figure 1: NRCS Soil Survey soil colors mapped in Oregon at a depth of 5 centimeters

United States Department of Agriculture

Natural Resources Conservation Service

Introduction

What is soil and how is it different from dirt? Soil is a complex mixture of both living and nonliving things. Soil is more than just the medium in which 95% of our food is grown. It is the *living* part of the environment, where geology and biology meet, which transforms decomposing matter back to new lifeforms. Soils are made of solids, liquids, and gases and are home to everything from the tiniest bacteria to a fungi that is the largest organism on Earth! Oregon loves and depends on soils so much, we have an official state soil called Jory. By contrast, *dirt* is soil that has been moved from where it was formed to elsewhere; for example under your fingernails, or tracked into a building. Transported dirt can convert back to soil if it remains undisturbed long enough to support plant life and begin to undergo soil-forming processes, as in filled urban areas.

Soils in Oregon range from dry, alkaline rangelands in the east to moist clays in the West Cascades; to human-altered urban areas; to ashy volcanic former landslides; to the sandy pumice of the volcanic High Cascades and lava plains of Central Oregon; to organic-rich tidal marshes and *subaqueous* (underwater) soils. Each soil landscape has its own ecology, limitations, and morphology. We rely on soil in many ways throughout each day from the breakfast we eat, the structures we live in, the waste we discard, to the fabric we sleep on at night. There are many functions of soil (Figure 2), however these are the five main functions:

Medium for plant growth- Soil is an anchor for plant roots to support plant structure and strength to hold against wind and rain. Soil supplies plants with the nutrients and water they need to feed and grow. Much of soil fertility is due to soil biology which thrives in a healthy soil environment.

Water storage and filtration- Without soil, the landscape would experience severe floods and droughts in response to each precipitation event. Soil stores moisture and slowly releases it into springs, ponds, lakes, and streams to supply plants and animals with water all year long. Under the right circumstances, water contaminated by waste or chemicals can be filtered and cleaned by passing through soil medium.

Habitat for organisms- Soil is home to many organisms big and small including badgers, moles, earthworms, mites, and microbes. In a large way the entire food chain begins with tiny critters that live in soil.

Cycling system for nutrients- Soil fauna and flora perform the essential duty of decomposing deceased organisms including plants and animals. Nutrients are then free to be recycled and used by new living organisms.

Engineering foundation- Soils are a vital material for the construction of roads, homes, buildings, dams, and more. These kinds of structures are made with soil, such as clay brick, or on soil whereby their foundation is laid and must be stable for structures to persist.

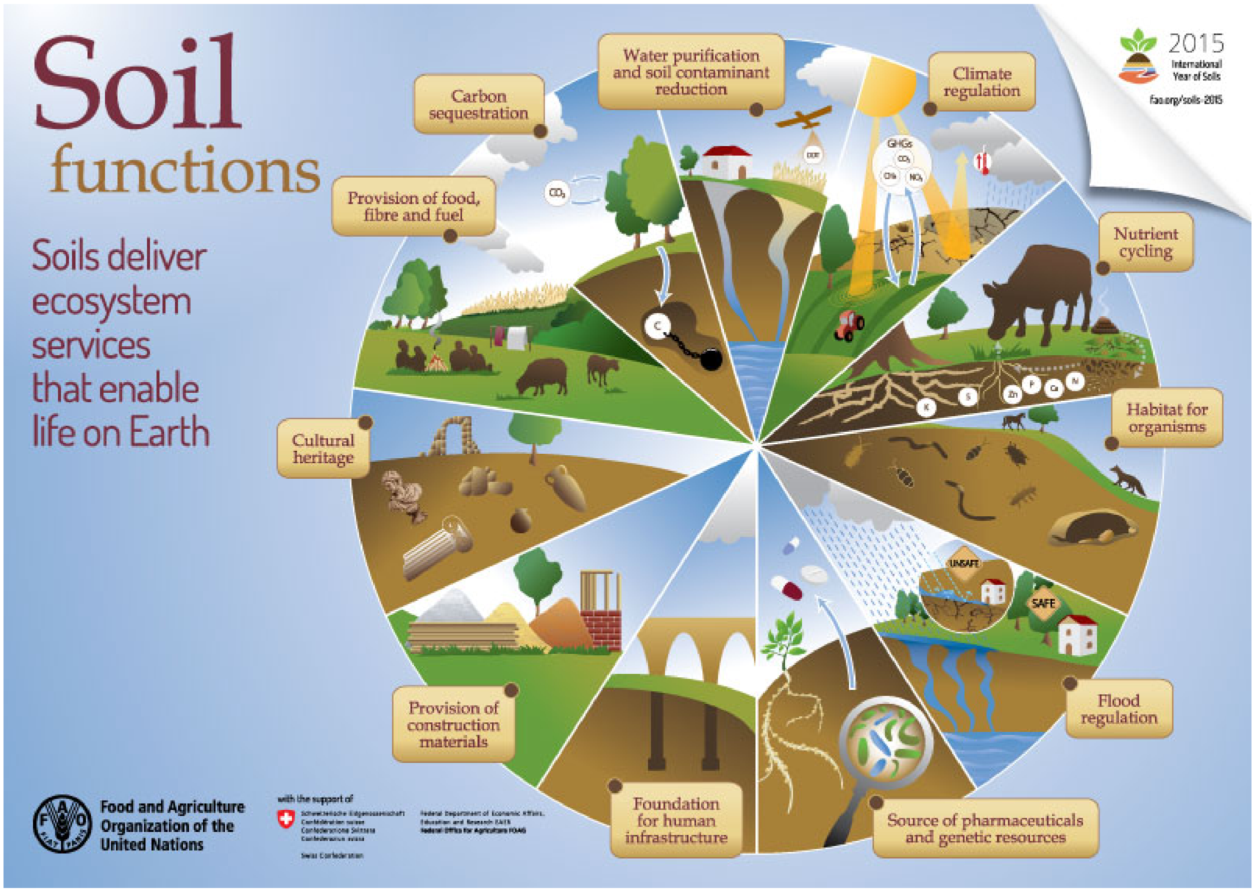


Figure 2: United Nations Food and Agriculture soil function [infographic]

The way we define and characterize soils depends on our background and intended function. For example, farmers view soils as a medium for plant growth, engineers view them as a resource to build on or with, potters see soil as an art medium, and geologists may call all material above bedrock "overburden". Depending on the use, you may look at a different soil depth or characteristic(s). A farmer may look at water-holding capacity of the topsoil, while a geologist wants to know the depth to bedrock. Because soils are so variable across the Oregon landscape, one parcel may have several types of soils with different potential uses. In this manual, land will be evaluated primarily from agricultural, forestry, and engineering perspectives.

Soil Formation

The processes of soil formation (Figure 3) can be summarized as:

<u>Additions</u>- adding material to the soil; examples are organic matter from decaying animals and plants, nitrogen from rain, sediment deposits from rivers and upslope erosion

<u>Losses</u>- losing material from the soil; examples are nutrient leaching by rainfall or irrigation, especially salt and lime, and erosion

<u>Translocations</u>- material movement within soil; examples are incomplete leaching, salts moved upward by evaporation, and clay *illuviation*, or downward movement by water

<u>Transformations</u>- chemical weathering within the soil; examples are organic matter to [*humus*]; clay particles breaking down into new minerals; *reduction* (mobilizing) and *oxidation* (rusting) of iron from a fluctuating water table, resulting in *redoximorphic features* (see the redoximorphic features section for more information)

Figure 3: United Nations Food and Agriculture soil formation infographic

In agriculture and forestry, the most prominent soil forming processes are the **addition** of organic matter in the topsoil and the **transformation**, or chemical weathering of minerals. Organic matter can accumulate in all soils in Oregon and is indicated by a darker color in the surface layer (Figure 1). Organic matter usually decreases with soil depth, except in floodplains and areas disturbed by humans.

Other important processes include chemical weathering such as oxidation, reduction, and hydration, and physical weathering, or the breakdown of soil particles into finer pieces. In some soils, iron compounds have been moved down, or **translocated**, through the soil. These compounds are generally precipitated in the subsoil as iron oxides, which results in reddish, orange, or brownish colors in the subsoil. Iron reduction, on the other hand, results in gray colors (see the redoximorphic features section). Soil colors often reflect the types of chemical weathering that have occurred, but may also come from the soil's *parent material*. Physical weathering is mainly a result of freezing and thawing or movement downhill by gravity.

Some processes modify, impede, or reverse the effects of soil forming processes. Examples are the mixing of soil by tilling, tree throw, *bioturbation* (animal burrowing), *cryoturbation* (frost heave), **loss** of soil layers through erosion or mass movement, and the deposition of new material from flooding, landslides, or human activity.

All soils are constantly undergoing *pedogenesis*, the process of soil formation. Changes in soil range from extremely gradual to drastic. The evaluated soil features can be used to determine if the intended use is ecologically and economically feasible. Soil science requires careful attention to soil texture, color, drainage conditions, depth to root-limiting layer, stoniness or rockiness, and slope. The soil forming factors influence each of these characteristics.

Soil Forming Factors (CLORPT):

CLimate
Organism (life, biota)
Relief (topography, lay of the land)
Parent material (geology, sediments)
Time the processes of soil formation have acted on parent material

Climate

Climate influences the rate of chemical and biological activity in soil through temperature and moisture. In environments that are both cold and dry or remain saturated for most of the year, the level of biological and chemical activity is low. Organic matter may accumulate in these environments because although the rate of production is low, it also breaks down very slowly. Biological and chemical weathering and organic matter decomposition occur faster in warmer moist soils. Leaching occurs in places like western Oregon where high rainfall washes minerals out of the topsoil, resulting in acidic (low pH) soils. In eastern Oregon where rainfall is limited, soils are more likely to have a higher pH and build up salts near the surface from evaporation. Climate can also influence which plants and animals live in the soil, which in turn affects soil properties. For example, moist wooded areas with trees that shed needles or leaves are more likely to have an O (organic) horizon than arid rangeland or plowed fields. Colder areas are more likely to undergo *cryoturbation*, or mixing of soil layers due to frost heave.

The climate in Oregon differs depending mainly on elevation, topography, and the *orographic* (rain shadow) effect of the Cascade Range. The five soil temperature regimes (Figure 4) recognized in the state for soil mapping are:

Mesic- regime which occurs in the Willamette Valley, Columbia River Basin, and Snake River Basin, is the warmest temperature regime in Oregon.

Cryic- regime which occurs in the high lava plains, Cascade Range, and other high peaks, is the coldest temperature regime in Oregon.

Frigid- regime occurs between the cryic high elevation areas and mesic lowlands

Isomesic and Isofrigid- regimes occur on the coast. The isomesic and isofrigid temperature regimes are tempered by the ocean's ability to moderate air temperature by holding solar energy, meaning the soil temperature fluctuates less than in the mesic or frigid temperature regimes (Soil Survey Staff 1999).

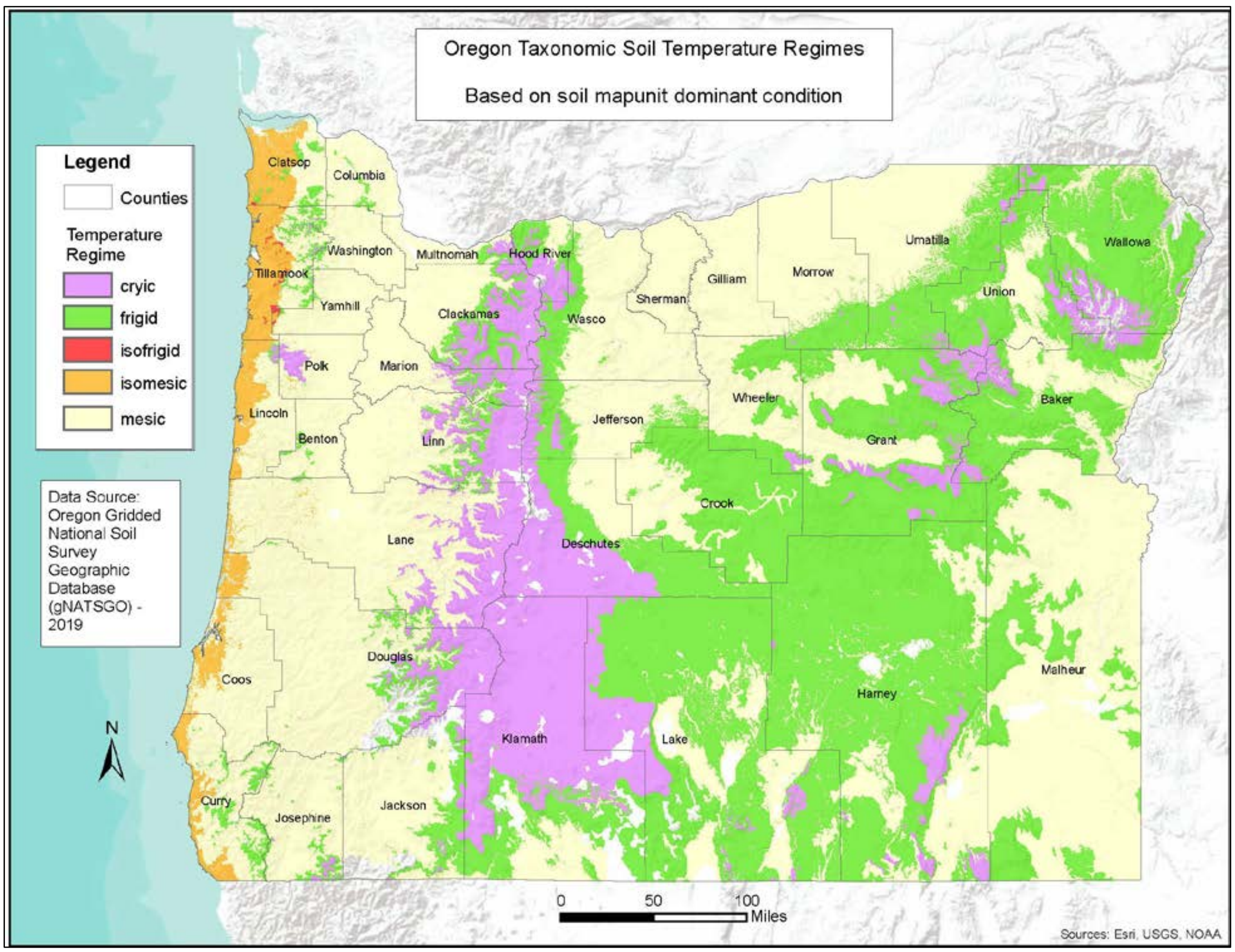


Figure 4: Oregon taxonomic soil temperature regimes map, courtesy of Oregon NRCS Soil Survey staff

Organisms

As you can see in Figure 5, the soil is a complex interconnected ecosystem. Soil biology is most easily observed in surface layers because that is where carbon, water, air, and thus life is most abundant. Roots help to break apart rocks, while holding topsoil in place. Plants and animals add organic matter and nutrients to the soil as they decay and become incorporated. Roots and *macrofauna* (visible insects and animals) provide larger channels for water and air movement through the soil. Plants provide protection from water and wind erosion and are a living mulch. Macrofauna and tipped over trees churn the soil. Soil bacteria and fungi break down the organic matter into *humus* (decomposed, stable organic material), release plant nutrients, and improve soil structure by producing substances including *glomalin*, a sticky protein produced by fungi. In response, plants release exudates, including proteins and carbohydrates, to fuel and support other living things.

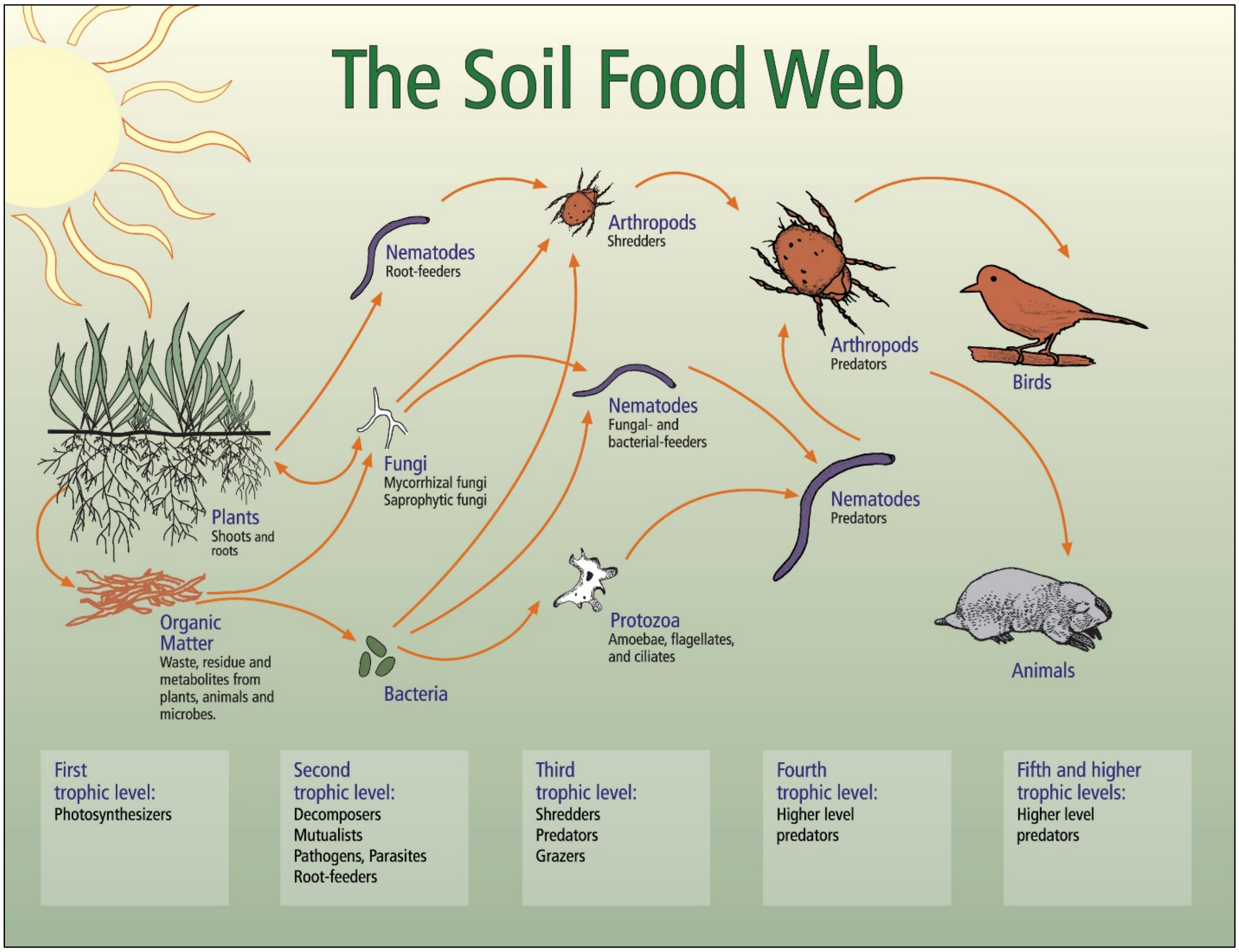


Figure 5: Soil and Water Conservation Society's soil food web

Relief

Relief is another word for **topography**, the shape and distinguishing features of the land surface. Relief affects soil formation through its influence on *drainage*, erosion, vegetation, and temperature. Slope is an important descriptor of local topography and can be measured as percent slope, (change in elevation across a distance), or slope degrees (angles relative to horizontal). In Oregon slopes range from nearly level (0%, 0º) to very steep (> 70%, >35º). Steeper slopes have higher runoff because water travels downhill. Thus, low-relief soils are often wetter. The lower landscape positions also receive deposition from upslope erosion, called *colluvium*. Windy areas on the plateaus above the Columbia River are likely to have *loess*, or silty wind-blown deposits. Mountainous regions may have different soil types depending on cardinal direction (*aspect*). In the northern hemisphere, south-facing aspects receive more sunlight and are drier and warmer than north aspects, which hold snow longer into the spring because they are wetter and cooler. This causes north aspects to have deeper soils due to higher vegetation productivity and reduced erosion.

Position	Code
summit	SU
shoulder	SH
backslope	BS
footslope	FS
toeslope	TS

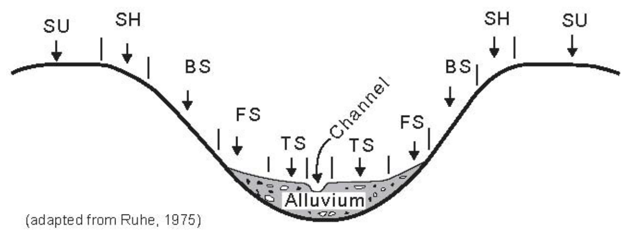


Figure 6: NRCS hillslope positions

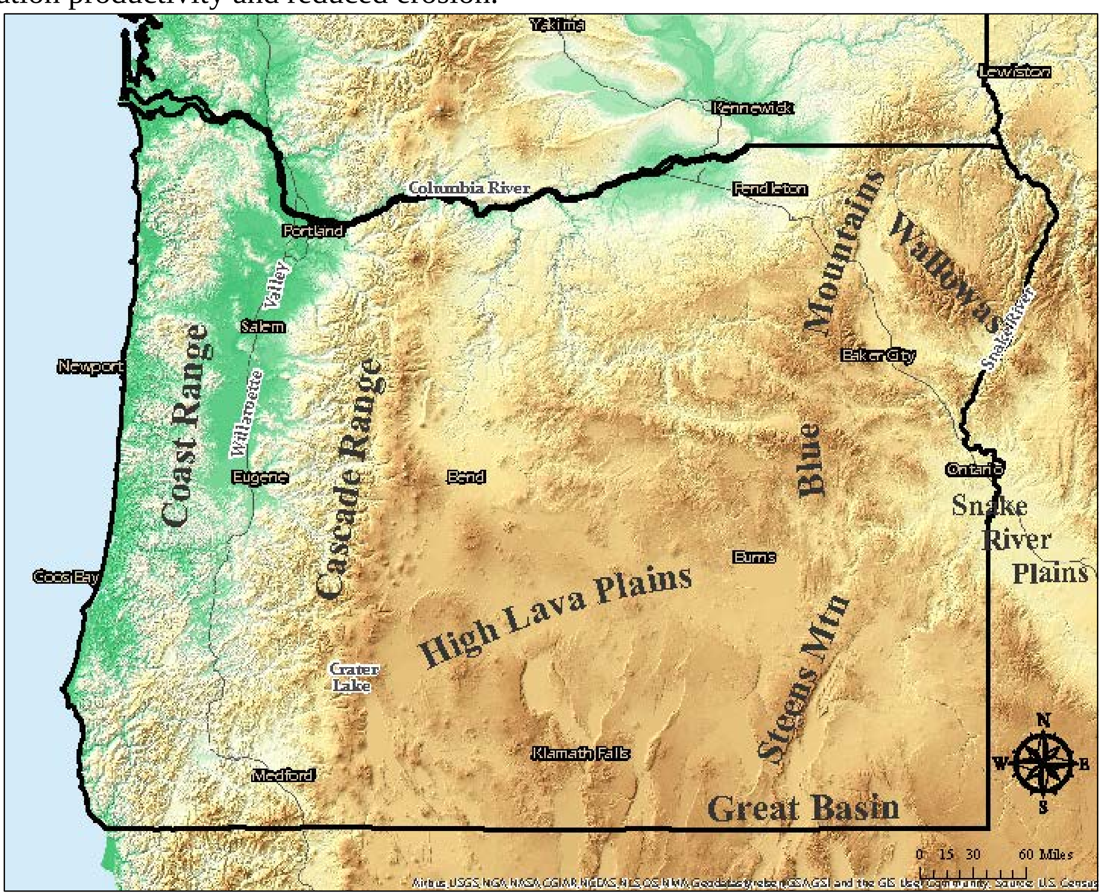


Figure 7: Elevation map of Oregon

Parent Material

Parent material is the unconsolidated or *structureless* geologic material from which soils form. It determines the baseline chemical and physical composition of the soil and may be bedrock or material that has been transported. It is useful to look at the whole landscape when identifying a parent material. In Oregon, parent materials include bedrock, human-altered material, volcanic deposits, wind-blown *loess*, organic matter, stream-deposited *alluvium*, cataclysmic *lacustrine* deposits, and others. Because of this, soil properties can sometimes vary greatly within small areas. In areas affected by wind, ice, water, and steep slopes, soils may also have more than one parent material. You can distinguish different parent materials by abrupt changes in texture, color, and rock fragment content. General categories of Oregon parent materials are:

> **Alluvium** is deposited along stream channels by floodwaters, so it is found near water channels in v-shaped valleys. Alluvium ranges in texture from silt to cobbly sands, depending on the speed of the water that deposited the material. Larger, faster flood events will deposit larger particles, while slower moving water allows finer particles to settle. Alluvial deposits are typically *stratified* (layered) with each strata representing a distinct flood event. They may include buried surface layers, which results in irregular organic matter content within the profile. Rock fragments in alluvium are often rounded from water transport. Alluvium may be deposited by old streams that have migrated away and are no longer present near the soil site.
>
> **Ash** is wind-blown volcanic debris like from the eruption of Mount Mazama, now Crater Lake. Ash holds water and nutrients well and is often stratified from eruption events. In soil, ash contributes a gray or tan color, loamy and silty textures with a greasy slipperiness, and a low *bulk density* (dry weight of a soil sample divided by its volume). Volcanic glass is typically intermixed with volcanic ash. Volcanic ash can be wind-transported for very great distances during volcanic eruptions, and becomes finer-textured with increasing distance from the source. Pumice and scoria are volcanic parent materials that are coarser-textured than volcanic ash (sand- and gravel-sized or larger) and do not travel as far from the eruption site because of their greater mass. Some parts of central Oregon, which were very close to Mt. Mazama, are blanketed in a thick layer of sandy pumice from that eruption. Wood ash can also result from wildfires, but charcoal is a better indicator of past fires in soil.
>
> **Colluvium** is any sediment or rock deposited by gravity. Think of the bottom and side slopes of a steep mountain. These areas have thicker soils than summits because material from the ridges has eroded and moved downslope. The underlying bedrock type may be the same or different from the colluvium.
>
> **Glacial deposits** are left from the rock-grinding ice movement of recent alpine glaciation as well as alpine glaciation during the Pleistocene epoch (2,580,000 to 11,700 years ago). Alpine soils, affected by both eras, occur on high mountain peaks and are generally cold, shallow, and bouldery. Moraine soils left by Pleistocene alpine glaciation are unsorted jumbles of rocks and soil which were pushed up along ice margins in u-shaped valleys and can be quite deep. The last continental glaciation did not reach Oregon, so only alpine glacial processes are evident.

Lacustrine deposits were laid in layers in a current or historic lake. Particles are typically silts and clays from deposition during still water conditions, resulting in *platy* soil structure. Rock fragments are typically absent. Lacustrine sediments often become *loess* (see below) when lakebeds dry out and the winds move exposed silts.

Loess or *eolian deposits* are wind-blown silts. Silt particles are light enough to be transported in flat, windy areas. This parent material makes the plateaus above the Columbia River fertile. Loess soils rarely have rock fragments and are very susceptible to wind and water erosion because of its silty texture.

Marine deposits or ocean-derived materials, were once underwater. These could be dune sands, weathered marine mudstone and sandstone sedimentary rock in the Coast Range, or even subaqueous soils in shallow waters. Marine deposits may contain shells or fossils like at Beverly Beach State Park in Newport.

Organic material consists of decomposed plant material. The degree of decomposition varies from slightly decomposed (fibric material/ peat) to moderately decomposed (hemic/ mucky peat) to highly decomposed (sapric material/ muck). Soil saturation aids in the build-up of organic deposits by slowing the decomposition rate. Organic matter may occasionally have mineral material mixed in, but rarely has rock fragments. It may be sourced from woody material or herbaceous material.

Residuum is material formed in place from bedrock as it is broken up by frost action, roots, dissolving by water, and chemical weathering aided by microorganisms. Residuum can form in any bedrock type as it weathers. For example, basalt and andesite weather to clayey soils, while coarse sandstones weather to sandy soils. There is generally an increase in rock fragments with depth in residual soils.

Urban soils may be comprised of many different fill materials. Examples are construction debris, sandy dredged material, and loamy caps placed for landscaping. Some urban soils, like those beneath roads, are stripped of their topsoil, leaving just the substratum. Like alluvial soils, these are usually marked by an irregular organic matter content within the profile. They sometimes have artifacts like glass, bricks, and plastic or shells if dredged.

Time

The degree of development in the soil profile often reflects the length of time that the parent material has been in place. Generally, in a wetter climate, soils become more leached, acidic, and clayey with time. Some soil features develop rapidly while others require thousands of years for the processes of soil formation to develop horizons. Soil continues to age until it is transformed back into sedimentary rock through cementation, heat, and/or pressure. In fact, some soil is billions of years old!

Soil Characteristics

Soil Profile

Soils are made of distinct layers called horizons (Figure 8). Each soil type has a unique combination of kinds, sequence, and thicknesses of horizons. The horizons that make up the soil profile can indicate water table presence, depth to bedrock, organic matter content, changes in parent material, and more. For more specific information about describing soil horizons, see the NRCS Field Book for Describing and Sampling Soils.

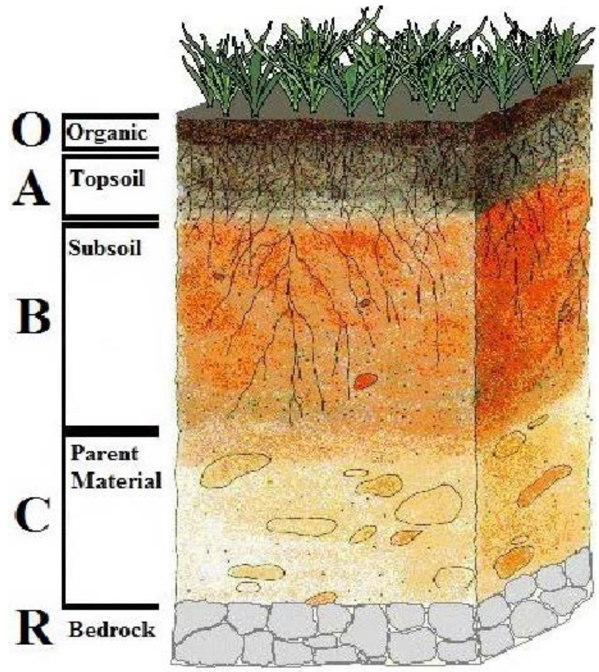


Figure 8: A soil profile from a forest showing the basic horizons. The O horizon is composed of organic matter. The A horizon in this unplowed soil is darker in color because of the high organic matter content. In a plowed soil the O horizon is mixed with the A.

The mineral horizon closest to the soil surface is referred to as the **A** horizon or topsoil. The A horizon is characterized by higher organic matter content than the layers below it. In floodplain and human-filled soils the A horizon may be buried.

There may or may not be an organic **O** horizon above the A made of decomposed plant material. The degree of decomposition varies from slightly decomposed (fibric material/ peat) to moderately decomposed (hemic/ mucky peat) to highly decomposed (sapric material/ muck). Recently fallen, undecomposed plant litter is not included in the O horizon. Some wetland or subaqueous soils have large, deep O horizons or have an entirely organic profile.

The mineral layer below the A horizon is the **B** horizon or *subsoil*. B horizons are characterized by a change in color or texture relative to the C horizon, which indicates pedogenic processes (Soil Formation section). In warm, moist environments, B horizons usually have a higher clay content than both the A and C horizons.

Sometimes a light-colored **E** or *eluvial* horizon forms beneath the A horizon when organic matter and minerals are leached down into the B horizon.

The **C** horizon or *substratum* is relatively undeveloped parent material (meaning that soil-forming processes haven't changed it very much from its original character). In soils formed from transported materials (alluvium, ash, colluvium, dune sand, and loess, for example) the C horizon looks the same as when it was originally laid down. In residual soils, the C horizon will look similar to the bedrock beneath (may be softened or broken into chunks). There are few to no roots or organic matter in the C horizon.

Where shallow bedrock occurs, an **R** (rock) horizon is present.

Soil Texture

Soil texture describes the relative proportions of the various sizes of *fine earth* soil particles, or particles that would pass through a 2 millimeter sieve (Figure 9). Particles larger than 2 mm in diameter are considered coarse fragments and are described separately. To properly assess soil texture, a sample should be sieved, or sorted, to remove coarse fragments.

Soil particles are tiny pieces of rocks and minerals, grouped by their size into sand, silt, and clay. Sand is visible by the naked eye, silt particles can be seen with a microscope, but clay can only be seen with an electron microscope. Sand and silt can be formed through physical weathering (rocks being mechanically broken down into smaller pieces), but clay can only be formed through chemical weathering processes (dissolving and recrystallization of minerals). Clay has a negative charge that attracts positive ions including plant nutrients. Texture and soil structure influence moisture, fertility, K_{sat}, erosion potential, and other factors. A textural triangle (Figure 10) is often used to illustrate how soil textures are determined by the percentages of each of sand, silt, and clay. Soil texture is determined by moistening the soil and rubbing a small amount between the thumb and fingers so the relative proportions of sand, silt, and clay can be estimated (Figure 11).

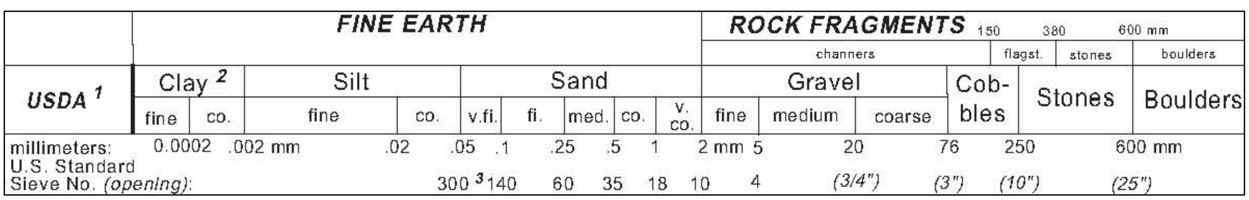


Figure 9: Particle Size (in millimeters) of USDA soil textures, image from the NRCS Field Book for Describing and Sampling Soils

The textural groups used in this manual are as follows:

Sandy- Sandy soils feel gritty and fall apart when moist. Specific textures are *loamy sand* and *sand*. They have lower nutrient and water holding capacity and permit water and air to move through rapidly. These soils do not compact easily.

Loamy and Silty- Loamy and silty soils contain a mix of sand, silt, and clay. Specific textures are *loam*, *sandy loam*, *silt loam*, and *silt*. Loamy soils feel slightly gritty but not sticky. Silty soils feel relatively smooth but not sticky. A ribbon does not form easily when a moistened sample is rubbed between the fingers and thumb (Figure 11). Loamy and silty textures have good water holding capacity and fertility. These are typically the most productive agricultural soils.

Clayey- Clayey soils contain at least 27% clay, with the exception of the sandy clay loam which contains only 20% clay. Specific textures are sandy clay, sandy clay loam, clay loam, silty clay, silty clay loam, and clay. When moist samples are rubbed between the fingers and thumb a long ribbon can be formed (Figure 11). The more clay in the sample, the stickier and stiffer it will feel and the longer and more flexible the ribbon will be. Because they contain finer pores, water moves slowly through clayey soils. These textures have good water holding capacity and high fertility, but are easily compacted when moist.

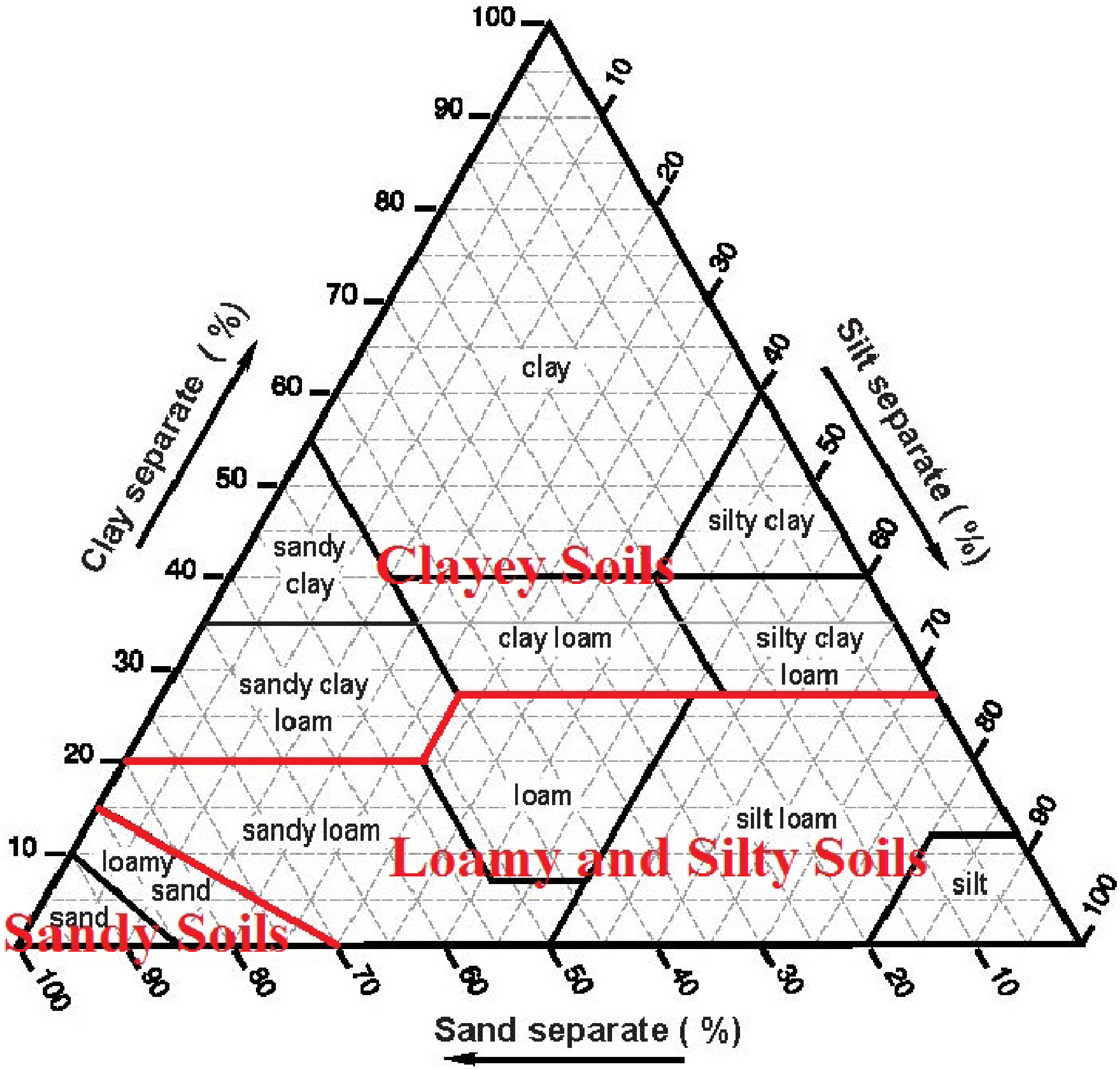


Figure 10: NRCS texture triangle; red lines show texture groups for this manual. Please see the next page for texture-by-feel worksheet.

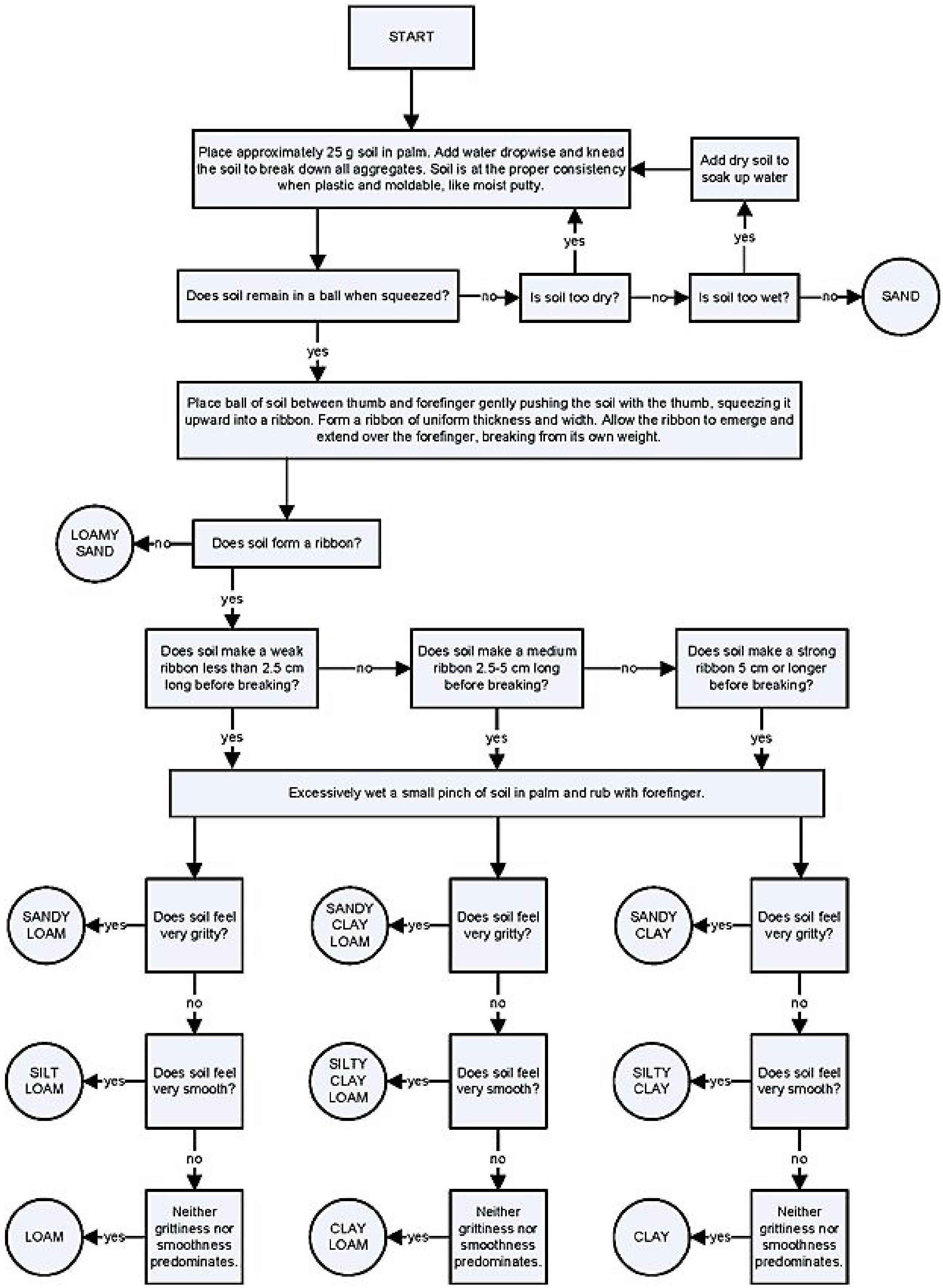


Figure 11: NRCS soil texture-by-feel flow chart

Soil Structure

In a soil pit, we can observe many different ways that soil particles group together or break apart into *peds* as a result of the processes of soil formation. To examine a soil's structure, take a *clod* (large piece of soil) in your hand and gentle apply pressure or gently shake. The different shapes (types), sizes, and grades that a soil naturally breaks into are collectively called **soil structure**. Figure 12 has examples of the main structure types. These can each be categorized into respective sizes and grades. Structure **grade** refers to how strongly the peds hold together –weak, moderate, or strong. To test structure grade, press on individual peds with your forefinger and thumb and notice how easily (weak structure grade) or difficult (strong structure grade) it is to crush or burst them. Generally, healthy topsoil is *blocky* or *granular* (also known as *crumb*). *Platy* structure occurs in layered soils formed in lacustrine deposits and in compacted soils. Clayey soils may develop *wedges*, *prisms*, or *columns* as they absorb water and dry out. Soil without structure can be described as *single grain* as in beach sand or *massive*, as in parent material in the C horizon. For more information about describing soil structure, see the NRCS Field Book for Describing and Sampling Soils.

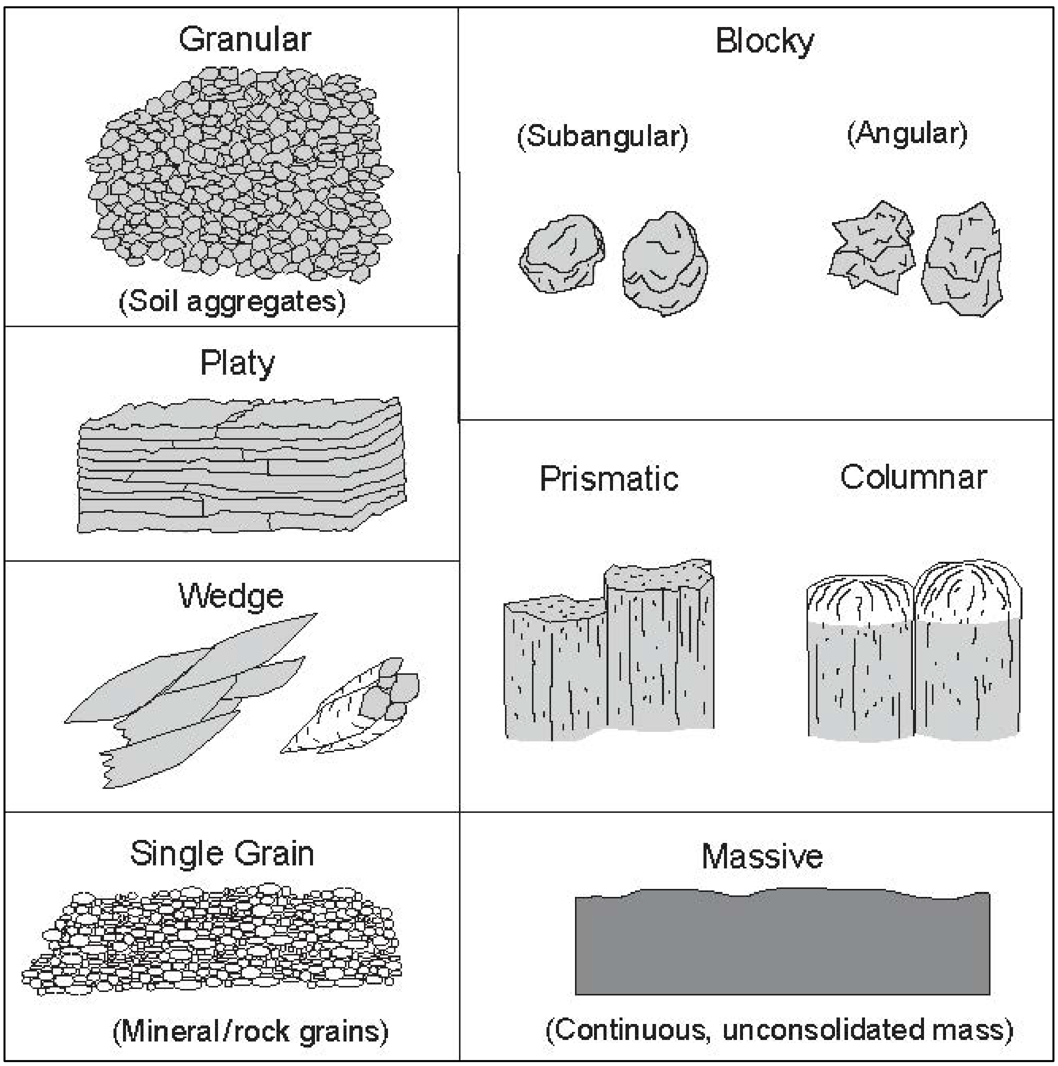


Figure 12: Soil structure types, image from the NRCS Field Book for Describing and Sampling Soils

Soil Color

Soil color (Figures 1, 13) is important to record so we can communicate what a soil looks like to other scientists. It can change depending on soil moisture and sunlight levels, so these must also be recorded (Figures 17 and 18). If a soil is dry, but you wish to record the moist color, simply add a few drops of water. Soils tend to be darker at the surface, where the most organic matter is present (O and A horizons), and change as you move down the soil profile (B and C horizons, soil profile section). Record the *matrix* or dominant color(s) as well as redox feature color(s) if present. Minerals in the parent material strongly influence soil color; for example, well-drained soils with high amounts of iron weather to a rusty brown to red color. Soil color can also indicate a water table within the profile, as described below in the *Redoximorphic Features* section. Soil color is measured using Munsell notation as in Figure 13. The three parts of this notation are:

Hue: the colors in the soil; notated as the page of the book in most color books

Value: how dark or light the soil is; darker colors have lower value

Chroma: how bright or dull the soil is; dull colors have low chroma

Figure 13: Munsell soil color chart, an example is **7.5YR 3/1** or **“very dark gray”**

Seasonal High Water Table

A seasonal high water table is defined as the highest level (nearest the soil surface) that water reaches during the year. Because of drought, heavy rain, plants, and other factors, no water table has a constant depth. The water table will fluctuate substantially during a normal year. Note that the seasonal high water table is not the same as groundwater. Groundwater goes deeper, filling rock fractures, soil, and sediment spaces.

Redoximorphic Features

The presence of redoximorphic or redox features (formerly called *mottles*) in a soil profile generally indicates at least seasonal saturation. Redox features in Oregon are typically red, orange, yellow, or gray and are distinguishable from the matrix color (Figure 14). Areas with distinctly gray colors known as *depletions* indicate a seasonal high water table. Reddish-orange redox features are *concentrations* of oxidized minerals, primarily iron (rust). These are commonly formed at a depth where water levels fluctuate creating alternating periods of *aerobic* (unsaturated, oxygenated) and *anaerobic* (saturated, lacking oxygen) conditions.

Soil horizons that have strongly contrasting textures can slow or *perch* water due to the change in size of soil pores. In these situations the redox features are found at only one depth, the depth of the texture change, and should not necessarily be interpreted as an indication of a seasonal high water table. Some soils have gray or red colors due to the parent material of the soil, which can make redox features difficult to detect.

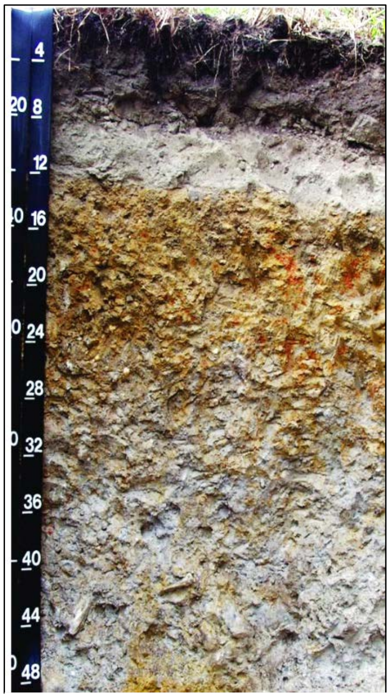


Figure 14: Redoximorphic features, photo from NRCS's Field Indicators of Hydric Soils in the United States

Hydric Soils

Hydric soils are formed under conditions of saturation, flooding, or ponding, long enough during the growing season to develop an anaerobic condition (a lack of oxygen) in the upper soil profile. These soils are usually in low landscape and/or low-relief positions like the toe slope in Figure 6. When saturated, nearly all soil pore space is filled with water, rather than air, which causes certain microbes to reduce iron and other minerals instead of oxygen. There are many indicators for hydric soils depending on the climate, parent material, texture, and other factors. One example of a hydric soil indicator is uniformly gray or *gleyed* soil matrix colors (high value, low chroma colors) which occurs when almost all of the iron is reduced, or *depleted*.

Soil Permeability, K_{sat}

The permeability, or *saturated hydraulic conductivity*, K_{sat}, is how easily liquids can move through a layer of soil. Many things affect the permeability of a soil, such as texture (Figure 10), structure (Figure 12), density (compactness), and impermeable layers like bedrock. The higher the K_{sat}, the faster water moves down the profile. Each soil horizon has its own K_{sat} which may be the same or different from the layer above or below it. The most limiting layer's K_{sat} dictates what a soil may be used for. For example, it is best to install a septic tank absorption field in soil with a moderate K_{sat} so that it filters, but does not impede wastewater flow. K_{sat} is also important when considering what species to plant, or what irrigation type or fertilizer to use. The NRCS [NRCS Soil Survey Manual], Chapter 3 defines a very high K_{sat} as greater than 14.17 inches per hour (100.00 µm/sec) and a low K_{sat} as less than 0.01 inches per hour (0.10 µm/sec).

Soil pH

The pH scale (1-14) is a common measure of soil chemistry. The lower the number, the greater the acidity. The midpoint of the pH scale, neutral (7.0), is a good level for the growth of most plants. Some species like blueberries prefer acidic conditions (lower pH) whereas alfalfa does not. Environments with high amounts of rain such as northwest Oregon will often have acidic (<7.0 pH) soils due to continuous leaching of bases, while arid environments such as southeast Oregon often have alkaline (>7.0 pH) soils because there is little moisture to leach away salts and bases that accumulate. Soil pH may be changed by adding amendments. For example, organic matter and fertilizer can decrease a soil pH, while lime and bone meal increase pH. Changes in soil pH can have significant effects on metals in soil. Metal toxicity to plants and animals increases in strongly acid soils with a low pH (≤3.5) because metal ions are released back into soil solution. At a higher pH (≥8.5), the metal ions are tightly bound to anions (negatively charged particle) in the soil.

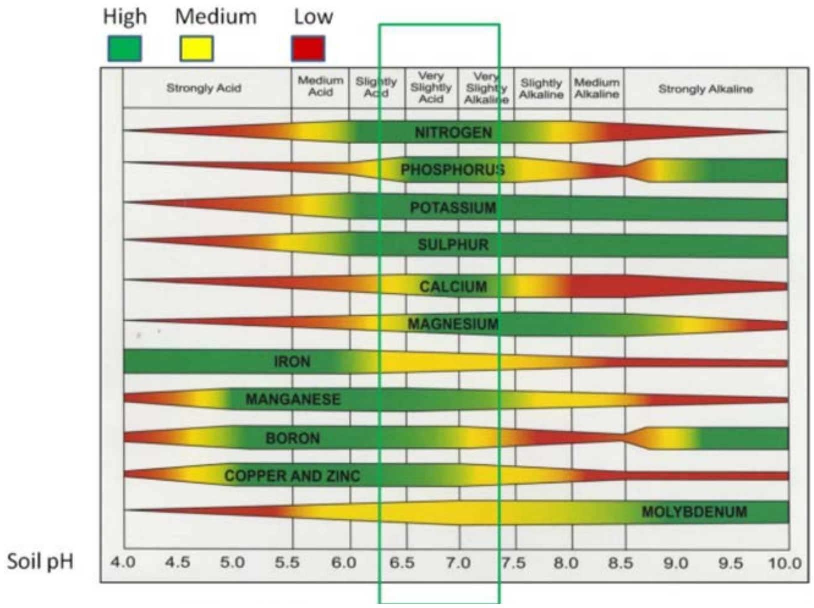


Figure 15: Effects of Soil pH on plant nutrient availability, image source: University of California website

Soil Drainage Classes
The drainage class of a soil is based on the presence and depth of the seasonal high water table in the soil profile. For more information, see the NRCS Soil Survey Manual, Chapter 3. Drainage class is generally determined by redoximorphic features as follows:

Excessively drained- sandy textures which rapidly *percolate* water, or allow it to move vertically through the profile; no redox features within 40 inches (100 centimeters)

Well drained- typically loamy and silty textures; no redox features present within 40 inches (100 centimeters); water does not inhibit plant growth

Moderately well drained- redox features (including depletions) typically present between 24 to 40 inches (60 to 100 centimeters), indicating a seasonal high water table; water may affect plant growth for part of the year

Somewhat poorly drained- redox features (including depletions) below surface layer within 8 to 24 inches (20 to 60 centimeters), indicating saturation near the surface; plant growth is affected by water most of the year; these are typically flat or low-lying areas or places with a water-restrictive layer near the soil surface

Very poorly drained- organic wetland soils, or mineral soils with 2-20% depletions or gleyed matrix colors near the surface; plant growth is affected by water year round; these are low-lying areas or depressions

Besides redox features, some other ways to help determine drainage class are:

Vegetation- water-adapted or *hydrophytic* plants may be present in very poorly or poorly drained areas

Rooting Depth- shallow rooting depth may indicate a high water table

Soil Color- uniform bright colors indicate a well drained soil; gray colors near the surface generally indicate a poorly drained soil, see the redoximorphic features section

Landscape Position- poorly drained soils are typically in depressions or foot slopes, Figure 6

Depth to Root Limiting Layer
Root limiting layers are features in the soil which limit most plant root growth, and include bedrock, seasonal high water tables, and dense layers. Dense layers are typically massive or have strong platy structure (Figure 12) and may be cemented by silica, calcium, or iron; they are difficult to break into pieces, and/or may prevent roots from growing deeper. The depth categories are:

Deep- >40 inches (100 centimeters) to bedrock or restrictive layer

Moderately Deep- 20 to 40 inches (50-100 centimeters) to bedrock or restrictive layer

Shallow- <20 inches (50 centimeters) to bedrock or restrictive layer

Slope
The steepness and length of a slope influences runoff and potential soil erosion. The steeper the slope, the more likely runoff is to occur. Steepness of slope is expressed in percent which indicates change in elevation in feet over a 100 foot distance. For example, 14% slope translates to a 14 foot change in elevation over 100 feet in length. Percent slope is measured using a *clinometer* or slope finder. Slopes may also be described in angle degrees where 0º is flat and 90º is vertical. You can also derive slope from topographic maps, LiDAR (Light Detection and Ranging), or imagery using Geographic Information Systems (GIS). Topographic maps and LiDAR slope maps are useful for identifying landforms, which give clues to what soils lie beneath (Figure 6). For soil mapping, slope classes are:

A- ≤ 3% slope
B- 4 to 8% slope
C- 9 to 15% slope
D- 16 to 35% slope
E- 36 to 60% slope
F- 61 to 80% slope

Soil Classification

Soils are classified just as we classify living species from broad categories called *orders* down to individual soil types called *series*. Our Oregon state soil is the Jory series. Soil series are the smallest unit soils are mapped at. They are grouped by similar characteristics including similar horizon colors, textures, structure, pH, and horizon sequence using the Keys to Soil Taxonomy. This system is used to communicate a soil's capabilities and limitations to scientists and land managers.

The 12 soil orders (Figure 16) are the broadest category of soil classification. Oregon has 10 of the 12 soil orders mapped, which reflects how diverse its soils are.

We also categorize soils based on the land use type they are most suitable for due to their wetness, dryness, slope, rockiness, pH, or other characteristic.

Figure 16: The USDA's 12 orders of soil taxonomy

Agriculture
Agricultural soils are characterized by a plowed A horizon. While there are many ways to farm, there is only so much soil on the planet that is suitable to farm on. Approximately 95% of our food comes from soil, which means we rely on the soil resource to feed and clothe ourselves. Luckily, Oregon is home to diverse and fertile soil types. For example, the Willamette Valley produces many specialty crops like grapes, hops, and hazelnuts, the Snake River Basin produces corn, onions, and potatoes, and central and southeastern Oregon produces grains, hay, and livestock. On a global scale, when you subtract the amount of the Earth's surface that is covered in water, ice, desert, mountains, buildings, or pavement, there is only about 3% of the planet available to farm. This area of soil must produce enough food to feed 8 billion people. Soil erosion and desertification result in the loss of this limited resource. To protect farmland from degradation, farmers employ several soil conservation practices including reduced tillage, cover crops, crop rotation, and manure management. Many agricultural soils are so important that they have classifications that influence how they can be managed. You can map the following farmland classes on Web Soil Survey.

Land Capability Classification
The Land Capability Classification groups soils based on their suitability to grow most kinds of crops. Crops that require special management are excluded. Soils are grouped according to their limitations for field crops, the risk of soil degradation if they are used for crops, and the way they respond to conventional crop management. The eight classes range from **Class 1** (agricultural land capable of supporting most land uses; no special land management is required) to **Class 8** (areas that are incapable of agricultural production and are limited to recreation, wildlife habitat, watershed, and aesthetic purposes). You can map these classes and many other soil interpretations using Web Soil Survey.

Prime farmland- is land that has the best combination of physical and chemical characteristics for producing food, feed, forage, fiber, and oilseed crops.

Unique farmland- is land other than prime farmland that is used for the production of specific high value food and fiber crops.

State and locally important farmland- This is land, in addition to prime and unique farmlands, that is of statewide importance for the production of food, feed, fiber, forage, and oil seed crops.

Forests
Forest soils are characterized by an O horizon made of decomposed leaf and/or needle litter. Soils used for forestry are generally too steep or rocky to farm or build on. As in agriculture, there are many ways to manage forest soils for timber which can result in different levels of soil quality. In Oregon, the Coast Range and Cascade Range have high timber productivity. These areas are also prone to high erosion and mass movement. Forests east of the Cascades have lower timber productivity, mainly due to lower precipitation, and are more stable due to gentler topography. Most forest soils in the state periodically burn in forest fires, so charcoal is present in the topsoil. Forest soils provide wildlife habitat, filter water, sequester even more carbon than the trees they support, provide recreation opportunities, and groundwater recharge.

Rangeland
Rangeland soils are too dry to have built up thick O horizons, and in an unaltered state generally support native grasses and shrubs. They are typical of high deserts like the Harney Basin, which receives only 25 centimeters (10 inches) of rain per year. The limited rainfall results in higher soil pH because bases like calcium carbonate are not leached from the system. In fact, bases are often concentrated near the surface, because the rate of evaporation exceeds the amount of precipitation. As water is evaporated from the soil, the dissolved minerals are left behind, sometimes as a crust at the surface. Rangeland soils may or may not have biological soil crusts, or a thin, often fragile layer of living lichen, cyanobacteria, algae, and moss which binds the soil together. Disturbance of biological soil crusts can take decades to recover. Additionally, when rangeland is overgrazed, soil may erode because of a lack of vegetative cover. Rangeland soil degradation is often costly and slow to recover due to its lack of moisture.

Subaqueous Soils
Typically these soils occur in fresh, salt, or brackish water less than 2.5 meters (8 feet) deep and are able to support submerged aquatic vegetation. Their physical and chemical characteristics are similar to those of wetland soils, but are even more likely to have anaerobic conditions. Because of their importance to aquiculture and benthic habitat, subaqueous soils have been mapped by NRCS since the 1990s. Subaqueous soils provide habitat for shellfish and other benthic life, allow for aquiculture, sequester carbon, provide a mooring substrate, and are often dredged for boat navigability.

Urban Lands
Urban soils are a loose group of soils located in cities and modified by humans. Filled soils may be composed of natural soil materials from another location, construction debris, dredged materials from a waterway, coal ash, municipal waste solids, or a combination. Urban soils may also be truncated (scraped with an excavator). These soils have been mapped by NRCS since the 1990s because of their ubiquity and because their properties are important for those who live in and visit human altered landscapes. They are used as a substrate for buildings, gardens and parks, as cemeteries, for storm water infiltration, waste disposal, and more. Urban soils must be handled carefully because they often contain cultural artifacts and/or contaminants. Filled areas may be less stable than natural soils because of differences in soil types and levels of compaction.

Wetlands
Wetlands are areas that have a predominance of hydric soils and are saturated by water often and long enough to support a prevalence of *hydrophytic*, or water-adapted vegetation. These soils may have gleyed matrix colors, have redoximorphic features, and/or be composed of organic matter in various stages of decomposition. Wetlands are important because they provide numerous ecological services including unique wildlife habitat, recreation, carbon sequestration, flood control, filtering of water, and groundwater recharge.

Soil Investigations
Depending on the intended land use, you may decide you need more data about a soil. Many specific soil properties, such as K_{sat}, texture, and color can be measured and recorded in the field without taking a sample at all, while other characteristics like nutrient content or soil pH require a soil sample for lab analysis. There are many ways to investigate soil. When possible, you

should always begin by digging a hole with a shovel or backhoe to observe the soil profile. In soils with high water tables, opening a pit may require a pump to remove water. When entering a soil pit, ensure OSHA safety guidelines are followed and pit walls are shored up if needed to prevent cave-ins. Soil digging tools can include 'tiling' or 'trenching' spades, which are helpful in slicing open the topsoil, wider 'bail out' shovels, good for removing more bulk soil at a time, and knives and screw drivers to help pick and pry at the soil profile. Rock bars and Montana sharp shooters are heavy and add leverage against rocky or dense layers. In some investigations, general horizon characterization is adequate using a small pit, push probe, and/or auger hole. Slender Dutch augers are useful in loamy and silty soil types while bucket augers are better for sandy soils. In fluid soils like saturated silts and organic matter, a soil core may be extracted by pushing a tube into the soil or using a vibracore setup (motor and irrigation pipe). It may or may not be pertinent to record your sample, description, or measurement location using a Global Positioning System (GPS) via a stand-alone unit or phone app. Collecting GPS data allows you to see your exact location in a GIS map.

A lab-tested soil sample can help establish baseline soil nutrient status, determine nutrient application recommendations, assess pH, measure change in nutrients over time, document nutrient management for certification requirements, avoid excessive nutrient applications, and develop a plan for possible variable-rate fertilizing within a field. When sampling soils, make sure the depth you take is representative of the question you're asking. For example, if you're looking for plant-available phosphorous within a field, you need to adequately sample the entire field at the plant roots' depth. Many individual samples may be necessary, and often one large combined sample made of many subsamples tells a field's story best.

The Big Picture

Soil is not only underfoot, it is the foundation of ecosystems. It lies where earth and atmosphere meet, creating a sphere of tremendous biological diversity. Soil contributes to the systems that provide food, timber, fiber, clean water, clean air, habitat, and regulate carbon. To keep soil healthy and functional we must consider multiple interactions with the water cycle, carbon cycle, nitrogen cycle, and more. For example, when soil erodes into a waterbody, both water quality and aquatic habitat suffer, in addition to the lost soil resource. Preventing erosion is especially important in areas connected to water bodies that are already contaminated. The complexity of the soil system is both challenging and rewarding for those who diligently work to care for it.

Soil Science Career Opportunities

How can you help? Consider a career working with soil. Soil Scientists and Conservationists work as consultants for farms, orchards, vineyards, ranches, and engineers. They map soils, delineate wetlands, measure soil properties, and help land managers make land use decisions on local, state, and federal levels. Some work in labs or do research at colleges in universities. Many soil scientists register as Certified Professional Soil Scientists by passing a national exam. Local professional organizations like the Oregon Society for Soil Scientists offer trainings and workshops to gain and maintain certifications. All federal careers are posted to https://www.usajobs.gov/. Follow these links for Soil Scientist qualifications and Soil Conservationist qualifications. State jobs are posted at https://www.oregon.gov/jobs. Jobs with Oregon Conservation Districts and other organizations are posted at http://www.conservationpartnership.org/jobs/.

USDA-NRCS	PEDON DESCRIPTION	Pedon ID # :		Feb, 2012

Series or Component Name: | Map Unit Symbol: | Photo #: | Classification: | Soil Moist. Regime (Tax.):

Describer(s): | Date: | Weather: Temp.: *Air:* *Soil:* *Depth:* | Latitude: ° ' " N Longitude: ° ' " W | Datum: | Location: Sec. T. R.

UTM: *Zone:* *mE:* *mN:* | Topo Quad.: | Site ID: *YR:* *State:* *County:* *Pedon #:* | Soil Survey Area: | MLRA / LRU: | Transect: *ID:* *Stop #:* *Interval:*

Landscape: | Landform: | Microfeature: | Anthro: | Elevation: | Aspect: | Slope (%): | Slope Complexity: | Slope Shape: (*Up & Dn / Across*)

Hillslope Profile Position: | Geom. Component: | Microrelief: | Physio. Division: | Physio. Province: | Physio. Section: | State Physio. Area: | Local Physio. Area:

Drainage: | Flooding: | Ponding: | Soil Moisture Status: | Permeability: Ksat: | Land Cover / Use:

Parent Material: | Bedrock: *Kind:* *Fract.:* *Hard.:* *Depth:* | Lithostrat. Units: *Group:* *Formation:* *Member:*

Erosion: *Kind:* *Degree:* | Runoff: | Surface Frag %: *GR:* *CB:* *ST:* *BD:* *CN:* *FL:* *Kind:* | Diagnostic Horz. / Prop.: *Kind:* *Depth:*

P.S. Control Section: *Ave.Clay %:* *Ave.Rock Frag %:* *Depth Range:*

VEGETATION :

SYMBOL	COMMON NAME	%GD COVER

MISCELLANEOUS FIELD NOTES / SKETCH :

Figure 17: NRCS Soil Description form, SOI-232 page 1

	Component Name:								Map Unit Symbol:					Date:
	Obser. Method	Depth (in) (cm)	Horizon	Bnd	Matrix Color Dry	Matrix Color Moist	Texture	Rock Frags Knd % Rnd Sz	Structure Grade Sz Type	Consistence Dry	Mst	Stk	Pls	Mottles % Sz Cont. Col Mst Shp Loc
1														
2														
3														
4														
5														
6														
7														
8														
9														
10														

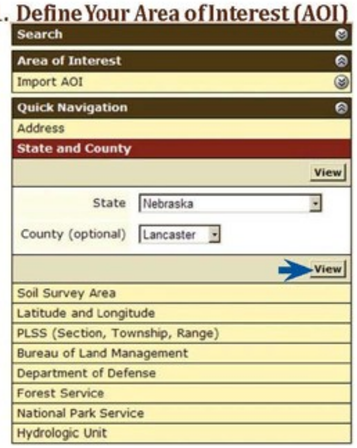
	Redoximorphic Features % Sz Cont. Hrd. Shp Knd Loc Bnd Col	Concentrations % Sz Cont. Hrd. Shp Knd Loc Bnd Col	Ped / V. Surface Features % Dst Cont Knd Loc Col	Roots Qty Sz Loc	Pores Qty Sz Shp	pH (meth) Effer. (agent) Clay %	Notes
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							

Figure 18: NRCS Soil Description form, SOI-232 page 2

Accessing Web Soil Survey

- Open the Web Soil Survey (WSS) site at: http://websoilsurvey.nrcs.usda.gov and click the "Start WSS" button.

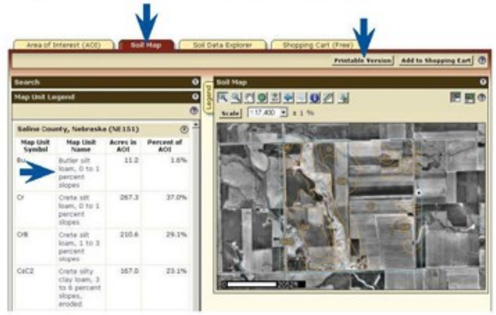
Step 1. Define Your Area of Interest (AOI)



- Several methods are available to zoom into a geographic area of interest. You can enter an address; select a state and county; enter section, township, and range information; or you can import a boundary file from your local computer to set the AOI.
- Click the "View" button to see the area.

- Use the zoom in tool (plus sign) to click and drag a rectangular box around a specific area. Repeat, as necessary, to zoom further.
- Select an AOI tool to draw a rectangular box or irregular polygon that defines the AOI and allows selection of associated soil data. Once the AOI has been defined, you can save it for use at a later date.

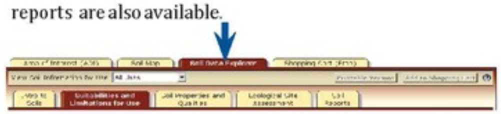
Step 2. View and Print Your Soil Map



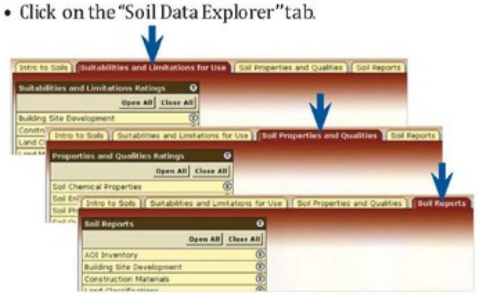
- Click on the "Soil Map" tab.
- Click on a map unit name to view a map unit description. Click the X to close the narrative.
- Print your soil map by clicking on the "Printable Version" button; then click the "View" button. On the browser menu bar, select File and Print; or click the print icon. Close the window.

Step 3. Explore Your Soil Information

WSS generates thematic maps of soil interpretations and chemical or physical properties. Tabular data reports are also available.



- Click on the "Soil Data Explorer" tab.



- Click on the tabs and explore available information (default tab is "Suitabilities and Limitations for Use").

Step 4. Add Items to the Free Shopping Cart and Check Out

WSS allows you to collect a variety of thematic maps and reports in the Shopping Cart, then print or download the content into one file or document.

- Soil map, map unit legend, and map unit descriptions are automatically added.

- Items viewed in Step 3 can be added by clicking the "Add to Shopping Cart" button.
- View your cart contents by clicking the "Shopping Cart (Free)" tab. Items checked on the Table of Contents are included.

- Get your Custom Soil Resource report.
  - -- Click the "Check Out" button
  - -- Select a delivery option and click OK

NOTE: At any time during Steps 2, 3, or 4, you can redefine the soil map location by clicking on the "Area of Interest" tab and clicking the "Clear AOI" button. Repeat Step 1.

Figure 19: Web Soil Survey guide

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