Soils – Fundamental Concepts

The Soil In Perspective:

A fundamental knowledge of soil science is a prerequisite to meeting the many natural resource challenges that will face humanity in the 21st Century. It is also true that the study of soils can be both fascinating and intellectually satisfying. It is in the soils that we are able to observe all of the principles of biology, chemistry, and physics at work. It is the understanding of these principles which enables us to minimize the degradation and destruction of one of our most important natural resources.

Soil Surveys – A Tool For The Future Slide Set & Narrative (Optional CD-Rom)

Much of our life's activities and pursuits are related to and influenced by the behavior of the soil around our houses, roads, septic and sewage disposal systems, airports, parks, farms, forests, schools, and shopping centers.

In the NRCS Conservation Planning process, it is essential that we understand the soils on which we design and install our practices. Not only is it important that our agency be the technical leaders in the field of natural resources, we should also understand the soil properties which impact the application of our technology as we use it to preserve and protect our most basic natural resource, our soils.

Soil Defined:

We have several definitions of soil depending on the discipline providing the definition:

Geologic definition – loose surface of the earth as distinguished from solid bedrock. (Support of plant life not required)

Traditional definition – material which nourishes and supports growing plants. (Includes rocks, water, snow, and even air – all of which are capable of supporting plant life)

Component definition – mixture of mineral matter, organic matter, water and air. (Example: Loam soil = 45% mineral matter, 5% organic matter, 25% water, and 25% air). (Figure 1).

Soil Taxonomy definition – collection of natural bodies of the earth's surface, in places modified or even made by man or earthy materials, containing living matter and supporting or capable of supporting plants out-of-doors. Its upper limit is air or shallow water. At its margins it grades to deep water or to barren areas of rock or ice. Its lower limit is the lower limit of biologic activity, which generally coincides with the common rooting depth of native perennial plants, the depth to which soil weathering has been effective, or both.

As a Portion of the landscape – collection of natural bodies occupying portions of the earth's surface that support plants and that have properties due to the integrated effect of climate and living matter, acting upon parent material, as conditioned by relief, over periods of time.

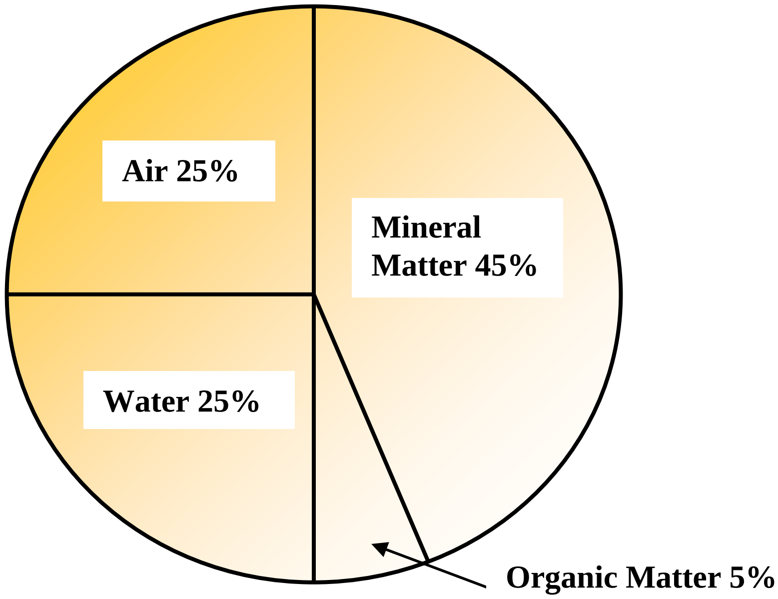

Figure 1: Composition of Average Soil

<u>The Soil Profile:</u>

A soil is a three-dimensional natural body in the same sense that a hill, valley, or mountain has three dimensions. By digging or augering a hole in the soil, you may retrieve some soil material, and, you can take this sample of soil material into the laboratory and analyze its contents, but you must go into the field to study a soil as a natural body. Soils occur on landscapes and are delineated on aerial photographs by trained soil scientists. These delineations are called polygons or polypedons, and they represent soil areas that are similar with regard to the intended uses of that soil. Polypedons have many pedons (soil profiles) included within their boundaries. See Figure 2 for a schematic of this relationship.

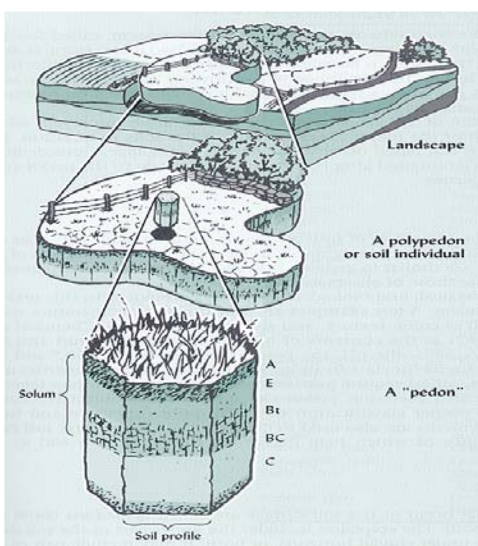

Figure 2: Relationship of Landscapes to soil polygons and a soil profile (pedon).

Soils range in depth form just a few inches to tens of meters and in may instances they have been transported many kilometers from the site of their initial formation and then deposited over materials such as bedrock which is much different than the original source of the soil materials. The effects of five soil forming factors alter the soil material: climate, time, relief, organisms, and parent material. These factors act together to differentiate individual bodies of soil. This is accomplished through four basic processes acting on the parent material to alter its properties and differentiate one soil from another. These are (A) Translocations, (b) Transformations, (c) Additions, and (d) Losses. (Figure 3)
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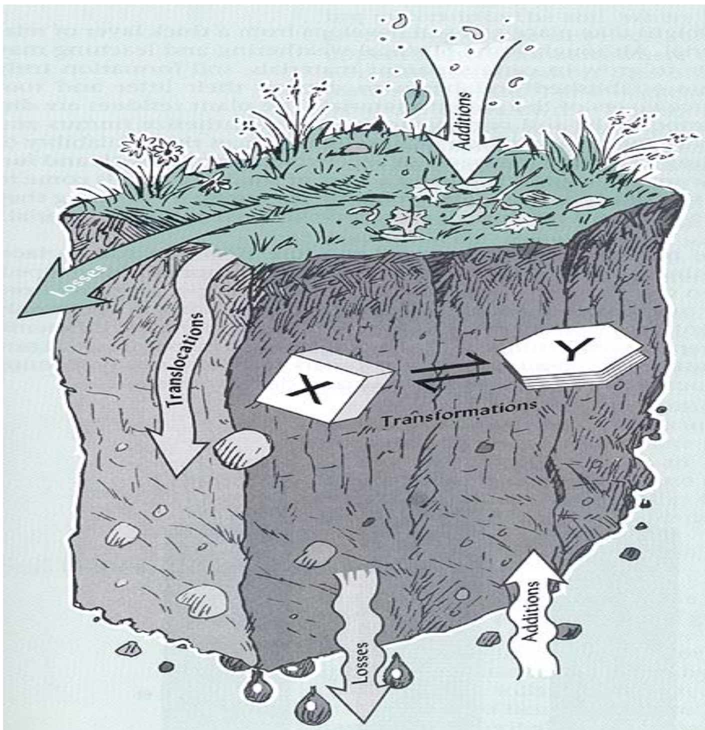

Figure 3: Soil forming processes

It is the interaction of these soil forming factors in various combinations that gives us the great variety of soils we see today. There are many variations within each factor, and even if there were only 10 gradations in each factor, there would be 10^5, or 100,000 different combinations, which would mean 100,000 different soils. In truth, no two soils are expected to be just alike, but soils, which are similar, are grouped together for purposes of classification for cultural practices and uses. We will discuss these factors in more detail in a later module.

The effects of these soil forming factors (weathering) results in the formation of layers within the soil from the surface down to varying depths depending on the intensity of the weathering. These layers are called horizons.

The combination of these layers in a sequence from the surface of the soil down represents a soil profile. Road cuts and other man made excavations can expose soil profiles and serve as windows to the soil. Observing how soils exposed in these excavations vary from place to place can add a fascinating new dimension to our understanding of soils. Once you have learned to interpret the different horizons, soil profiles can warn you about potential problems in using the land as well as tell you about the environment and history of the region. For example, soils developed under grasslands may have a very different soil profile than those developed under forestland.

The layers in a soil profile are called horizons. Horizons within a soil survey vary in thickness and have somewhat irregular boundaries, but all of the boundaries generally parallel the earth's surface. Since the weathering of the soil profile starts at the earth's surface and works its way downward, the uppermost layers have been changed the most, while the deepest layers are most similar to the original parent material Exceptions to this vertical aging process occur when transport mechanisms move the soil material and deposit it on the surface of previously formed soil profiles. Soil horizons are sometimes very easily identified and at other times are very gradual and faint.

The horizons recognized in soil profiles are identified by letters A, E, B, C, O, and R. Refer to (Figure 4) to see the idealized relationship of some of these horizons.

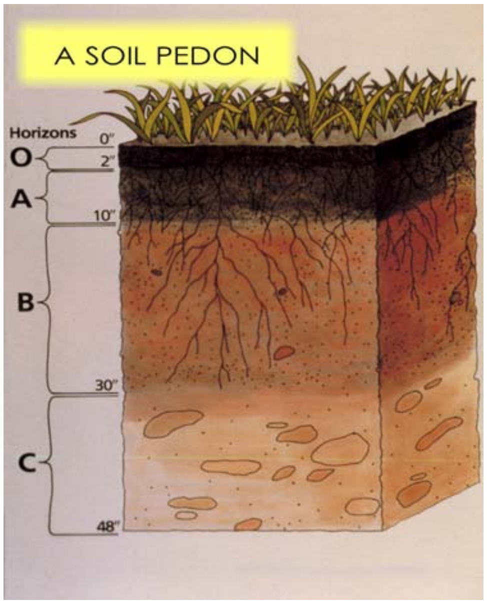

Figure 4: Idealized soil profile showing some of the soil horizon relationships

The upper mineral horizons are designated as A horizons. Sometimes there is a layer of organic material covering the upper mineral horizon. This is designated as an O horizon. A horizons are darker colored than the lower horizons and contain more organic matter. Some constituents such as oxides and clay have been moved downward from the A horizon by percolating rainwater. These often accumulate in the next layer called a B horizon. In some soil profiles there is a zone between the A and B horizons which has been strongly leached and is designated as an E horizon. The Unconsolidated parent material is called the C horizon. C horizons are the least weathered of the unconsolidated material and are directly above the unweathered bedrock, the R horizon. The O and A horizons are commonly referred to as topsoil. The layers that underlie the topsoil are often referred to as subsoil.

<u>Composition of Soil</u>

Soils have four major components: (a) mineral matter, (b) organic matter, (c) air, and (d) water.

Air and water occupy the pore spaces in soils. Pore spaces are the voids between the soil particles. Air and/or water occupy approximately half the volume of soil. Fine-textured soils have more total pore space than coarse-textured soils. As soils absorb water, the air space decreases. Generally speaking, it is desirable to have a soil which, when well drained, will have about half or its pore spaces filled with water. Soils which have all of their pore space filled with water for several days after a rain are considered in many of the definitions of wet soils within NRCS programs.

Except for gravel and rocks that occur occasionally in soils, there are three fractions, sand, silt, and clay. Sand particles are large enough to be seen without the aid magnification and give soils a gritty feel. Larger silt particles can barely be seen by the eye, and the smaller silt particles can be seen only with the aid of a microscope. Silt feels smooth within rubbed between the thumb and fingers and feels much like talcum powder or wheat flour. Clay includes the fraction smaller than silt and feels sticky and plastic when wet, and harsh and hard when dry. Since clay includes all particles below the size of silt, this fraction contains the available plant nutrients not contained in the organic matter.

The organic matter of soils is made up of undecomposed and partially decomposed residues of plants and animals and the tissue of living and dead microorganisms. Organic matter contains appreciable quantities of nitrogen, phosphorus and sulfur which become available to higher plants as decomposition occurs. Furthermore, the decomposition of organic matter helps to produce substances that make all of the plant nutrients more available. From a physical point of view, organic matter improves the aeration of soils, increases the water-holding capacity of the soil, and contributes to aggregate stability by supplying food for microorganisms whose function it is to produce chemicals which hold the soil particles together.

Physical Properties of Soils

Soil Texture – Soil texture is determined by the relative proportions of sand, silt, and clay in the soil. (Figure 6). These proportions are placed into various classes to aid in communicating to others the significance of the various combinations. Each class name has maximum and minimum percentages of each fraction. A triangle showing the range in limits for each fraction and the various class names associated with these limits is called the Textural Triangle. (Figure 5).

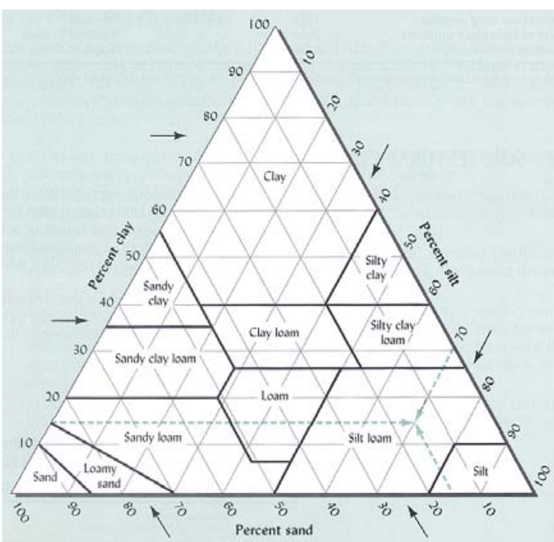

Figure 5: USDA Textural Triangle

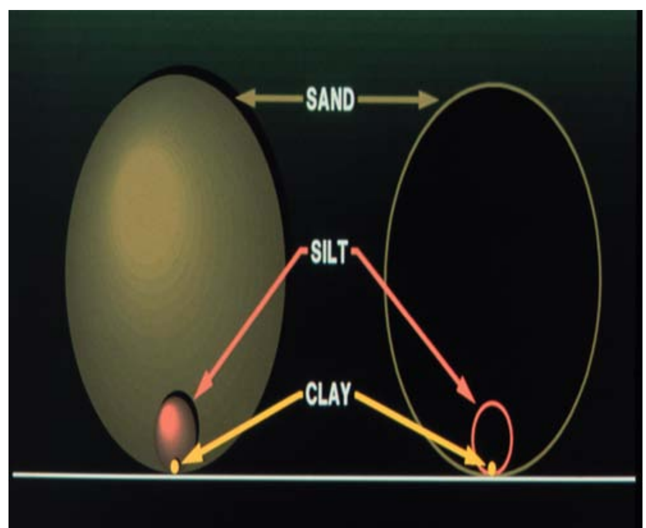

Figure 6: Relative Sizes of sand, silt, and Clay

In using the triangle, the following procedure is recommended: Assume the sample of soil contains 15 percent clay, 70 percent silt, and 15 percent sand. First, consider the clay. The base line at the bottom of the triangle is 0 percent clay. Read up the left side of the triangle to 15 percent clay. Draw a pencil line parallel to the base line for clay and through the 15 percent point for clay. Next, consider the silt. The zero line for silt is along the left edge of the triangle. Read down the right side of the triangle to just past 70 percent silt, and draw another line parallel to the zero line for silt. You will note that the lines cross in the area designated *Silt loam*. This is the class name of the soil. To check on your accuracy, it is a good idea the draw a line for the sand. The zero line for sand is along the right side of the triangle. Read to the left along the bottom of the triangle to 15 percent. Draw a line parallel to the zero line for sand. You will note that all three lines cross at the same point.

If *sand* or *sandy* is part of the name, it is necessary to state whether there is a predominance of very coarse sand, coarse sand, medium sand, fine sand, or very fine sand. The sand separate which occurs in an amount greater than any other separate is used to indicate the name; for example, fine sandy loam indicates a predominance of fine sand.

In case lines cross on a line between two class names, it is customary to use the name that favors the finer fraction. For example, if the lines all cross at 40 percent clay, the name *clay* is used rather than *clay loam*. An individual can become quite proficient at estimating the various soil fractions in the field by practicing on samples containing known percentages of the various fractions.

Soil Structure – Structure refers to the arrangement of soil particles. Soils made up of practically all sand or all silt do not show any appreciable structural arrangement because of a lack of the binding properties provided by clay. A well-developed structure usually indicates the presence of clay. Soil structure is classified into various classes. There are three major classes and several sub-classes. They are as follows: Structureless which includes *Single grain* and *Massive*; With structure which includes *Granular*, *Platy*, *Wedge*, *Blocky*, *Prismatic*, and *Columnar*; and Structure Destroyed which includes *Puddled*.

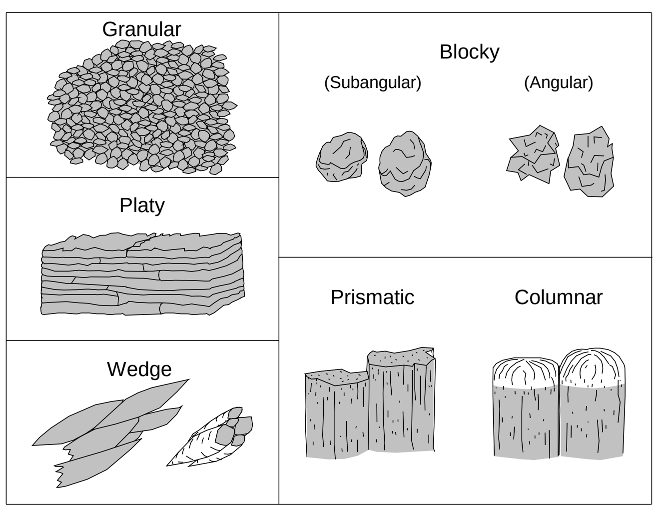

Figure 7: Examples of soil structure

Soil structure is of particular importance in the absorption of water and the circulation of air. A desirable structure should have a high proportion of medium-sized aggregates and an appreciable number of large pores through which water and air can move. Structure of both the B horizon and the A horizon is very crucial to proper drainage, infiltration, and productivity. In soils with poor structure, root penetration is limited thus reducing the plants access to water and nutrients. Structure of the A horizon has received a great deal of attention because of its relation to (a) seedbed preparation, (b) erosion potential, (c) aeration, (d) water infiltration, and (e) overall soil health.

There are three very important aspects of soil structure. They are (a) the arrangement into aggregates of a desirable shape and size, (b) the stability of the aggregate, and (c) the configuration of the pores, that is, whether or not they are connected by channels or isolated. Aggregates that are stable in water permit a greater rate of absorption of water and greater resistance to erosion. Aggregates that are unstable in water tend to slake and disperse. These aggregates, when exposed to raindrops, are particularly subject to dispersion and the resultant crusting of soils. This crusting greatly affects seeding emergence, and increases runoff and erosion.

The stability of aggregates is due to the kind of clay, the chemical elements associated with the clay, the nature of the products of decomposition or organic matter, and the nature of the microbial population. The expanding type of clay is more likely to produce unstable aggregates, other things being equal. An excess of sodium associated with clays tends to cause dispersion. A high proportion of hydrogen and/or calcium is associated with aggregation. The mycelial growth of fungi appears to have a binding effect on soils.

Although kind of clay and amount of organic matter affects soil structure, there are other factors that also affect soil structure. The following have long been known to improve structure: freezing and thawing, wetting and drying, action of burrowing insects and animals, and the growth of root systems of plants. All of these have a loosening effect on the soil, but it should be kept in mind that they have no part in aggregate stability. The loosening of the soil is a necessary part of aggregate formation, not aggregate stability.

Bulk Density – Bulk density refers to the weight of the oven-dry soil with its natural structural arrangement. The pore space is a part of the volume of soil measured for bulk density. Bulk density is determined by dividing the weight of oven-dry soil in grams by its volume in cubic centimeters. The variation in bulk density is due largely to the difference in total pore space. Because finer textured soils have higher percentages of total pore space, it follows that finer textured soils have smaller bulk density values. Obviously then, compacted soils have lower percentages of total pore space and therefore, higher bulk densities. High and low bulk densities have great influences on engineering properties, water movement, rooting depth of plants, and many other physical limitations for soil interpretations.

Soil Color – Color of soil is an important feature in recognizing different soil types, but color is also an indicator of certain physical and chemical characteristics. Color in soils is due primarily to two factors, humus content and the chemical nature of the iron compounds present in the soil. Humus has a dark brown, almost black, color. A very high content of humus may mask the color of the mineral matter to such an extent that the soil appears almost black regardless if the color status of the iron compounds.

Iron is an important color material because iron appears as a stain on the surfaces of mineral particles. About 5 percent or more of mineral soils is iron. In unweathered soils where the iron exists as an unweathered mineral, it has little or no influence on color. The iron that has the greatest effect on color is that which has weathered from primary minerals and exits in the oxide or hydroxide form. The following table depicts the forms of iron in weathered soils:

Form	**Chemical formula**	**Color**
Ferrous oxide	FeO	Gray
Ferric oxide (Hematite)	Fe_2O_3	Red
Hydrated ferric oxide	$2Fe_2O_3 \cdot 3H_2O$	Yellow

There are various degrees of hydration, and the color varies between red and yellow. It is important to note that the yellow iron s in oxidized form as well as hydrated. This means that a supply of oxygen must be associated with moist conditions to cause yellow colors to form. Too much water and an absence of oxygen cause anaerobic microorganisms to reduce the ferric iron to ferrous form, and a gray color would be the result. The red color is associated with good aeration, and a generally lower amount of water is present than is found in yellow materials. Soil colors are not limited to dark brown or black with gray, red, or yellow or their intermediates. There are some soils with various other shades, generally as a result of other minerals present in the parent materials.