

Understanding Soils

1. What is Soil?

Soil: (i) The unconsolidated mineral or organic material on the immediate surface of the earth that serves as a natural medium for the growth of land plants. (ii) The unconsolidated mineral or organic matter on the surface of the earth that has been subjected to and shows effects of genetic and environmental factors of: climate (including water and temperature effects), and macro- and microorganisms, conditioned by relief, acting on parent material over a period of time. A product-soil differs from the material from which it is derived in many physical, chemical, biological, and morphological properties and characteristics.

2. What does soil do for us?

Soil provides a physical matrix, chemical environment, and biological setting for water, nutrient, air, and heat exchange for living organisms.

Soil controls the distribution of rainfall or irrigation water to runoff, infiltration, storage, or deep drainage. Its regulation of water flow affects the movement of soluble materials, such as nitrate nitrogen or pesticides.

Soil regulates biological activity and molecular exchanges among solid, liquid, and gaseous phases. This affects nutrient cycling, plant growth, and decomposition of organic materials.

Soil acts as a filter to protect the quality of water, air, and other resources.

Soil provides mechanical support for living organisms and their structures. People and wildlife depend on this function.

3. How do soils form?

There are five **soil-forming factors** which effect soil development. These are:

- a. Parent material
- b. Climate
- c. Living organisms (Biota)
- d. Landscape position (Topography)
- e. Time

Parent Material

Parent material refers to that great variety of unconsolidated organic (such as fresh peat) and mineral material in which soil formation begins. Mineral material includes partially weathered rock, ash from volcanoes, sediments moved and deposited by glaciers. The material has a strong effect on the type of soil developed as well as the rate at which development takes place, Soil development may take place quicker in materials that are more permeable to water, Dense, massive, clayey materials can be resistant to soil formation processes.

Climate

Climate is a major factor in determining the kind of plant and animal life on and in the soil. It determines the amount of water available for weathering minerals and transporting the minerals and elements released. Climate, through its influence on soil temperature, determines the rate of chemical weathering.

Warm, moist climates encourage rapid plant growth and thus high organic matter production. The opposite is true for cold, dry climates. Organic matter decomposition is also accelerated in warm, moist climates. Under the control of climate freezing, thawing, wetting, and drying break parent material apart.

Rainfall causes leaching. Rain dissolves some minerals, such as carbonates, and transports them deeper into the soil. Some acid soils have developed from parent materials that originally contained limestone. Rainfall can also be acid, especially downwind from industrial processes.

Living Organisms

Plants affect soil development by supplying upper layers with organic matter, recycling nutrients from lower to upper layers, and helping to prevent erosion. In general, deep rooted plants contribute more to soil development than shallow rooted because the passages they create allow greater water movement, which in turn aids in leaching. Leaves, twigs, and bark from large plants fall onto the soil and are broken down by fungi, bacteria, insects, earthworms, and burrowing animals. These organisms eat and break down organic matter releasing plant

nutrients. Some change certain elements, such as sulfur and nitrogen, into usable forms for plants.

Microscopic organisms and the humus they produce also act as a kind of glue to hold soil particles together in aggregates. Well-aggregated soil is ideal for providing the right combination of air and water to plant roots.

Landscape Position

Landscape position causes localized changes in moisture and temperature. When rain falls on a landscape, water begins to move downward by the force of gravity, either through the soil or across the surface to a lower elevation. Even though the landscape has the same soil-forming factors of climate, organisms, parent material, and time, drier soils at higher elevations may be quite different from the wetter soils where water accumulates. Wetter areas may have reducing conditions that will inhibit proper root growth for plants that require a balance of soil oxygen, water, and nutrients.

Steepness, shape, and length of slope are important because they influence the rate at which water flows into or off the soil. If unprotected, soils on slopes may erode, leaving a thinner surface layer. Eroded soils tend to be less fertile and have less available water than un-eroded soils of the same series.

Aspect affects soil temperature. Generally, for most of the continental United States, soils on north-facing slopes tend to be cooler and wetter than soils on south-facing slopes.

Time

Time is required for horizontal formation. The longer a soil surface has been exposed to soil forming agents like rain and growing plants, the greater the development of the soil profile. Soils in recent alluvial or windblown materials or soils on steep slopes where erosion has been active may show very little horizon development.

4. What are the soil forming processes?

The four major processes that change parent material into soil are:

- a. Additions
- b. Losses
- c. Translocations
- d. Transformations

Additions

The most obvious addition is organic matter. As soon as plant life begins to grow in fresh parent material, organic matter begins to accumulate. Organic matter gives a black or dark brown color to surface layer. Even young soils may have a dark surface layer. Most organic matter additions to the surface increase the cation exchange capacity and nutrients, which also increase plant nutrient availability.

Other additions may come with rainfall or deposition by wind, such as the windblown or eolian material. On the average, rainfall adds about 5 pounds of nitrogen per acre per year. By causing rivers to flood, rainfall is indirectly responsible for the addition of new sediment to the soil on a flood plain.

Losses

Most losses occur by leaching. Water moving through the soil dissolves certain minerals and transports them into deeper layers. Some materials, especially sodium salts, gypsum, and calcium carbonate, are relatively soluble. They are removed early in the soil's formation. As a result, soil in humid regions generally does not have carbonates in the upper horizons. Quartz, aluminum, iron oxide, and kaolinitic clay weather slowly. They remain in the soil and become the main components of highly weathered soil.

Fertilizers are relatively soluble, and many, such as nitrogen and potassium, are readily lost by leaching, either by natural rainfall or by irrigation water. Long-term use of fertilizers based on ammonium may acidify the soil and contribute to the loss of carbonates in some areas.

Oxygen, a gas, is released into the atmosphere by growing plants. Carbon dioxide is consumed by growing plants, but lost to the soil as fresh organic matter decays. When soil is wet, nitrogen can be changed to a gas and lost to the atmosphere.

Solid mineral and organic particles are lost by erosion. Such losses can be serious because the material lost is usually the most productive part of the soil profile. On the other hand, the sediment relocated to lower slope positions or deposited on bottom lands has the potential to increase or decrease productive use of soils in those areas.

Translocations

Translocation means movement from one place to another. In low rainfall areas, leaching often is incomplete. Water starts moving down through the soil, dissolving soluble minerals as it goes. There isn't enough water, however, to move all the way through the soil. When the water stops moving, then evaporates, salts are left behind. Soil layers with calcium carbonate or other salt accumulations form this way. If this cycle occurs enough times, a calcareous hardpan can form.

Translocation upward and lateral movement is also possible. Even in dry areas, low-lying soils can have a high water table. Evaporation at the surface causes water to move upward. Salts are dissolved on the way and are deposited on the surface as the water evaporates.

Transformations

Transformations are changes that take place in the soil. Microorganisms that live in the soil feed on fresh organic matter and change it into humus. Chemical weathering changes parent material. Some minerals are destroyed completely. Others are changed into new minerals that form during soil development.

Other transformations can change the form of certain materials. Iron oxides (ferric form) usually give soils a yellowish or reddish color. In waterlogged soils, however, iron oxides lose some of their oxygen and are referred to as being reduced. The reduced form of iron (ferrous) is quite easily removed from the soil by leaching. After the iron is gone, generally the leached area has a grayish or whitish color.

Repeated cycles of saturation and drying create a mottled soil (splotches of colored soil in a matrix of different color). Part of the soil is gray because of the loss of iron, and part is a browner color where the iron oxide is not removed. During long periods of saturation, gray lined root channels develop. This may indicate a possible loss of iron or an addition of humus from decayed roots.

5. What are soil horizons?

Soils are deposited in or develop into layers. These layers, called horizons, can be seen where roads have been cut through hills, where streams have scoured through valleys, or in other areas where the soil is exposed.

Where soil forming factors are favorable, five or six master horizons may be in a mineral soil profile. Each master horizon is subdivided into specific layers that have a unique identity. The thickness of each layer varies with location, under disturbed conditions, such as intensive agriculture, or where erosion is severe, not all horizons will be present, young soils have fewer major horizons.

The uppermost layer generally is an organic horizon, or O horizon. It consists of fresh and decaying plant residue from such sources such as leaves, needles, twigs, moss, lichens and other organic material accumulations. Some organic materials were deposited under water. Subdivisions of O_a, O_e, O_i are used to identify levels of decomposition. The O horizon is dark because decomposition is producing humus.

Below the O horizon is the A horizon. The A horizon is mainly mineral material. It is generally darker than the lower horizons because of the varying amounts of humified organic matter. This horizon is where most root activity occurs and is usually the most productive layer of soil. It may be referred to as a surface layer in a soil survey. An A horizon that has been buried beneath more recent deposits is designated as an "Ab" horizon.

The E horizon generally is bleached or whitish in appearance. As water moves down through this horizon, soluble minerals and nutrients dissolve and some dissolved minerals are washed (leached) out. The main feature of this horizon is the loss of silicate clay, iron, aluminum, humus, or some combination of these, leaving a concentration of sand and silt particles.

Below the A or E horizon is the B horizon, or subsoil. The B horizon is usually lighter colored, denser, and lower in organic matter than the A horizon. It commonly is the zone where leached materials accumulate. The B horizon is further defined by the materials that make up the accumulation, such as "t" in the form of "Bt", which identifies that clay has accumulated. Other illuvial concentrations or accumulations include iron, aluminum, humus, carbonates, gypsum, or silica. Soil not having recognizable concentrations within B horizons but show color or structural differences from adjacent horizons is designated "Bw."

Still deeper is the C horizon or substratum. The C horizon may consist of less clay, or other less weathered sediments. Partially disintegrated parent material and mineral particles are in this horizon. Some soils have a soft bedrock horizon that is given the designation Cr, C horizons described as "2C" consist of different material, usually of an older age than horizons which overlie it.

The lowest horizon, the R horizon, is bedrock. Bedrock can be within a few inches of the surface or many feet below the surface. Where bedrock is very deep and below normal depths of observation, an R horizon is not described.

6. What are the soil properties?

Soils have physical, chemical, and biological properties that affect their appearance and the way they function. The following is a selected list of important soil properties.

Soil Texture

Texture is the relative proportion of sand, silt, and clay sized particles in a soil. Sand size particles are the largest of the soil particles and clay size particles the smallest. Silt size particles are intermediate in size.

Sandy soils (soils that are high in sand content) tend to have low strength, greater susceptibility to wind erosion, and less available water for plants than soils of other textures. In addition, trenches and banks are susceptible to caving, which may pose a safety hazard.

Clayey soils (soils that are high in clay content) have more available water than sandy soils. They may hold large amounts of water, making them difficult to cultivate and subject to soil creep or landslides in sloping areas. Some clayey soils exhibit shrink-swell characteristics. They crack when dry and expand when wet. This instability can cause problems for structures and roads, sometimes damaging foundations.

Medium textured soils (soils with a balanced mix of sand, silt, and clay) generally provide the most available water to plants. They also usually provide better aeration and water percolation rates than fine textured soils.

Soil texture can be estimated in the field using the "feel method." See the page which describes this method at the end of this section.

Soil Structure

Soil structure refers to the nature of soil particle aggregation. Soil aggregates are clumps of soil particles that develop naturally. Soil structure is important to water infiltration into a soil, soil aeration, root penetration, and resistance to soil erosion. Soil structure is described as to its type (shape), aggregate size, and distinctness.

Soil Color

Soils vary considerably in color. Several different colors may occur in the same soil profile. Soil color indicates many things about the soil, such as mineralogy, organic matter content, and natural drainage regime. Bright soil colors, such as reds and orange, indicate well-drained, oxidized conditions. Gray colors indicate poorly-drained, reduced conditions. Blotchy color patterns of bright and gray colors in a soil are called mottles. These indicate fluctuating drainage conditions, perhaps due to seasonal weather patterns. A soil color book is used to describe soil color in the field.

Soil Organic Matter

Soils are composed of mineral particles (sand, silt, and clay) and organic matter. Organic matter is the remains of plants and animals that are in the process of decomposition. Organic matter darkens the soil color. Highest organic matter content occurs in soil surface horizons, such as the A horizon. Organic matter contains stored plant nutrients and helps soil retain water. It also improves soil structure and aggregate stability.

Soil Reaction

Soil reaction, measured as pH, is an expression of the degree of acidity or alkalinity of a soil. It influences plant nutrient availability. A very acid soil (pH <5.0) typically has lower levels of nitrogen, phosphorus, calcium, and magnesium available for plants, and higher levels of availability for aluminum, iron, and boron than a neutral soil at pH 7.0. At the other extreme, if the pH is too high, availability of iron, manganese, copper, zinc, and especially phosphorus and boron may be low. A pH above 8.3 may indicate a significant level of exchangeable sodium.

Permeability

Permeability is saturated hydraulic conductivity. Saturated hydraulic conductivity is influenced by texture, structure, bulk density, and large pores. Soil structure influences the rate of water movement through saturated soil, in part, by the size and shape of pores. Granular structure readily permits downward water movement, whereas a platy structure requires water to flow over a much longer and slower path. Permeability is used in drainage design, irrigation scheduling, and many conservation practices.

Permeability Classes

Class	Rate (in/hr)
Very slow	<0.06
Slow	0.06-0.2
Moderately slow	0.2-0.6
Moderate	0.6-2.0
Moderately rapid	2.0-6.0
Rapid	6.0-20
Very Rapid	>20

Drainage Class (Natural)

The drainage class refers to the frequency and duration of saturation or partial saturation during soil formation. Seven classes of natural drainage are used:

- a. Excessively Drained
- b. Somewhat Excessively Drained
- c. Well Drained
- d. Moderately Well Drained
- e. Somewhat Poorly Drained
- f. Poorly Drained
- g. Very Poorly Drained

Available Water Capacity

The available water capacity is an estimate of how much water a soil can hold and release for use by plants, measured in inches (or cm) of water per inch (or cm) of soil. It is influenced by soil texture, content of rock fragments, and depth to a root-restrictive layer, organic matter and compaction. This information is used in scheduling irrigation. The size and strength of soil structure can influence the availability and the rate of water release to plant roots.

Bedrock

Bedrock is the solid rock under the soil and parent material. Sometimes it is exposed at the surface, and is referred to as rock outcrop. The depth from the soil surface to bedrock influences the soil's potential for plant growth. A shallow depth to bedrock results in a lower available water capacity and thus drier conditions for plants. It also restricts the rooting depth. Five depth classes are defined for use in soil surveys.

Depth Classes

Very Shallow	Less than 10" to bedrock
Shallow	10"-20" to bedrock
Moderately deep	20"-40" to bedrock
Deep	40"-60" to bedrock
Very deep	More than 60" to bedrock

Salinity

Salts mainly sodium, magnesium, calcium, and chloride or sulfate, may interfere with the absorption of water by plants. They also create a nutrient imbalance in some plants. Soils that have more than 2 mmhos/cm of electrical conductivity in soil solution are considered saline.

Slope

Slope is the gradient of the elevation change. A 10 foot rise in 100 feet is a slope of 10 percent. Ranges of slope assigned to map units represent practical breaks on the landscape that are important for the use and management of the area. Terraces, irrigation, and tillage practices are all considered. For example, terraces for erosion control are a concern in some areas that have more than about 1 or 2 percent slope: thus a separation of 0 to 2 percent and more than 2 percent for the same kind of soil may be used in mapping. However, they are not site specific, and for conservation planning, site investigation is necessary to determine the slope.

Flooding

Inundation by overflowing streams or runoff from nearby slopes may damage crops or delay their planting and harvesting. Scouring can remove favorable soil material. Deposition of soil

material can be beneficial or detrimental. Soil stratification is an indication of deposition by flooding. Long periods of flooding reduce crop yields. The table below gives the frequency and duration classes used in soil surveys.

Flooding Frequency and Duration Classes

Flooding frequency classes	
None or rare	Less than 5 times in 100 years
Occasional	5-50 times in 100 years
Frequent	More than 50 times in 100 years
Flooding duration classes	
Very brief	Less than 2 days
Brief	2-7 days
Long	7 days to 1 month
Very long	More than 1 month

7. What are soil management problems?

Each soil has limitations for its use and management. These limitations can often be overcome or minimized using appropriate management techniques. Below is a selected list of soil management problems.

Soil erosion

Soil erosion is caused by both agents of water and wind. Soil particles are first detached from soil aggregates and then transported by either water or wind. Water erosion occurs when the soil particles are detached by raindrop impact. Over-land flow of water then carries the particles down slope. The particles may then enter surface water bodies where they are termed sediments. The loss of soil degrades the productive capacity of the land and the sediment represents a major source of non-point source water pollution.

Removal of protective vegetative cover and exposure of bare mineral soil is the primary cause of accelerated soil erosion. The steepness and length of slope, the erodibility of the soil material, the amount of exposed soil, and the nature of the rainfall events, all influence the amount of soil erosion. Soil formation is a very slow process, so replacement of soil lost to erosion takes decades or centuries to occur.

Soil erosion can be avoided by maintaining protective cover on the soil, by creating a barrier to the erosion agent, and by modifying the landscape to control runoff amounts and rates.

Specific practices to avoid water erosion:

- a. Growing forage crops in rotation or as a permanent cover
- b. Growing winter cover crops
- c. Interseeding
- d. Protecting the surface with crop residue
- e. Shortening the length and steepness of slopes
- f. Increasing water infiltration rates
- g. Improving aggregate stability

Wind erosion occurs when vegetative cover is removed and bare soil is exposed. Wind erosion occurs on non-cohesive soils, such as sandy soils or organic soils.

Specific practices to avoid wind erosion:

- a. Maintaining a cover of plants or residue
- b. Planting shelterbelts
- c. Strip-cropping
- d. Increase surface roughness
- e. Cultivating on the contour
- f. Maintaining soil aggregates at a size less likely to be carried by wind

Soil Compaction

Soil compaction occurs when soil particles are pressed together, reducing the pore space between them. This increases the weight of solids per unit volume of soil (bulk density). Soil compaction occurs in response to pressure (weight per unit area) exerted by machinery or animals. The risk for compaction is greatest when soils are wet.

Compaction restricts rooting depth, which reduces the uptake of water and nutrients by plants. It decreases pore size, increases the proportion of water-filled pore space at field moisture, and decreases the rate of decomposition of soil organic matter and subsequent release of nutrients.

Compaction decreases infiltration and thus increases runoff and the hazard of water erosion.

Soil Salinization

Salinization is the process by which water-soluble salts accumulate in the soil. Salinization is a resource concern because excess salts hinder the growth of plants by limiting their ability to take up water. Salinization may occur naturally or because of conditions resulting from management practices.

Any process that affects the soil-water balance may affect the movement and accumulation of the salts in the soil. These processes include:

- a. Hydrology

- b. Climate
- c. Irrigation
- d. Drainage
- e. Plant Cover and Rooting Characteristics
- f. Farming practices

Salinization on the soil surface occurs where the following conditions occur together:

- a. The presence of soluble salts, such as sulfates of sodium, calcium, and magnesium in the soil
- b. A high water table
- c. A high rate of evaporation
- d. A low annual rainfall

In semiarid areas, salinization often occurs on the rims of depressions and edges of drainage ways, at the base of hill slopes, and in flat, low-lying areas surrounding sloughs and shallow bodies of water. These areas receive additional water from below the surface, which evaporates, and the salts are left behind on the soil surface.

Salts in the soil increase the efforts by plant roots to take in water. High levels of salt in the soil have a similar effect as droughtiness by making water less available for uptake by plant roots.

Early Signs

- a. Increased soil wetness in semiarid and arid areas to the point that the soil does not support equipment
- b. The growth of salt-tolerant weeds
- c. Irregular patterns of plant growth and lack of plant vigor

Advanced Signs

- a. White crusting on the surface
- b. A broken ring pattern of salts adjacent to a body of water .
- c. White spots and streaks in the soil, even where no surface crusting is visible
- d. The presence of naturally growing, salt tolerant vegetation

Soil salinity can be estimated by measuring the electrical conductivity of the soil solution.

Electrical conductivity increases in a solution in direct proportion to the total concentration of dissolved salts.

8. What is a soil survey?

Soil survey: (i) The systematic examination, description, classification, and mapping of soils in an area. Soil surveys are classified according to the kind and intensity of field examination. (ii) The program of the National Cooperative Soil Survey that includes developing and implementing standards for describing, classifying, mapping, writing, and publishing information about soils of a specific area.

Soil survey publications are very useful tools for anyone involved with land use or land management.

A soil survey contains soil maps which show where different soil types occur in an area. These maps are usually produced on an aerial photo base map which helps users orient themselves on the land.

The soil survey also contains an interpretations section where information about suitability of individual soils for different land uses is explained. The interpretations section of the soil survey report gives the user information on land suitability for agricultural activities, forestry, and wildlife uses, and also engineering uses, such as septic tank installations, roads, foundations, and more.

Examples of a soil survey map page and interpretation sheets are found at the end of this section.

9. What are hydric soils?

Hydric soils are defined as soils that formed under conditions of saturation, flooding, or ponding long enough to develop anaerobic conditions in the upper part. Hydric soils are associated with wetland ecosystems and are one of the criteria used in determining wetland boundaries. A guide for identifying and delineating hydric soils is enclosed at the end of this section.