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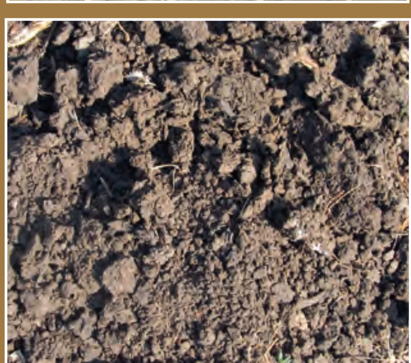

Properties of Landscape Soils

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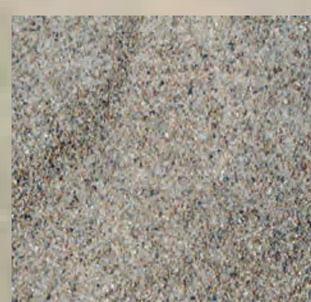

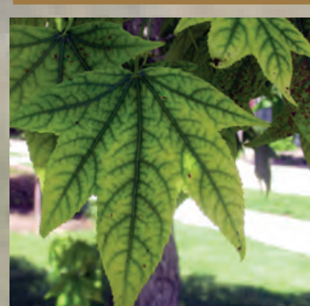

Extension is a Division of the Institute of Agriculture and Natural Resources at the University of Nebraska–Lincoln cooperating with the Counties and the United States Department of Agriculture.

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According to the Soil Science Society of America, soil is "*(i) The unconsolidated (loose) mineral or organic material on the immediate surface of the earth that serves as a natural medium for the growth of land plants.*"

Soil is not dirt but it is a complex system that provides many services to the environment. Soil is an ecosystem with living and non-living components that provide many functions (*Figure 1* and *Table 1*). Gardeners and landscape managers must understand the fundamentals of soils to properly manage landscapes. This EC is the first of a three-part series and contains information on soil formation, composition, and physical and chemical properties. The second EC, *Plant Nutrients and Soil Fertility*, describes essential plant nutrients, movement of nutrients into and within plants, types of fertilizers, and fertilizer calibration. The third publication, *Managing Landscape Soils*, describes specific soil management challenges, including pH, compaction, drainage, and slope.

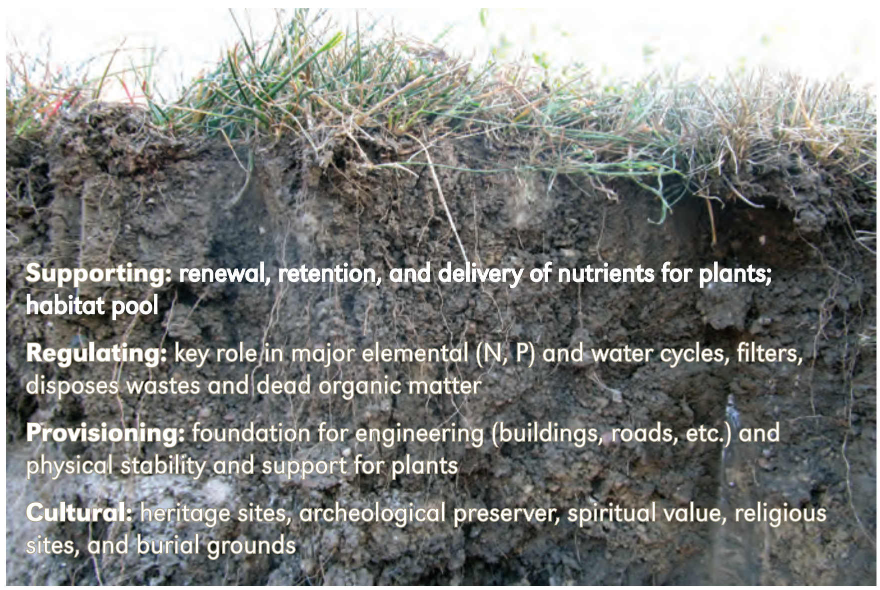


Figure 1. Soil provides supporting, regulating, provisioning, and cultural services to the environment. Additional benefits are described in videos from the Natural Resources Conservation Service, *http://soils.usda.gov/education/resources/videos/soil_stories.html*.

Soil Formation

Soil formation is influenced by five factors. These factors include: climate as it relates to precipitation and temperature; biological activities (plants, animals, microorganisms); relief (aspect and slope); parent material (original material exposed at the surface and subjected to breakdown); and time. The characteristics of the soil formed are dependent on the interaction of these factors.

- **Climate** influences soil pH, microbial activity, vegetation type, and soil depth. Just as plant materials change from west to east and north to south, soils are vastly different across the country. Western climates are drier and warmer than those found in the eastern United States. Dry, arid climates promote water evaporation and lime accumulation in the soil. Increased rainfall promotes increased plant and microbial growth (*Figure 2*). As a result of this increased growth, more soil organic matter is created and soil depth increases in eastern soils.

Table 1. Soil as a natural capital allows it to provide services to the environment.

Natural Capital	Measurable Natural Capital	Management to Maintain Capital
Solid	Mineral materials, nutrient stock	Return plant residue to soil, apply fertilizers and compost or manure, minimize water and wind erosion, reduce excess water to avoid nutrient losses
Liquid	Water	Mulch to reduce evaporation, add organic material, reduce traffic to minimize compaction and increase water entry into soil
Gas	Soil air (oxygen)	Reduce excess watering, reduce traffic to minimize compaction, create drainage
Thermal energy	Soil temperature and heat	Maintain soil cover and use appropriate tillage to prepare seedbed
Chemical energy	Soil carbon (roots, organisms)	Return plant residue to soil, apply compost or manure, reduce excess tillage-disturbance, maintain adequate moisture, temperature, and pH

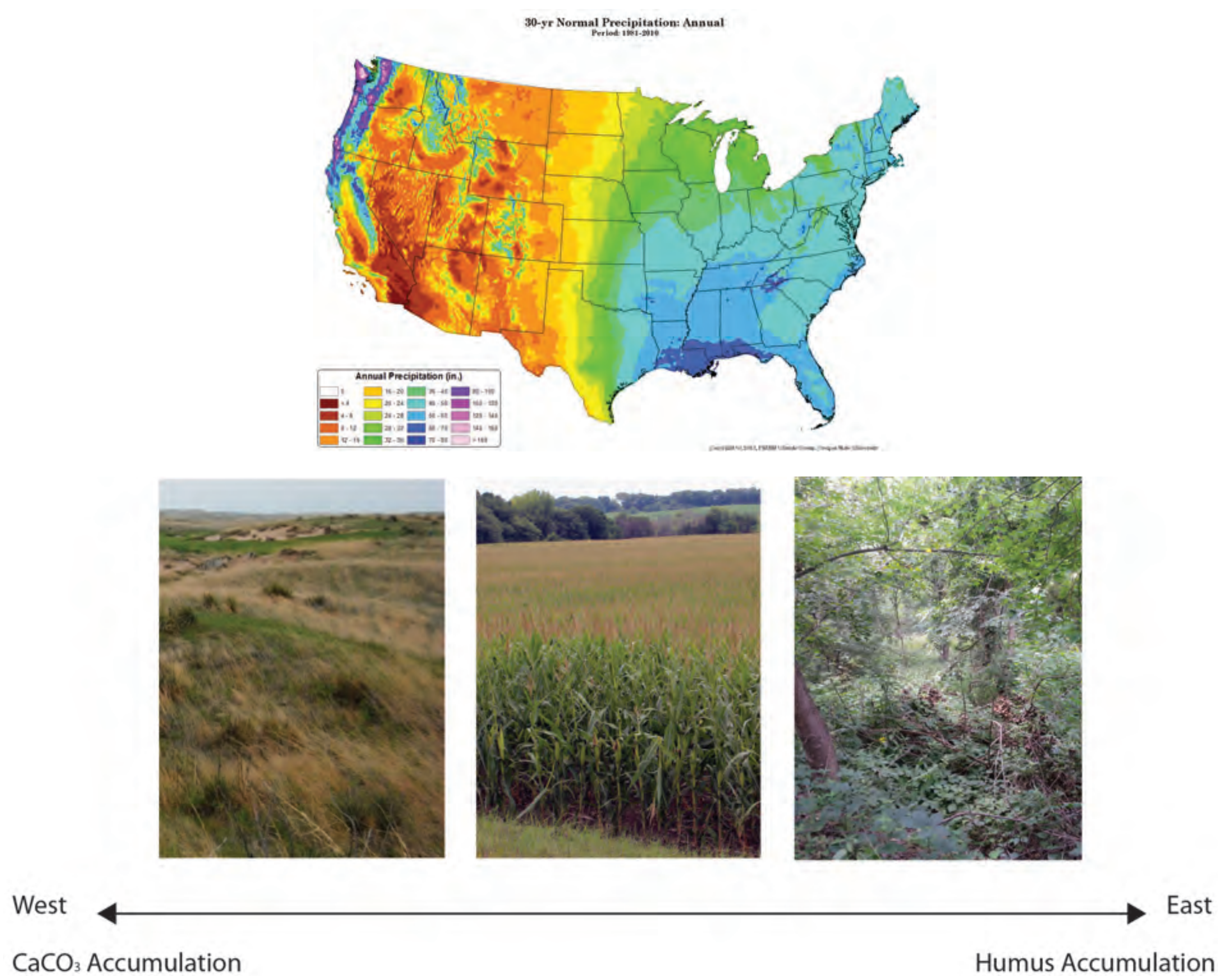


Figure 2. Total precipitation influences vegetation type and soil characteristics. Under high precipitation found in the eastern United States, more humus is formed compared to the drier conditions found in the western United States where more calcium carbonate is formed. The same affect can be seen from eastern to western Nebraska. ***Nebraska map published by UNL Conservation and Survey Division, 1993*****.**

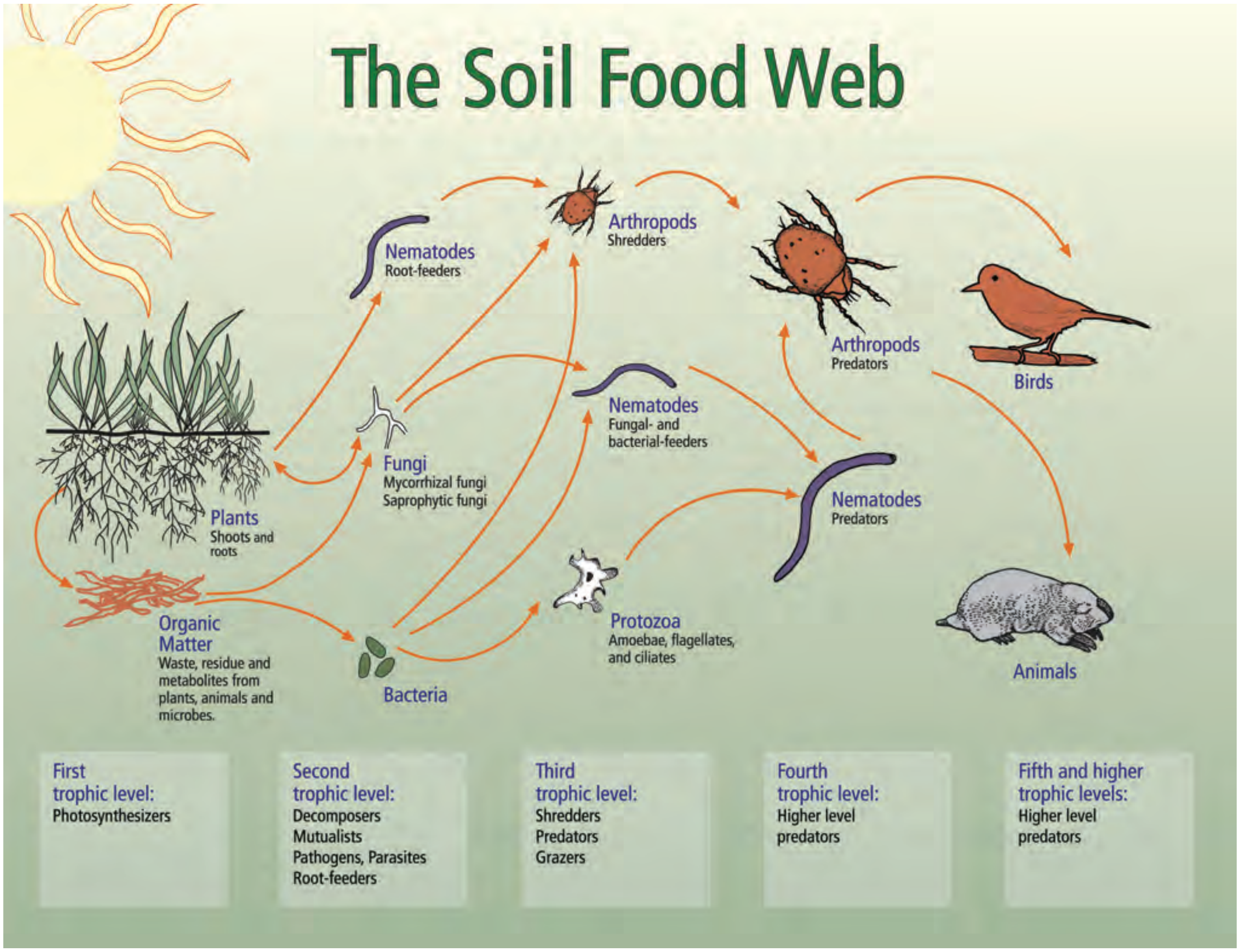


Figure 3. The soil food web is a complex network of organisms that live all or part of their lives in the soil. The arrows show movement of energy and nutrients from one organism to another. The food web is initially supplied with energy and nutrients by organisms that photosynthesize. All other organisms must obtain energy and nutrients from consuming another organism. ***Figure courtesy of USDA-NRCS.***

The greatest influence on soils when moving north to south is the amount of organic matter accumulation. Increased soil temperature increases soil microbial activity and breakdown of organic matter. More organic matter accumulation occurs in cooler northern areas because the rate of decomposition or breakdown is slow. Climate influences soil formation as rainfall rate affects how well things accumulate, dissolve, and/or leach. Climate also affects the degree of vegetation (productivity and decomposition) and erosion level.

- **Living organisms** include plants, animals, and microorganisms. These organisms influence the amount of organic matter accumulation in the soil. Organisms such as earthworms and microbes decompose organic material produced by plants and animals, such as leaves, roots, and animal waste. This organic material serves as food sources for decomposers and allows them to increase their population (*Figure 3*). An organic product called humus is the final, stable product of decomposition. The type of plant influences the rate of decomposition and amount of humus found in the soil.

- **Topography** influences soil organic matter accumulation, color, drainage, and depth. Soils formed on top of hills are usually deep. Soils formed on slopes are usually shallow due to erosion. Soils formed in low areas are usually deeper due to the deposition of soil from erosion. Darker soil colors may come from increased water accumulation in low areas. Soils with poor drainage or high water tables usually have higher organic matter content than those

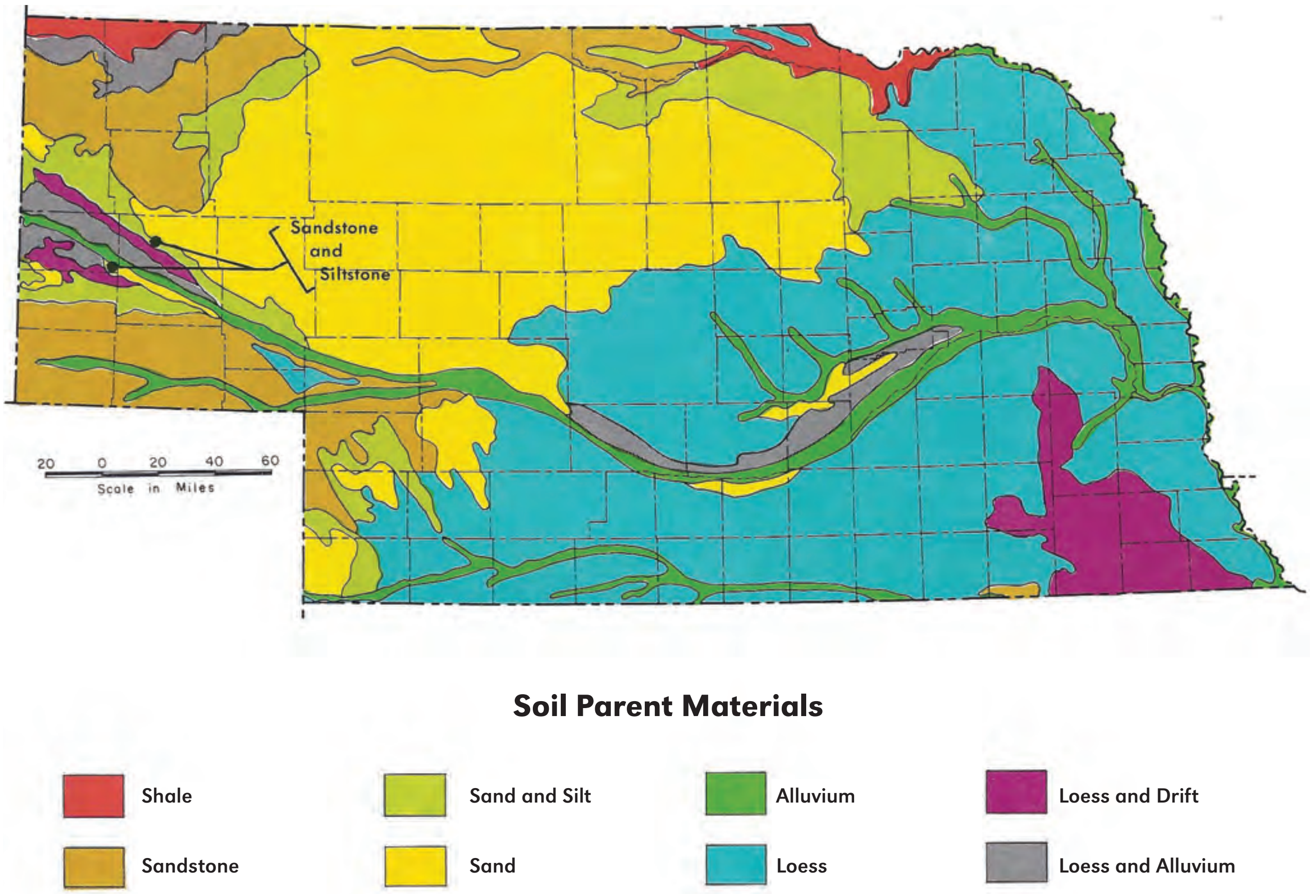


Figure 4. Eight general areas of similar earth materials constitute the parent material of Nebraska soils. ***Map published by UNL conservation and Survey Division, 1969.***

which are well-drained because of slow rate of decomposition.

- **Parent material** is the substance from which soil is developed and influences the mineral and nutrient composition of the soil. Parent material is classified based on how it was deposited. **Glacial till** parent material was transported by ice. This method transported all sizes of particles the same distance, so soil created from this parent material has many different particles sizes. **Alluvium** is parent material carried by water. Water is a good sorter of particle sizes, and as a result, larger soil particles are dropped closer to the water sources, while small particles settle further away from the water source. **Colluvium** parent material is moved by gravity. Like ice, gravity does not sort particle size effectively. As a result, soil particle sizes are mixed throughout the site. Parent material deposited by wind has several names based on where it originated. **Loess** is the most common windblown parent material. Like water, wind is a good sorter of soil particle sizes. **Lacustrine** and **marine** parent materials are deposited by lakes and oceans. Since water is the moving force, there is a high degree of soil particle separation. **Residual** or **residuum** parent material is weathered where it was found. There is no soil particle separation because it has not moved. There are several parent materials for Nebraska, but windblown sand and loess make up the majority of the parent materials (*Figure 4*).

- **Time.** Soil formation is a complex process that takes many years. The rate of weathering varies depending on the climate, living organisms, topography, and parent material. When new parent material is exposed or deposited, the process starts anew.

Nebraska's Soils

Much of Nebraska's soil developed from windblown loess under grass vegetation; however, glacial till is often found in the eastern counties where the till was not covered by loess. Rain-fall amounts increase from west to east

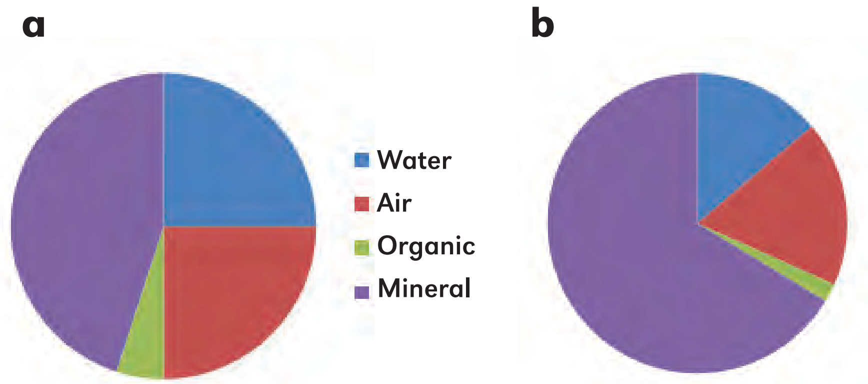


Figure 5. The major components of soil are air, water, mineral matter, and organic matter. An ideal soil contains approximately 2-5 percent organic matter, 25 percent air-filled pores, 25 percent water-filled pores, and 45-48 percent mineral matter, based on total soil volume (a). In disturbed sites, such as home landscapes, the percentages shift and the soil may contain very little organic matter due to removal of topsoil and fewer air-filled pores due to soil compaction (b). During times of low rainfall, soils may have more air and less water. Immediately after a rain, there is more water and less air in the pore space.

and had a marked influence on soil development. Soils in eastern Nebraska are generally more weathered and more acidic than soils in western Nebraska.

Nebraska soils are classed into more than 138 soil series (the most used unit of soil classification) but fewer than 20 series constitute over 50 percent of the land area. Soil maps and descriptions of the soil series and associations are found in county soil survey reports, available at farm service offices, county extension offices, and online at *http://soils.usda.gov/survey/printed_surveys/state.asp?state=Nebraska&abbr=NE*. A general soil map for Nebraska can be found at *http://snr.unl.edu/data/geologysoils/soilmap/NebraskaSoilMap.asp*.

In addition, specific information about each soil series along with interactive maps can be generated online using the Soil Survey at *http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm*.

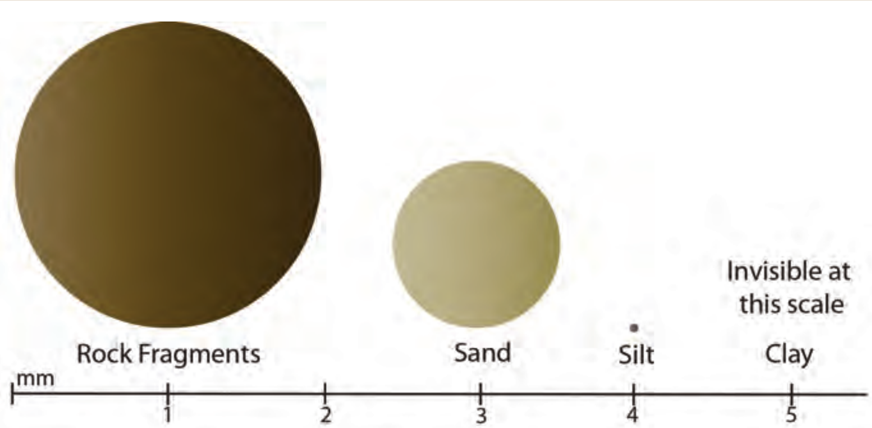


Figure 6. Soil separates are the fine portions (< 2 mm) of the inorganic soil material. The coarsest mineral particle of soil is sand (0.05-2 mm in diameter). The finest textured soil particle is clay (< 0.002 mm in diameter). Inorganic particles greater than 2 mm are classified as rock fragments.

Soil Composition

Soils are made up of organic matter, pores, and mineral matter. Under ideal or near ideal soil conditions, soils will contain approximately 2-5 percent organic matter, 25 percent air-filled pores, 25 percent water-filled pores, and 45-48 percent mineral matter, based on total soil volume (*Figure 5*).

- **Organic matter** is carbon-based plant and animal material found in the soil in varying stages of decomposition. This material is decomposed primarily through microbial, earthworm, and insect action. Decomposers break large molecules, such as cellulose, down into smaller molecules and mineral nutrients that can be taken up and utilized by plants. Humus is the final product of decomposition. Humus promotes good soil structure through binding soil particles together to make soil aggregates. In sandy soil, humus coats and binds sand grains together, increasing water holding capacity. In a fine-textured soil, organic matter is important to the stability and formation of soil aggregates, allowing water to move more rapidly through the soil.

- **Mineral matter** is the sand, silt, and clay components of the soil. This component is made up of many different kinds and sizes of particles, ranging from those visible to the unaided eye to particles so small that they can only be seen with the aid of an electron microscope (*Figure 6*). The proportion of sand, silt, and clay in a soil is described as soil texture.

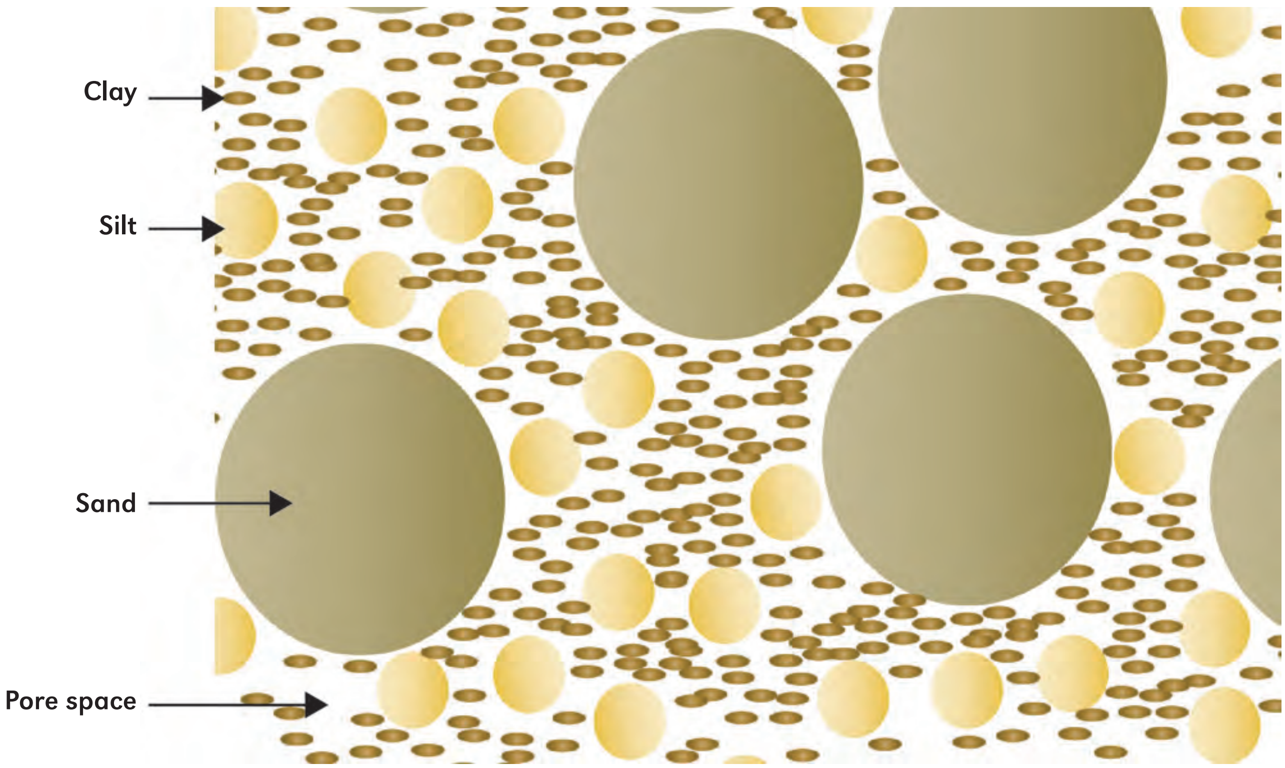


Figure 7. Clay particles are shaped like a saucer and fit together very tightly. This organization creates many small pores with a large total surface area. Conversely, sand and silt particles are round in shape and do not pack as tightly as clay particles. Since soils are a mixture of many different soil textures, there are a variety of pore sizes in most soils.

- **Pore space** is the non-solid portion of soil and is found within soil aggregates and between soil aggregates. Pores can either be air-filled or water-filled. Large soil pores are found between soil aggregates and hold mostly air. When soil compaction occurs, these large pores are compressed and destroyed. Small pores are found within soil aggregates and hold mostly water. Aggregates have varying amounts of pore spaces based on the solid portion of the aggregate (*Figure 7*).

Soil Horizons or Layers

Most soils have three distinct principal layers or horizons, collectively called the soil profile (*Figure 8*). Each layer can have two or more sub-horizons. Horizons usually differ in color, texture, and structure. In addition, there is usually considerable difference in chemical characteristics or composition. The following are distinct soil layers.

- **'A' horizon or surface soil** contains more organic matter than other soil layers. Organic matter gives a dark-brownish or blackish color to the surface horizon. Soils that are highest in organic matter usually have the darkest surface colors. This surface layer is usually the most fertile and has the greatest concentration of plant roots of any horizon of the soil. Plants obtain much of their nutrients and water from the surface soil.
- **'B' horizon or subsoil** is usually finer and firmer than the surface soil due to an accumulation of clay. Organic matter content of the subsoil is usually much less than in the surface layer. Subsoil colors are strong and bright with shades of red, brown, and yellow frequently visible. The subsoil is a soil reservoir providing storage space for water and nutrients for plants, aiding in regulating soil temperature, and supplying air for the roots of plants.
- **'C' horizon or subsoil** is decomposed rock that has acquired some characteristics of the 'B' subsoil and retained some characteristics of the rock from which it weathered. The parent material influences soil texture, natural fertility, rate of decomposition of organic matter, acidity, depth and, in some cases, topography on which the soil is formed.

Figure 8. Most soils have three distinct principal layers or horizons, collectively called the soil profile. In some soils there is an E horizon present. The E horizon indicates a zone of organic matter and clay removal (eluviation). The soil profiles above show a variety of color, texture, and structure differences in soils across Nebraska.

Landscape Soils

Landscape soils are different from agricultural and native or undisturbed soils. They are usually highly disturbed. During construction, topsoil (i.e., 'A' horizon or surface soil) is often removed and not replaced to its original depth after construction is completed. This results in limited organic matter and microbial populations, which are critical for healthy plant growth. Landscape soils are commonly compacted from construction vehicles. This limits air in the soil, water infiltration, and proper plant rooting. Construction debris (concrete, sand, lumber, trash) is often left behind, sometimes buried just below the soil surface. This creates problems with increased soil pH, dry spots, and limited root growth. Disturbed landscape soils increase soil variability and site problems, which makes managing the landscape challenging.

Physical Properties of Soil

Physical properties directly affect the soil's ability to support seed germination and plant growth, cycle essential nutrients, absorb and hold water, facilitate gas and heat exchanges, reduce erosion, filter pollutants, and support roads and structures. Properties such as soil texture and depth do not normally change with management, but properties such as soil aggregate stability, infiltration rate, bulk density, and water and nutrient-holding capacity can change over time due to landscape management practices.

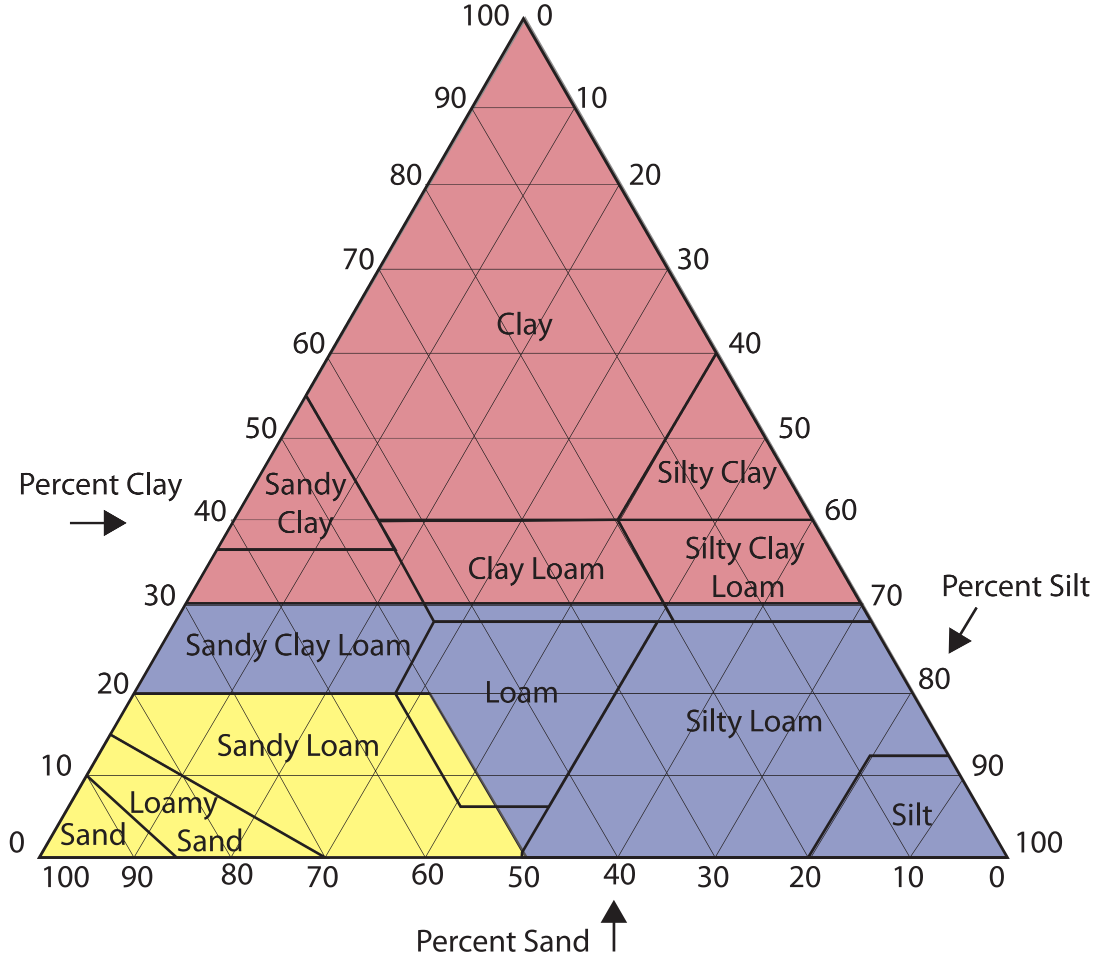
- **Soil texture** refers to the relative proportion of soil separates that make up the mineral or inorganic portion of the soil. The soil separates are sand, silt, and clay and each have different sizes, shapes, and feel (*Table 2*). There are 12 major classes of soil texture. In each textural class, a range of sand, silt, and clay amounts is present (*Figure 8*). Soil texture affects soil aggregation, water infiltration, water holding capacity, plant available water, temperature fluctuations, nutrient storage, and ease of tillage (tilth). Coarse-textured soils (sandy soils) have high infiltration rates, low water and nutrient holding capacity, low aggregate stability, high temperature fluctuations, and are easy to till, while fine-textured soils (clayey soils) have the opposite characteristics.

Table 2. Soil texture can be estimated in the field by feeling moist to wet soil between the thumb and fingers. The principle surface soil textural classes found in Nebraska are marked with an '*'.

Soil Textural Group	Soil Textural Class	Feel by Hand
Coarse to very coarse	Sandy, loamy sand*	Gritty — Does not ribbon or ball, or leave a smear on hand
Moderately coarse	Sandy loam*	Gritty — Leaves smear on hand, does not ribbon; breaks into small pieces.
Medium	Loam*, silt loam*, silt	Smooth and flour-like, does not ribbon, breaks into pieces about ½" long or less
Moderately fine	Sandy clay, sandy clay loam, clay loam*, silty clay loam*, silty clay*, clay	Forms ribbon; clays form longer ribbons than clay loams. Clay loam feels gritty.

- **Soil structure** describes the arrangement of soil particles into groups called aggregates. Aggregates have different forms and shape, which define the soil structural characteristics of a given soil (*Figure 9*). Some processes that affect aggregation include soil organic matter decay, wetting and drying, freezing and thawing, microbial activity, and cation adsorption. These processes bind soil particles and form aggregates. Soils with good structure or stable aggregates allow favorable movement of air and water, unlike those with weak aggregates. Since plant roots move through the same channels in the soil as air and water, well-structured soils allow extensive root development. Organic matter is one of the main properties that promote soil aggregation and soil structural development. Tilling a wet soil should be avoided as it degrades soil structure.

- **Soil water** comes from natural precipitation and irrigation. Water enters the soil through cracks, earthworm holes, and openings between the soil aggregates. The vertical movement of water into the soil is called infiltration. Saturation, field capacity, and permanent wilting point describe the amount of water held by a soil. Saturation is the soil water content at which all pores are filled. Field capacity is the soil water after saturated soil has drained for 24-48 hours, while wilting point is the soil water content at which plants can extract no more water. Plant available water refers to soil water between the field capacity and wilting point levels. Plant avail-



Soil Textural Classes In Order From Fine to Coarse

1. Clay	6. Sandy Clay Loam	10. Sandy Loam
2. Silty Clay	7. Silt	11. Loamy Sand
3. Sandy Clay	8. Silt Loam	12. Sand
4. Silty Clay Loam	9. Loam	
5. Clay Loam		

Figure 9. The soil textural triangle shows each of the 12 soil textures and the relative percentage of each soil separate.

able soil water and water holding capacity varies with soil texture (*Figure 10*).

- **Soil drainage** is defined as the rate and extent of water movement across the soil surface and downward in the soil. Slope or lack of slope is important to external (horizontal) soil drainage. Other factors that affect external and internal (vertical) drainage include texture, structure, and physical condition of surface and subsoil layers. Excess soil moisture negatively influences plant growth due to lack of oxygen required for root respiration. Not enough water negatively influences plant growth through slowed photosynthesis. The most desirable soil moisture condition is one in which approximately one-half of the pore space of the soil is occupied by water.

- **Soil color** is another measure of soil conditions. Color is determined by organic matter content, drainage, and the degree of

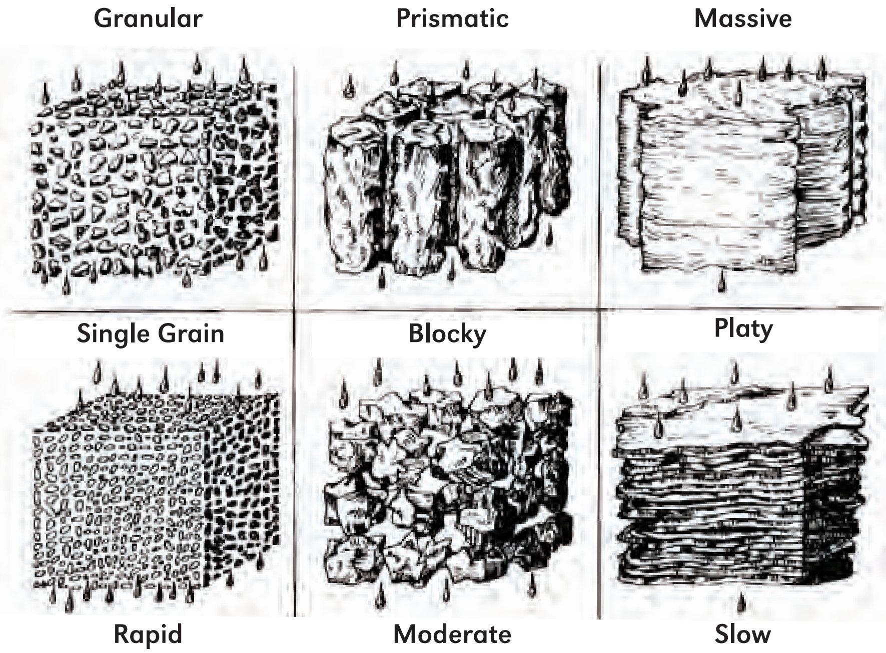


Figure 10. Soil aggregate shapes and sizes are commonly used to describe soil structure. Management practices can change soil structure. The rate of air and water movement in and through soil is influenced by its structure. *Drawing courtesy of USDA.*

Table 3. Bulk density is a measure of soil compaction. As bulk density increases, compaction increases and root penetration is restricted.

Soil texture	Ideal bulk density for plant growth (g/cm^3)	Bulk density that restricts root growth (g/cm^3)
Sand	<1.60	>1.80
Silt	<1.40	>1.65
Clay	<1.10	>1.47

oxidation or extent of weathering. Organic matter, manganese, and iron are the primary coloring agents in soil. Light or pale surface soil colors indicate low organic matter content and are typically associated with relatively coarse textured and highly leached soils. Dark colors indicate high organic matter content and may result from high water table conditions (poor drainage). Dark colors may also result from the parent material. Dark soils warm up faster than light colored soils. Red, yellow, and brown subsoil colors indicate a well-drained and well-aerated soil. Gray-colored subsoils indicate wetness and lack of oxygen. Drainage is usually poor in gray-colored soils.

- **Bulk density** is the mass of dry soil per unit volume. Soil texture, organic matter, and the degree of compaction influence soil bulk density. Soils with large pore spaces often have low bulk densities. Clay soils often have lower bulk densities than sandy soils with low organic matter. Water movement, rooting depth, and soil aeration are restricted as bulk density increases (*Table 3*). Poor landscape management practices such as untimely tillage (wet soil) increase bulk density and reduce the pore spaces.
- **Soil depth** is the vertical distance into the soil from the surface to a layer that essentially reduces the downward growth of plant roots. Rock, sand, gravel, dense clay, or a compacted layer may reduce root growth. Soils that are deep, well-drained, and have desirable texture and structure are suitable for the production of most landscape plants. Deep soils hold more plant nutrients and water, and are more productive, than shallow soils with similar textures. Trees growing in shallow soils have shallow root systems and are more frequently blown over by wind than those growing in deep soils. Most soils in Nebraska are deep.

Chemical Properties of Soil

Soil chemical properties arise from the ways soil water interacts with soil solids and gases in soil pores. The following describes several chemical properties which affect the behavior of most soils and the plants growing in them.

- Cation exchange capacity (CEC) is a measure of the soil's ability to hold positive particles, called cations. Cation exchange capacity arises because many soil particles, especially clay and humus, have a negative charge. This charge allows them to attract and hold dissolved positive cations but repel dissolved negative particles (anions). Cations are not held permanently, though, and may be exchanged by other cations. Because some plant nutrients are cations, high CEC is

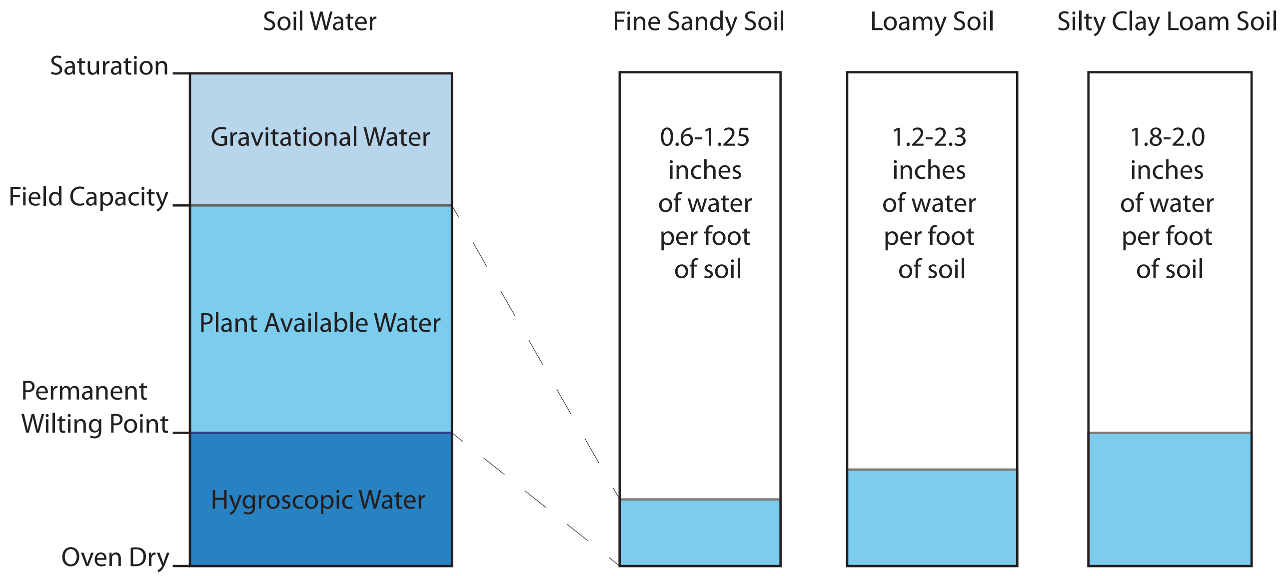


Figure 11. The water holding capacity of a soil depends on its texture and organic matter content. Soils with a high amount of clay hold more water than sandy soils. However, the infiltration rate or rate that water moves into the soil for sandy soils is higher than clay soils due to the large pore spaces. Sandy soils may have infiltration rates up to 12 inches per hour, where compacted clay soils may have zero or near zero infiltration per hour.

Table 4. Cation exchange capacity increases as the amount of finer soil particles increase.

Soil	CEC (meq/100 g)
Sand	2 to 5
Sandy loam	5 to 12
Loams	10 to 18
Silt and silt clay loams	15 to 30
Clay and clay loams	25 to 40

generally good for plant growth (*Figure 11*). Cation exchange capacity has no direct effect on the retention of nutrients in anion (negative) forms, such as nitrate. On a weight basis, humus has an average CEC of 2 ½ times that of clay, another reason showing the importance of soil organic matter content (*Table 4*).

- Soil pH describes the acidity or alkalinity of soils. It is an indirect measure of hydrogen (H^+) activity (approximately equal to concentration) in the soil. The usual pH scale runs from 0-14, but most soils have pH values between 3.5 and 9.5. A pH value of 7 is described as neutral and has an equal activity of H^+ and OH^- (hydroxyl) ions. As a soil becomes more acidic, that is as its pH falls below 7, its H^+ activity rises and OH^- activity falls; as a soil becomes more alkaline, that is as its pH rises above 7, its H^+ activity falls and OH^- activity rises. It is important to remember that the pH measurement scale is not a linear scale but a logarithmic scale. Therefore, a soil with a pH of 8.0 is 10 times more alkaline than a soil with a pH of 7.0, and a soil with a pH of 5.0 is 10 times more acidic than a soil with a pH of 6.0. Soil pH can affect plant growth in many ways, but most directly through nutrient availability. For most plants, the pH range from 6.0-7.0 (slightly acidic to neutral) is best for nutrient availability. Extremes of pH can reduce the availability of some nutrients and even increase availability of others to

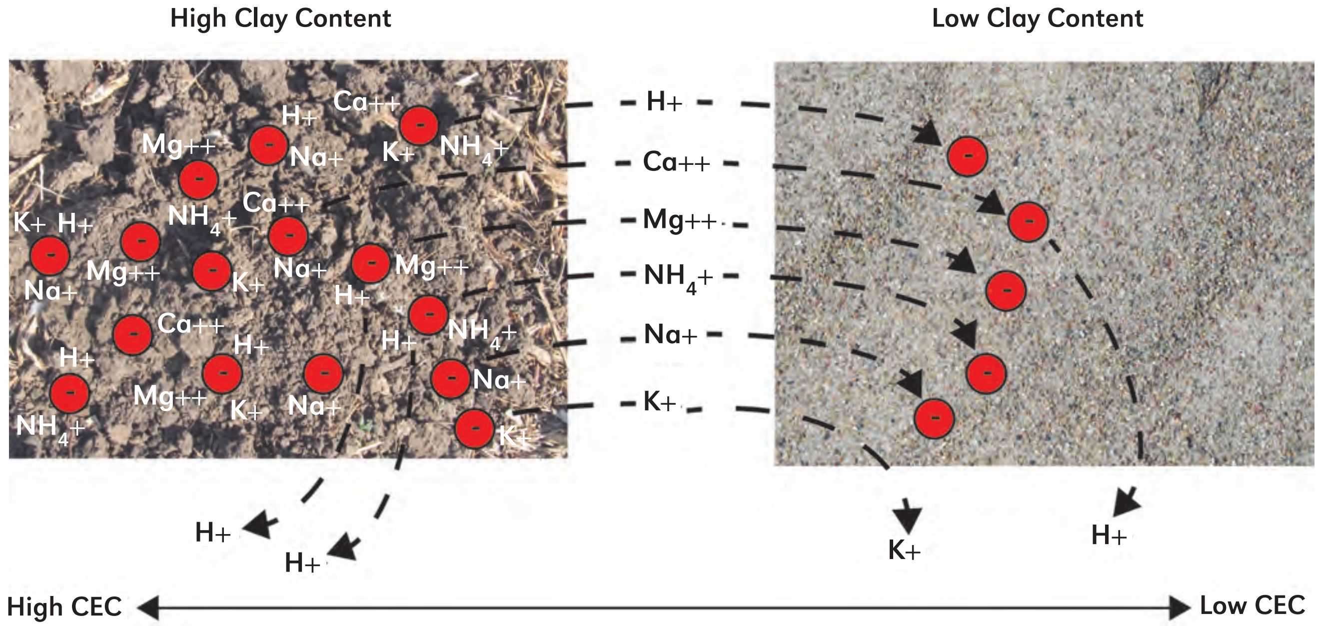


Figure 12. Soils with high clay and organic matter (humus) content have more negatively charged positions on which they can hold cations than soils with lower clay and humus content. As a result, high clay, high humus soils have a higher cation exchange capacity and can hold more nutrients than sandy, low humus soils. Cations from soil solution can exchange with cations held on the soil.

toxic levels (*Figure 12*). Materials containing lime can be used to increase pH. A soil test for lime requirement is necessary to determine exactly how much lime will be effective in a given soil. Many factors can affect soil pH, but it is most common that soils become more acidic as they age. If a soil is alkaline or becomes alkaline, it is likely because of the presence of undissolved lime or accumulation of salts. More information about dealing with calcareous, saline-sodic, high pH, and low pH soils can be found in the EC *Managing Landscape Soils*.

- Soil salt content (salinity) describes the amount of salt which is or can be dissolved in the soil solution. This is important because most landscape plants do not perform well if they are forced to grow in a saline soil. The presence of dissolved salts reduces the availability of soil water so that a plant may wilt, even if the soil is perceptibly moist. Certain salts may also interfere with the uptake of essential plant nutrients. The most common quantity for diagnosing salinity is the electrical conductivity (EC). Soils are described as saline if they have an EC above 4 deciSiemens/meter (dS/m), although some salt-sensitive plants may be damaged by ECs lower than 4.
- Base saturation describes the percentage of the CEC that is occupied by "basic cations," usually the total of calcium (Ca), magnesium (Mg), sodium (Na), and potassium (K). Base saturation corresponds roughly to soil pH because a low pH acidic soil, with its high concentration of H^+, will have low base saturation. Such soils generally are unfavorable for plant growth, both because of the acidic pH itself and because of low availability of nutrient cations.

Summary

Soil is an important factor in healthy plant growth. Its formation is dependent on climate, living organisms, topography, parent material, and time. The amount of organic matter, mineral matter, and pores space a soil has will influence its physical and chemical properties. Ultimately, the physical and chemical properties of a soil will impact plant selection and management practices.

Portions of this EC were adapted from the Nebraska Master Gardener Manual.

For more detailed information regarding soils, see the Plant & Soil Science eLibrary lessons at *passel.unl.edu.*

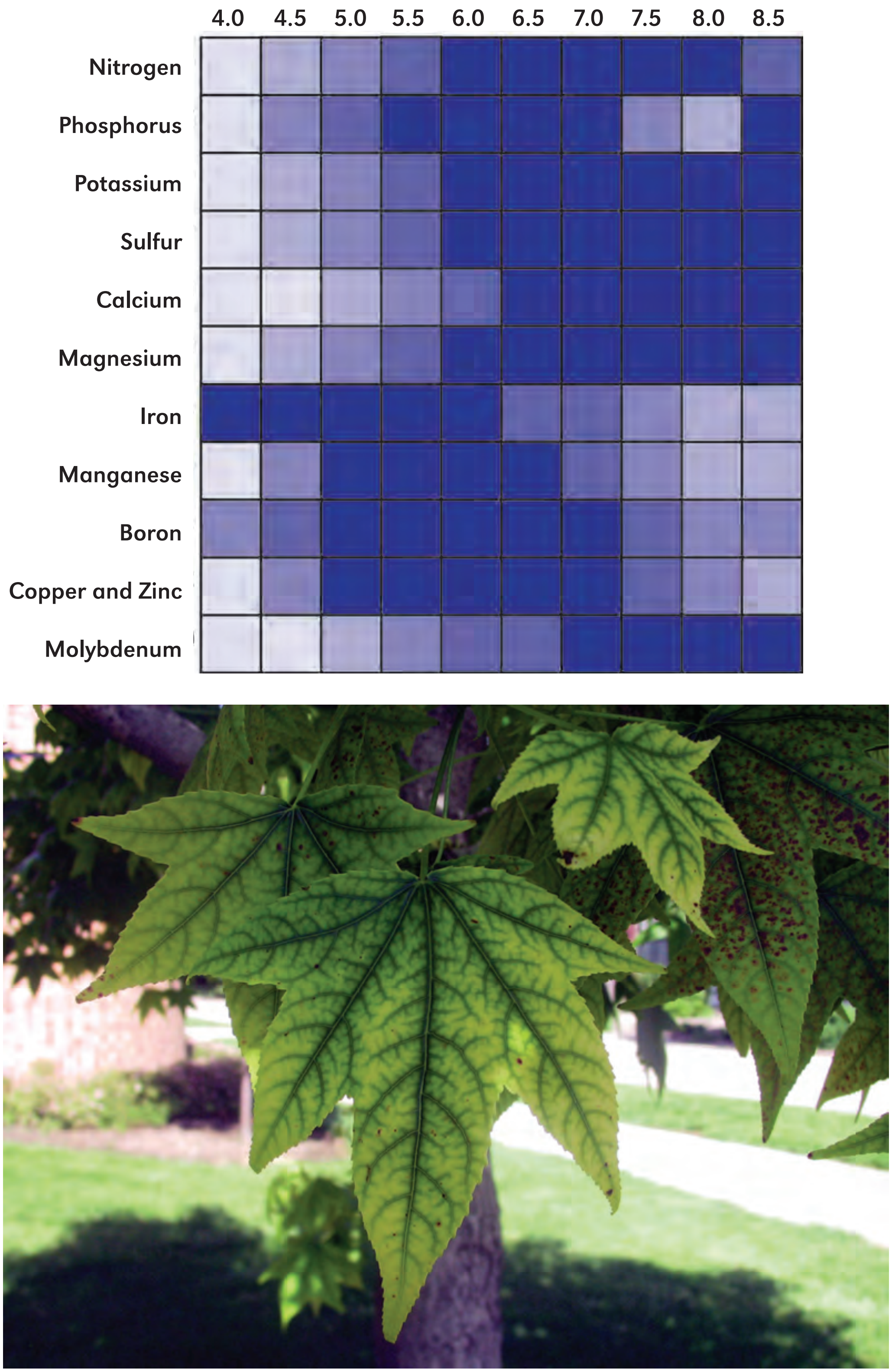


Figure 13. Soil pH influences a plant's ability to take up and assimilate nutrients from the soil. Darker shading indicates more availability for plant uptake. For example, in alkaline soils (> 7 pH), iron becomes unavailable for plant uptake and plants grown in those soils may show interveinal chlorosis, a sign of iron deficiency, even though there are adequate amounts in the soil.

This publication has been peer reviewed.