

SOIL and WATER RESOURCES

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Table of Contents

Chapter Topic

- **Soil Development**
- **Texture and Structure**
- **Soil Water**
- **Soil Organic Matter**
- **Soil Nutrients, Testing and Fertilizer Recommendations**
- **pH and Liming**
- **Soil Survey Report**
- **Soil Erosion**
- **Irrigation**
- **Soil and Water Pollution**

SOIL DEVELOPMENT

[Top](#)

Soil formation from geological rocks and minerals takes a very long time. No soil is formed in one lifetime. Thus "saving the soil" is very important. However, it is difficult to know how to save it if we do not know how it forms. We also must know how to judge what the soil has gone through in the past by how it looks today. These judgments will allow us to make some predictions about how to manage and preserve this soil in the future.

Learning Objectives

- Define parent material, cumulose and residual material, transported material, soil profile, soil horizon, and soil age.
- Describe the six (6) soil forming factors.
- Differentiate between the various soil horizons.
- Identify a soil as young, mature or old.

Geologic or Parent Materials

All soils are formed in some geologic or "parent" material. In discussing soil formation, parent materials are classified as to how they were formed. First, they are divided into sedentary and transported materials.

Sedentary materials are those that have been in place for a very long time (over a million years). They are divided into cumulose (organic) materials and residual (inorganic) materials. Cumulose

materials include peats and mucks. These are present only in scattered areas around the world. Residual materials are bedrock. They include limestone, sandstone, shale, granite, and other rocks. In Nebraska only about 10% of the soils are formed in residual materials and none are formed in cumulose materials.

Transported materials have been moved to their present position more recently (10,000 to 100,000 years). They are named by the way they were moved. Thus we have glacial till (glaciers), eolian (or aeolian) materials (wind), alluvium (streams), and colluvium (gravity). Others not found in Nebraska are lacustrine (lakes) and marine (oceans). Eolian materials are divided into sand (coarse materials) and loess (fine materials). About 45% of Nebraska soils are formed in loess and 25% in sand, so wind has always been an important force in Nebraska. In addition, 10% are formed in alluvium, 10% in glacial till, and 10% in residual materials. There are small scattered areas of colluvial materials.

Soil Forming Processes

Normal soil development is accompanied by the accumulation of organic matter in the surface layer of soil and the downward movement of soil components such as clay, lime, and salts. The rates at which these changes occur depend on the effects of the six soil forming factors: climate, biological activities, topography, parent material, drainage, and time. Two terms are needed in the description of soil forming processes. The first is leaching, the movement of materials by water downward through the soil. The second is weathering, the sum of all processes which convert a parent material to a soil.

The major effects of climate are rainfall and temperature. The rainfall determines how fast materials are moved downward in the soil and the temperature determines the rate of formation and decomposition of the soil organic matter. Biological activities determine the amounts and kinds of organic matter supplied to the soil. They may also affect the amount of rainfall that runs off the soil and the amount that moves downward through the soil.

The effect of topography is mainly in the slope of the land affecting whether water runs off the soil surface or percolates downward through the soil. Drainage determines, again, whether water passes through the soil or stands on the surface. It also affects the rate of organic matter accumulation. Poor drainage slows down organic matter decomposition. The nature of the parent material determines how fast roots can be established, the rate of water supply, and the ease with which plant nutrients can be released from the soil minerals. The final factor is time, the amount of time the parent material has been exposed to the elements.

Soil Horizons

We can make some judgments about how a soil was formed by looking at the soil profile. The soil profile is a vertical section or cut through the soil from the surface into the parent material. It shows the layers, or soil horizons, which can be differentiated from each other by color, texture, structure, and other indications. As will be indicated later, not all horizons are found in all soils.

O horizon In soils which have been developed in areas where the natural vegetation is trees, a layer of leaves, needles and twigs may form on the soil surface. This layer is not usually found in grassland soils.

A horizon This is the upper horizon of most soils. It is the layer of organic matter accumulation. It is also a layer from which clay, lime, and other soil components have been removed and leached to lower horizons. It is usually easily identified by its darker color.

E horizon In soils in which water stands part of the year an E horizon might be formed. Owing to the lack of aeration, chemical reduction causes the solubility of many soil components which, like in the A horizon, are leached downward. The intense chemical action in this layer gives it light, almost white, color.

B horizon This horizon is where all the clay, lime, and other materials moved out of the A and E horizons end up. Therefore, it often contains more clay than any other horizon. Lime may also accumulate here if leaching is not too severe. Often the B horizon is called the "subsoil".

C horizon The O, A, E, and B horizons constitute the "true" soil or solum, that part of underlying geological material affected by weathering. The C and R horizons are parent material and are only slightly affected by weathering. The C horizon constitutes "loose" material: eolian, alluvial, colluvial, or glacial materials or loose materials broken up from bedrock.

R horizon The R horizon is parent material which is solid rock. It consists of residual materials such as limestone, sandstone, shale, granite, and other solid materials.

Horizons often have subscript letters or numbers that denote subdivisions within the horizons. Sometimes it is difficult to find a clear separation between horizons. In this case there may be an AB horizon between the A and B horizons, or a BC horizon between the B and C horizons.

Soil Age

Like persons, soils have an age. However, this age is not determined in years. It is determined by the extent of conversion of parent material into soil as measured by the number of soil horizons, the thickness of the horizons and the differences among them.

A young soil is one in which there are only one or two very thin horizons formed from the present parent material. Soils which may have been covered up are ignored. Young soils include those on bottom lands where there has been inadequate time for soils to form, steep slopes where any A horizon formed is eroded away, and the soils formed in hard rocks which are very difficult to break up.

A mature soil will contain A and B horizons having fair thickness. In forest soils, an O horizon should also be present. An old soil has horizons that are usually thick and at least one is very different from the others. An E horizon or a claypan B horizon are indications of an old soil. Tropical soils are usually old because of the high temperature and rainfall which cause intensive weathering.

Sample Questions

What name is given to parent material that has been formed as the result of gravity?

How does climate affect soil formation?

Name the six different soil horizons?

What horizon is whitish in color?

Would a soil be classified as young, mature or old if it has only an A horizon?

TEXTURE and STRUCTURE

[Top](#)

From a physical perspective the soil constitutes the building blocks upon which we walk, construct buildings, grow crops and filter natural and manmade compounds. It is the physical properties which we see. Soil physical, chemical and biological properties and processes interact to enhance its value as a natural resource.

Learning Objectives

- Define texture, textural class, soil separate, soil structure, and aggregate.
- Understand the complexity of the physical system and identify its major components.
- Determine the textural class of a soil using a textural triangle.
- Describe how natural forces influence aggregation and soil structure.
- Identify soil structure by type and determine horizons where they are usually found.

Composition

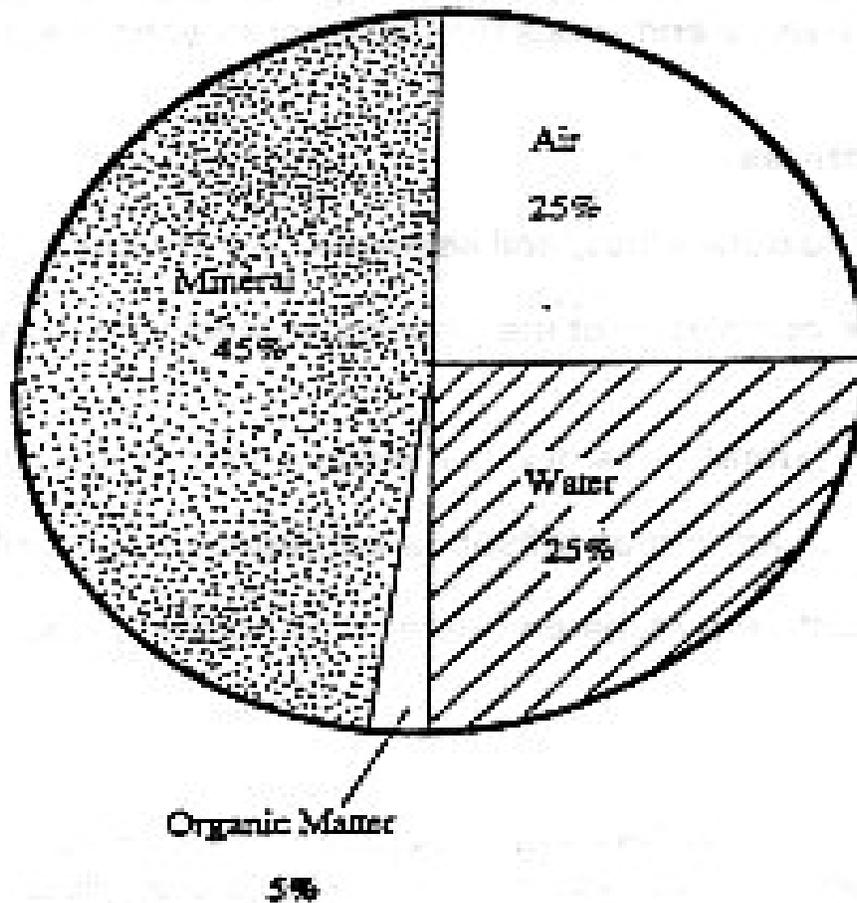
Soil may look simple however, it is an extremely complex system. It is most often described by its physical, chemical and biological properties and processes. Soil is organic and inorganic; inert and active; living and non-living. Soil contains many organisms: bacteria, nematodes, fungi, earthworms, and small animals.

Complex as it is, soil can be described simply. It consists of only four major components: air, water, organic matter, and mineral matter (Fig. 1). In an ideal soil, air and water fill the pore space and compose about 50% of the volume; organic matter accounts for about 1 to 5% of the soil volume; and mineral matter accounts for the remaining 45 to 49%. The partitioning of these four components vary considerably, for example an organic soil in Michigan may be 45% organic, while a desert soil from Arizona may be 60% mineral.

The mineral and organic matter fractions of the soil are the solids and serve as the storehouse and exchange sites for plant nutrients and other chemicals; thus, they are important from a fertility and environmental standpoint.

It is also these fractions, along with cultural practices, that influence other physical properties and processes.

Figure 1. Major components of soil.



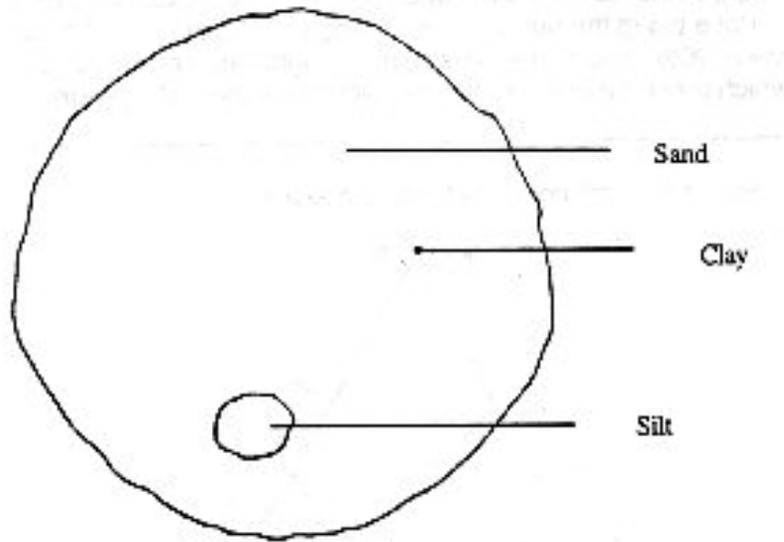
Soil Texture

A close look at soil will clearly indicate that the makeup of the mineral portion is quite variable. The soil is composed of small particles. These small particles are the result of massive rocks of different mineralogy that have weathered to produce smaller rock fragments and finally soil particles. Soil particles vary in size, shape and chemical composition. Some are so small they can be seen only with a microscope.

Three categories for soil particles have been established - sand, silt and clay. These three groups are called soil separates. The three groups are divided by their particle size. Clay particles are the smallest while sand particles are the largest. The size ranges for the soil separates and the relative size of the particles are shown in Figure 2.

Sand particles can be seen by the naked eye. A microscope must be used to see silt particles. An electron microscope is needed to see clay particles. In comparison to spheres we know and understand, a sand particle may be equivalent to a basketball; a silt particle to a golf ball; and a clay particle to the head of a pin.

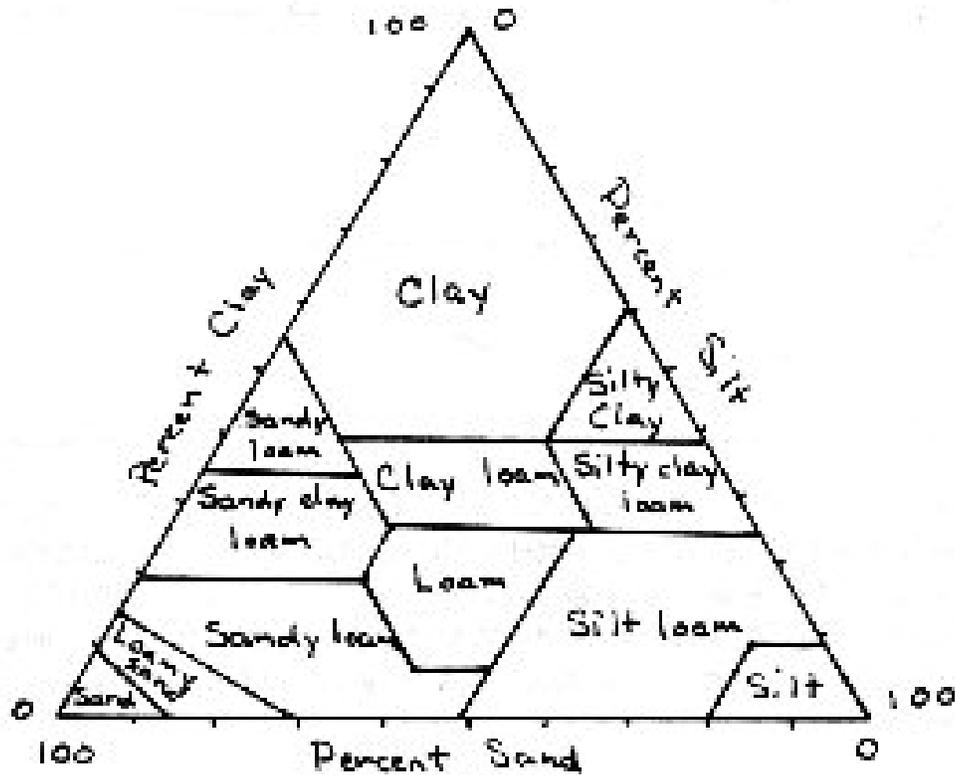
Figure 2. Relative size of soil separates.



The proportion of the different soil separates in a soil defines its soil texture. In total there are 12 different soil textural classes. For example, if most particles are large and coarse the soil is called a sand. It looks and feels sandy as well. A silt soil is dominated by medium sized particles and feels like flour. Small sized soil particles primarily make up a clay soil which feels slippery or greasy when wet.

The textural triangle is used to represent all possible combinations of soil separates and to determine the soil textural class of a soil sample (Fig. 3). The three sides of the textural triangle represent increasing or decreasing percentages of sand, silt and clay particles. When the percent of sand, silt and clay are added together, they equal 100%. The percentage indicates the proportion of the weight of a soil that is sand, silt or clay.

The textural triangle is easy to use once it is understood. Assume that you have a soil that is 60% clay, 20% silt and 20% sand. The percent of clay is identified on the left side of the triangle. From the lower left corner to the top of the triangle, the percent clay increases from 0% to 100%. Move along the left side of the triangle until you reach 60% clay. Then draw a line at 60% clay that is parallel to the bottom of the triangle. The percent silt is identified along the right side of the triangle. From the top of the triangle to the lower right, the percent silt increases from 0 to 100%. Move along the right side of the triangle until you reach 20% silt. Now draw a line at 20% silt that is parallel to the left side of the triangle. The bottom of the triangle identifies the percent sand. From the lower right corner to the lower left corner, the percent sand increases from 0 to 100%. Move along the bottom of the triangle until you reach 20% sand. Draw a line at 20% sand that is parallel to the right side of the triangle. The point at which these three lines intersect will define the soil's texture.



Determine soil texture for the soils in Table 1. The soil textural class you determine from the triangle should match the texture listed.

Table 1. Soil separates and textural classes			
% Clay	% Silt	% Sand	Textural Class
24	37	30	Loam
8	10	82	Loamy sand
35	52	13	Silty clay loam

Some small rock fragments may be present in soil as stones or gravel. While these rock fragments play a role in the physical properties and processes of soil they are not considered in the determination of soil texture.

Clay is the smallest mineral particle in soil. These small particles are the active portion of a soil because chemical reactions occur at their surface. The chemical reactions control the adsorption and release of plant nutrients and many other chemicals in the environment. Sand and silt particles are much larger than clay and are quite inactive chemically because of their mineral composition and limited surface area.

Soil Structure

Soil structure refers to the arrangement of soil separates into units called soil aggregates. An aggregate possesses solids and pore space. Aggregates are separated by planes of weakness and are dominated by clay particles. Silt and fine sand particles may also be part of an aggregate. The aggregate acts like a larger silt or sand particle depending upon its size.

The arrangement of soil aggregates into different forms gives a soil its structure. The natural processes that aid in the formation of aggregates are (1) wetting and drying, (2) freezing and thawing, (3) microbial activity that aids in the decay of organic matter, (4) activity of roots and soil animals, and (5) adsorbed cations.

The wetting/drying and freezing/thawing action as well as root or animal activity push particles back and forth to form aggregates. Decaying plant residues and microbial by-products coat soil particles and bind particles together into aggregates. Adsorbed cations help form aggregates whenever a cation is bonded to two or more particles.

Aggregates are described by their shape, size and stability. Aggregate types are used most frequently when discussing structure (Table 2, Fig. 4).

Table 2. Structure type and description	
Type	Description
Granular	Rounded surfaces
Crumb	Rounded surfaces but larger than granular
Subangular blocky	Cube-like with flattened surfaces and sharp corners
Blocky	Cube-like with flattened surfaces and rounded corners
Prismatic	Rectangular with a long vertical dimension and flattened top
Columnar	Rectangular with a long vertical dimension and rounded top
Platy	Rectangular with a long horizontal dimension
Single grain	No aggregation of coarse particles when dry
Structureless	No aggregation of fine particles when dry

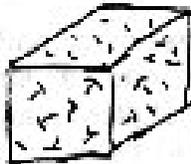
Figure 4. Soil structural types.



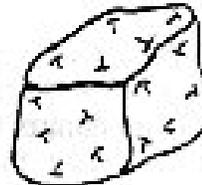
Granular



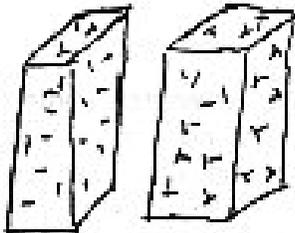
Crumb



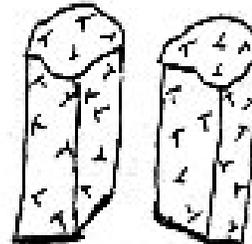
Blocky



Subangular blocky



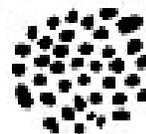
Prismatic



Columnar



Platy



Single grain/structureless

Structure is one of the defining characteristics of a soil horizon. A soil exhibits only one structure per soil horizon but different horizons within a soil may exhibit different structure. All of the soil forming factors influence the type of structure that develops at each depth, especially climate.

Granular and crumb structure are usually located at the soil surface in the A horizon. The subsoil, predominately the B horizon, has subangular blocky, blocky, columnar or prismatic structure. Platy structure can be found in the surface or subsoil while single grain and structureless structure are most often associated with the C horizon.

Sample Questions

What physical property describes the size of a soil separate?
What name is given to the terms silt, loam and silty clay loam?
Using a textural triangle determine what textural class includes a soil containing 32% sand and 25% silt?
What is the maximum and minimum percentage of silt for a clay loam?
What soil separate is 0.01 mm in size?
What is the textural class of the soil in Container D?
What natural processes influence aggregation?
What name is given to an aggregate that is cube-like with flattened surfaces and rounded corners?
What name is given to the aggregate in Container A?
In what horizon would you expect to find granular structure?

SOIL WATER

[Top](#)

Plants need sunlight, water and nutrients. Soil holds the water and nutrients needed by plants. It evaporates and adds moisture to the atmosphere. Groundwater is recharged by water that moves downward through the soil. Thus, soil water is an integral part of our global hydrologic cycle.

Learning Objectives

- Define infiltration, permeability, water content, saturation, field capacity, permanent wilting point, gravitational water, water holding capacity, plant-available water, and unavailable water.
- Classify a soil based on its permeability.
- Describe how soil holds and transmits water.
- Calculate and estimate the amount of water in a soil profile for all water relationships.

Movement

Soil acts as a sponge to take up and retain water. Movement of water into soil is called infiltration, whereas, downward movement of water within the soil is called percolation, permeability or hydraulic conductivity. Pore space in soil is the conduit that allows water to infiltrate and percolate. It also serves as the storage compartment for water.

Infiltration rates can be near zero for very clayey and compacted soils or in excess of 10 inches per hour for sandy and well aggregated soils. Low infiltration rates lead to ponding on nearly level ground and runoff on sloping ground. Organic matter, especially crop residue and decaying roots, promotes aggregation so that larger soil pores develop; thus, allowing water to infiltrate more readily.

Permeability also varies with soil texture. Permeability is generally rated from very rapid to very slow (Table 3). This is the mechanism by which water reaches the subsoil and rooting zone of plants. It also refers to the movement of water below the root zone. Water that percolates deep in the soil may reach a groundwater aquifer.

Permeability Class	Rate (inches/hour)
Very rapid	greater than 10
Rapid	5 to 10
Moderately rapid	2.5 to 5
Moderate	0.8 to 2.5
Moderately slow	0.2 to 0.8
Slow	0.05 to 0.2
Very slow	less than 0.05

Infiltration and permeability describe the manner by which water moves into and through soil, respectively. Several different terms are used to describe the water held in a soil. Generally, water held in a soil is described by the term water content. It is usually quantified on a volumetric (mml water/ml soil) basis. Since 1 g of water is equal to 1 ml of water, we can easily determine the weight of water and immediately know its volume. Our discussion below will consider water content to be on a volumetric basis.

Relationships

Saturation is the soil water content when all pores are filled with water. Thus, the water content in the soil at saturation is equal to the % porosity. Field capacity is the soil water content after the soil has been saturated and allowed to drain freely for about 24 to 48 hours. Free drainage occurs because of the force of gravity pulling on the water. When water stops draining, we know that the remaining water is held in the soil with a force greater than that of gravity. Permanent wilting point is the soil water content when plants have extracted all the water they can. At the permanent wilting point a plant will wilt and not recover. Unavailable water is the soil water content that is strongly attached to soil particles and aggregates that can not be extracted by plants. This water is held as films coating soil particles. These terms illustrate soil from its wettest condition to its driest condition.

There are also terms used to describe the water held between these different water contents. Gravitational water refers to the amount of water held by the soil between saturation and field capacity. Water holding capacity refers to the amount of water held between field capacity and wilting point. Plant available water is that portion of the water holding capacity that can be absorbed by a plant. As a general rule of thumb, plant available water is considered to be 50% of the water holding capacity.

The volumetric water content measured is the total amount of water held in a given soil volume at a given time. It includes all water that may be present including gravitational, available and unavailable water.

The relationship between these different physical states of water in soil can be easily illustrated using a sponge. A sponge is just like the soil because it has solid and pore space. Obtain a sponge

that is about 6 x 3 x 1/2 inch in size. Place it under water in a dishpan and allow it to soak up as much water as possible. At this point, the sponge is at saturation. Now, carefully support the sponge with both hands and lift it out of the water. When the sponge stops draining, it is at field capacity and the water that has freely drained out is gravitational water. Now, squeeze the sponge until no more water comes out. The sponge is now at permanent wilting point and the water that was squeezed out of the sponge is the water holding capacity. About half of this water can be considered as plant available water. You may notice that you can still feel water in the sponge. This is the unavailable water.

All pores at the soil surface are filled with water before water can begin to move downward. When precipitation or irrigation ceases, gravitational water will continue to percolate downward until field capacity is reached.

Calculations

Use of water estimates on a percentage volume basis does not allow for any practical interpretation. Therefore, water is usually converted from a percentage volume basis to a depth basis of inches of water/foot of soil. Both water and soil are expressed on an acre basis. Estimated values of soil water per foot of soil are given in Table 4.

Table 4. Estimated soil water for three soil textures.			
	Sand	Loam	Silty Clay Loam
Characteristic	-----inches of water/foot of soil-----		
Saturation	5.2	5.8	6.1
Field capacity	2.1	3.8	4.4
Permanent wilting point	1.1	1.8	2.6
Oven dry	0.0	0.0	0.0
Gravitational	3.1	2.0	1.7
Water holding capacity	1.0	2.0	1.8
Plant available	0.5	1.0	0.9
Unavailable	1.1	1.8	2.6

The table values are derived from laboratory analysis of soil samples. Some of this information is also published in the Soil Survey. Other techniques have been developed to estimate soil water if laboratory data is not available. As a rule of thumb, field capacity is considered to be 50% of saturation and permanent wilting point is 50% of field capacity.

Water holding capacity designates the ability of a soil to hold water. It is useful information for irrigation scheduling, crop selection, groundwater contamination considerations, estimating runoff and determining when plants will become stressed. Water holding capacity varies by soil texture (Table 5).

Textural Classes	Water Holding Capacity (inches per foot soil)
Coarse sand	0.25 - 0.75
Fine sand	0.75 - 1.00
Loamy sand	1.10 - 1.20
Sandy loam	1.25 - 1.40
Fine sandy loam	1.50 - 2.00
Silt loam	2.00 - 2.50
Silty clay loam	1.80 - 2.00
Silty clay	1.50 - 1.70
Clay	1.20 - 1.50

Medium textured soils (fine sandy loam, silt loam and silty clay loam) have the highest water holding capacity while the coarse soils (sand, loamy sand, and sandy loam) have the lowest water holding capacity. Medium textured soils with a blend of slit, clay and sand particles and good aggregation provide a large number of pores that hold water against gravity. Coarse soils are dominated by sand and have very little silty and clay. Because of this, there is little aggregation and few small pores that will hold water against gravity. Fine textured clayey soils have a lot of small pores that hold water against gravity. Water is held very tightly in the small pores making it difficult for plants to adsorb water; thus, little of it is available to the plant.

Since soil texture varies by depth, so does water holding capacity. A soil may have a clayey surface with a silty B horizon and a sandy C horizon. To determine water holding capacity for the soil profile, the depth of each horizon is multiplied by the available water for that soil texture and then the values for the different horizons are added together. These determinations are illustrated in Table 6.

Depth from soil surface	Depth of layer	Soil texture	Water holding capacity	Plant-available water-	
in	ft		in/ft	in/layer	in/5 ft
0-6	0.5	Loamy fine sand	1.2	0.6	
6-24	1.5	Loamy fine sand	1.0	1.5	
24-60	3.0	Fine sand	0.7	2.1	
Total					4.2

Sample Questions

- What soil textures tend to have the fastest percolation/permeability?
- What soil texture is most likely to have a permeability rate of 1 in per hour?
- What soil textural class has more water at saturation? permanent wilting point?
- You want to grow a plant in a soil that has the greatest plant available water.
- What soil texture would you grow it in?
- If a soil holds 4 inches of water per foot of soil at saturation, how much water would there be at permanent wilting point?
- Calculate the amount of plant available water in 18 in of soil if the water holding capacity is 1 in of water per foot of soil?

SOIL ORGANIC MATTER

[Top](#)

Soil organic matter is a component of almost all soils. Normally, the amount in the surface horizon of soils is much higher than below. In soils developed in alluvium (stream-deposited materials) it may be found in significant amounts to some depth. It provides many benefits to the soil and to those who use the soil. It comes in a variety of chemical forms from complex plant residues and humus to very simple organic compounds like sugars and amino acids. It is intimately involved in the soil biosphere (living part of the soil). It is hard to conceive of a productive soil without organic matter.

Learning Objectives

1. Define organic matter, humus, allelopathy, and composting.
2. Describe how organic matter and humus are formed.
3. List the benefits of organic matter within and above the soil.
4. Describe the process of composting.

Soil Organic Matter

Soil organic matter is usually described as all carbon-containing compounds in the soil except carbon dioxide and the carbonates (the carbonate system). Almost without exception, the soil organic matter was derived from plant or animal residues. An exception is synthetic urea and its derivatives and other organic compounds which were added to the soil as fertilizers.

The action of elements of water (liquid and solid), temperature, and wind, accompanied by animal and microbial action reduces plants and their residues to simpler compounds, carbohydrates, proteins, aldehydes, ketones, chitin, lignin, fats, waxes, soils and others. Nutrients in the residues are gradually leached out and into the soil by water, potassium, calcium and magnesium going first, and others later. The simpler organic compounds will be further decomposed by more specialized groups of fungi, bacteria, and actinomycetes until everything is reduced to carbon dioxide, water, nitrates, sulfates, phosphates, and other inorganic compounds that are common in the soil. In these forms they are available to plants.

Humus

Note that humus was not mentioned in the previous paragraph. It is not a product of organic decomposition. However, the first step of decomposition must occur before humus can be formed. Humus is synthesized or build up from other intermediate organic components, particularly proteins and lignins. It is different from the other organic compounds in that it is fairly resistant to decomposition. Therefore, it persists in the soil for fairly long times. It is also much richer in nitrogen, phosphorus, and sulfur than the original plant residues. Therefore, it is an excellent plant nutrient source.

In order for humus to be formed, adequate oxygen and water must be provided. Humus is often formed by the process of composting which requires that aeration and continual dampness must be maintained. The decomposition of humus is aerobic. Good soil aeration accelerates the loss of humus from the soil.

Benefits of Soil Organic Matter

- The organic matter serves as the storehouse of nitrogen, phosphorus, and sulfur in the soil. Humus-forming organisms take up these three nutrients and incorporate them into humus, which slowly releases them to plants. This also protects the nitrogen from leaching to the groundwater where it becomes a contaminant.
- It serves as a source of electrical charge which holds cation nutrients such as calcium, magnesium, and potassium in the soil where they can be used by plant roots.
- It improves the soil structure. As a result, the pore size in fine soils becomes larger, improving the infiltration and movement of water through the soil and also the movement of air. However, in order to receive these benefits, it must be incorporated into the soil. A disadvantage of this improvement is a slight decrease in the water-holding capacity of the soil.
- It improves the water-holding capacity of sandy soils. Here the pores are too large to hold water. The pore size can be reduced by entrapment of organic matter in the soil pores.
- Organic matter acts as a "chelate." Chelates are organic compounds that may unite with micronutrient cations such as iron, zinc, copper, and manganese to improve their mobility and availability to the plant.
- It serves as a source of carbon for many macro- and microorganisms in the soil that perform other useful functions. Earthworms are a good example. Nitrogen-fixing organisms associated with the roots of legume plants are another.

Allelopathy

Allelopathy is the harmful effects of one plant on another by producing toxic compounds in the soil. Normally, these toxins are not produced. But if the conditions of decomposition are not very favorable, such as in cold, very wet, poorly aerated conditions, toxins may be formed which inhibit germination of seedlings.

Organic Matter above the Soil

Most of the discussion above is based on organic matter that is mixed with the soil. Organic matter above the soil (a mulch of sorts) does not decompose as readily as that in the soil, mostly

because of drier conditions. Humus is less likely to be formed for the same reason, although residues in contact with the surface soil may stay damp long enough to produce it. In any case, if the benefits of nutrient release, soil structural improvement, and cation retention are to be maximized, the organic matter must be mixed with the soil.

However, surface residues have some other benefits. They protect the soil from pounding raindrops, thus reducing structural breakdown and crust formation. They shade the soil from the sun, reducing water loss from the soil into the atmosphere. In certain cases they may reduce the rate of weed seed germination as a result of shading. They may reduce erosion as a result of protecting the soil from raindrops as described above, or reducing the contact of running water with the soil. The residues may also form small "dams" on the soil surface which reduce the amount of water flowing over the surface and encouraging infiltration into the soil. If there is a large amount of residues, soil temperature changes are reduced owing to the protection of soil from sun and wind and promoting higher soil water content.

This last benefit has a negative side as well. If the soil is cold from the winter, and surface residue is present, the soil will warm up much more slowly than a bare soil. Therefore, planting may have to be delayed until appropriate soil temperatures for germination have been reached. In poor conditions, surface residues can produce allelopathy as described above, although this is not common.

Adding Organic Materials as a Nutrient Source

Plant or animal residues contain significant amounts of nitrogen, phosphorus, and sulfur. Therefore, they can serve as nutrient sources. Two problems arise. First, many of these materials decompose rather slowly. Second, their nutrient concentrations are relatively low. Suppose we have some waste alfalfa hay damaged by too much rain. We want to use it to add 50 pounds of phosphorus per acre for wheat. Further assume that 10% of the hay will decompose the first year. This means 1.5 tons of the hay must be added per acre. This problem is less important for organic materials higher in nutrients like sewage sludge, animal manures, and compost.

Composting

Composting is managed decomposition of organic materials above ground. The purposes are to reduce the volume of the materials, to increase nutrient content, and to reduce the number of weed seeds and pests. Compost piles must be well-aerated, damp (not wet), and contain adequate nutrients for the decomposing microorganisms. Good conditions will allow the temperatures to increase in the pile to a point which reduces pests. When the compost has been largely converted to humus, it is an excellent material to use in a variety of plant cultures.

Sample Questions

- What is the original source of organic matter?
- What organisms serve as the final decomposers of organic matter?
- Why is humus a good source of plant nutrients?
- How does organic matter affect soil structure and water-holding capacity?

- Under what conditions will an allelopathy develop?
- What benefit is derived from organic materials on the soil surface?
- What is composting?

[Top](#)

SOIL NUTRIENTS, TESTING and FERTILIZER RECOMMENDATIONS

For economic, environmental, and agronomic reasons, we strive to apply the correct amounts of fertilizer to plants. We do this through a process called "soil testing". By definition, soil testing is the process of using soil analysis, field information, and research data to produce a prediction of fertilizer needs for a future crop. This is a prediction because no one knows what the growing conditions will be like for the coming year. Yet most of the fertilizer must be applied before these conditions are known. Although some errors are possible in fertilizer recommendations because of unanticipated growing conditions, soil testing is still by far the most accurate means to utilize fertilizer wisely.

Learning Objectives

1. Define soil testing, nutrient, soil sample, and soil test report.
2. Identify the different macro- and micro- nutrients.
3. Understand the components of soil testing.
4. Describe how to take soil samples properly.
5. Make a fertilizer recommendation based on soil test results.

Nutrients

There are seventeen nutrients needed for plant growth. Three of these - carbon, oxygen, and hydrogen are supplied by air and water. The others are supplied by the soil. When nutrients are in short supply they are typically added as fertilizers.

Macronutrients. Six of the fourteen essential elements are considered macronutrients. They are needed in large quantities by plants for proper growth. These nutrients include nitrogen, phosphorus, potassium, sulfur, calcium, and magnesium.

Micronutrients The other nutrients are needed in very small quantities so are called micronutrients. These include iron, manganese, copper, zinc, boron, molybdenum, chlorine, and cobalt. Micronutrients are in relatively small quantities in soils. As a result, cropping over a number of years may cause some soils to be deficient in micronutrients. The most likely soils for deficiencies are sandy soils, organic soils, and alkaline soils.

Soil Test Component

Soil analysis One essential part of the soil testing process is the soil sample. The nature of the sample will be discussed later. Through the use of chemical procedures, which have been selected by a procedure called soil test correlation to reflect the nutrient level in the soil, an index

of nutrient availability is derived. For most nutrients, this index is NOT a measure of the amount of available nutrient in the soil but is related to it. This index is of little value without research to interpret it. Not all soil test laboratories use the same indices.

The field information The person who submits the soil sample will be asked to provide information about the field from which the soil sample was taken. Types of information asked for include slope, topographic position, past erosion, cropping history, yield information, water supply, fertilizer history, applications of nutrient containing materials other than fertilizers, and any problems that have occurred on this field in the past. This information helps soil test lab personnel make the best fertilizer recommendations.

Research information This information is needed to know how the soil test index mentioned above relates to the actual fertilizer needs of the crop. Many experiments are conducted on producers' fields to develop this information. They are conducted over a period of years to include the effects of different growing conditions. The process of completing this research is called "soil test calibration." Since it must be done for every crop and every nutrient that might be deficient, it is a very extensive program. The results of calibration are published in the *NebGuide Series*. Appropriate issues are listed below.

The Soil Sample

Since the amount of fertilizer recommended for the field depends so highly on the one-pint or less soil sample, it must be carefully taken. The key is that it must represent the field accurately. The best way to do this is to include only uniform areas in one sample and to take a lot of subsamples. The depth of sampling is usually limited to 8-10 inches except for nitrogen. Because of its mobility in the soil, significant amounts of nitrogen may be found in the subsoil. Various depths of sampling are recommended by various laboratories. The more detailed and deeper the sampling, the more accurate are the fertilizer recommendations.

As soon as the soil sample is collected, it should be air-dried to stop processes such as nitrification that may change the nutrient availability in the sample. This is particularly important if the sample is left in a warm place which speeds up these changes. However, the sample should not be oven-dried since the heat itself may cause other undesirable changes in the sample which will be reflected in the fertilizer recommendations.

Soil samples can be taken at any time of the year, but the closer they are taken to the planting time, the more accurate they will be, particularly for nutrients such as nitrogen or sulfur, which may be made available or lost over short time periods. Phosphorus, potassium, and micronutrient availability are fairly stable over time.

The number of soil samples taken per field depends on the size of the field and its variability. The general recommendation is that one sample represents about 20 acres. If the field is very uniform the number of acres can be increased, but if there are several soil types in the field, it may need to be reduced. Only similar soil types should be included in one sample. If there is a small area in the field that is unlike the other soils, a management decision will need to be made whether to have a separate soil sample or whether to omit the area from the sampling.

If more than one sample is taken from a field and the fertilizer recommendations are different for each, a management decision must be made. Often the producer will use the highest recommendations since overfertilization is seen as less of a problem than underfertilization. A more conservative approach is to use a weighted average of the recommendations. Another approach is to try to fertilize each area appropriately. If Global Position System (GPS) equipment is available, this is relatively easy to do. It is important here to remember that the fertilizer recommendations are a prediction and have some inherent error. If differences in recommendations are not too great, it may not matter which route is taken.

Soil Test Report

The format of soil test reports from various laboratories varies. At a minimum, they include the soil test index and a rating (low, medium, high) for each nutrient included in the analysis, and the recommended amount of nutrients to apply for the crop(s) requested. They may also provide graphical indications of nutrient availability and some comments about suggested fertilizers, application times and methods, and other suggestions.

The producer or consultant should always examine the reports carefully along with the previous reports from the same field. On the basis of their first-hand knowledge and experience, they may need to adjust the recommendations to take into account information unavailable to the soil test laboratory.

***NebGuides* (including calibration tables)**

1. Fertilizer Management for Alfalfa G 73-2
2. Fertilizer Suggestions for Corn G 74-174-A
3. Fertilizing Grass Pastures and Haylands G 78-406
4. Fertilizing Grain Sorghum G 74-112
5. Fertilizer Suggestions for Soybeans G 87-859
6. Fertilizing Nebraska Turfs G 77-369
7. How Much Fertilizer on Wheat G 73-37

These *NebGuides* differ in their format and use. Therefore, no general guidelines can be suggested for their use. Different quantities such as organic matter content, soil pH, yield level, and geographic locations may affect how the table is used. For nitrogen, the depth of sampling may be a factor. For turf grasses, the species of grass and level of management may be a more important factor than soil test levels. Use of each table requires some study of the associated printed material for best results.

Sample Questions

1. Identify the following nutrients as macro- or micro- nutrients: copper, nitrogen, sulfur, zinc?
2. What is the purpose of the soil analysis?
3. What is the purpose of subsampling?

4. A soil analysis rates potassium as low for corn. How much potassium fertilizer should be applied
5. per acre?

[Top](#)

pH AND LIMING

Relatively large areas of acid soils exist in eastern and parts of northern Nebraska. Where rainfall is higher or soils are sandier, or both, acid soils are more likely to form. On the other hand, the western part of the state has large areas of basic soils. They result from the types of parent materials present and a lack of rainfall to acidify the soil. Both of these conditions have existed or developed during the weathering process of parent materials to soils over many thousands of years, although some management practices can increase soil acidity in a rather short time. Plant growth problems may result from both acid and basic soils.

Learning Objectives

1. Define soil reaction, pH, acidity, alkalinity, and lime requirement.
2. Classify a soil as basic, neutral or acid according to its pH.
3. Describe the undesirable effects of acidification and high pH soils.
4. Calculate a lime requirement.
5. Determine materials used to increase or decrease soil pH.

Soil pH

Soil acidity and alkalinity determine soil reaction. Soil reaction is usually described in terms of soil pH, a measure of the amount of hydrogen ions in the soil. The pH scale goes from 1 to 14, 1 being very acid indicating very large amounts of hydrogen, and 14 being very basic (alkaline) indicating very low amounts of hydrogen. The midpoint, pH 7, is neutral, meaning that the soil is neither acid nor basic. All things considered, the most desirable pH for the growth of most plants is about pH 6.5, very slightly acid. In Nebraska, soil pH values run from about pH 4.5 to pH 9.0.

Soil Acidification

Soils in semi-humid or humid climates naturally become more acid. Several processes are responsible. Rainwater containing carbon dioxide passing through the soil acidifies it. Uptake of nutrients by plants releases hydrogen ions to the soil water making it more acid. The decomposition of organic matter produces carbon dioxide which, when dissolved in the soil water, generates hydrogen ions and acid. In managed systems, ammonia or ammonium fertilizers cause acidification during the conversion of ammonium to nitrate. Since there are no common natural forces which raise soil pH, in all soils, whether cropped or not, the soil pH usually decreases very slowly as time passes unless action is taken to maintain the soil pH.

When soils become strongly acid, several undesirable effects occur:

- Toxicity of aluminum and manganese to plants.
- Reduced availability of phosphorus to plants.
- Decreased beneficial microbial activity.
- Poor growth of legumes (partly as a result of reductions in microbial activity).
- Replacement of calcium, magnesium, and potassium on very sandy soils by hydrogen.

High pH Soils (Alkaline or Basic Soils)

High pH soils are usually the result of natural lime (calcium and magnesium carbonates) in the soil. In most cases this lime was originally present in the soil parent material. Unlike acid soils, basic soils tend to correct themselves naturally by the acidifying processes of climate and plant growth described above. However, complete correction may take many hundreds of years if left to natural processes. Plant growth problems in basic soils include:

- Lime-induced chlorosis - a physiological problem with iron in the plant.
- Reduced micronutrient availability to plants.
- Reduced phosphorus availability to plants.

Plant Tolerance to Acid or Basic Soils

Plant species differ in their tolerance to soil acidity. Some species prefer an acid soil. These include oats, potatoes, rye, and watermelon. Corn, sorghum, most grasses, crown vetch, and wheat are fairly tolerant of soil acidity. Alfalfa, cotton, peas, most clovers, soybeans and sugar beets grow best on neutral or slightly basic soils. Legumes are very intolerant of soil acidity for two reasons. First, the plants themselves prefer neutral soils, and second, the bacteria which perform nitrogen fixation for the plants are not tolerant of soil acidity. Therefore, leguminous plants grown on acid soils may experience nitrogen deficiency.

As indicated above, the greatest problem with high pH soils is the occurrence of lime-induced chlorosis. Pin oaks are very susceptible to this problem. Certain species of soybeans are also very susceptible. Other plants are less susceptible but some varieties may show the characteristic yellow color of the leaves, indicating some effect. This problem is serious because it is not easily corrected once it has appeared. The treatment is usually spraying iron chelates on the plant leaves to release the bound iron. This treatment gives temporary improvement but may have to be repeated several times.

Correcting Acid Soils

Fortunately, the correction of acid soils is a relatively simple matter. Soil testing procedures are well established. Correction is usually accomplished with agricultural lime (calcium and magnesium carbonates). Rates of application usually vary from 1 to 5 tons per acre. Lime is quarried at several places in eastern Nebraska. The cost of the lime is largely the transportation cost since it is usually a by-product.

The lime recommendation is based on the soil pH and the buffer pH. If the soil pH is greater than 6.2, no lime is recommended. If the soil pH is not greater than 6.2, then the amount of lime

needed, the "lime requirement" (L.R.) in tons per acre can be determined from the buffer pH (BpH) according to the following formula:

$$\text{L.R.} = (7.0 - \text{BpH}) \times 5.0$$

Thus a field with soil pH 5.4 and buffer pH (BpH) 6.4 will need 3 tons of lime per acre.

Since lime is very insoluble in water, it does not move in the soil. Also, it does not react very quickly. Therefore, it is important that the lime be very fine and applied well before it will actually be needed. Also, it needs to be mixed thoroughly with the soil. If any one of these conditions is not met, it may be necessary to increase the rate of application.

Liming acid, no-till soils is very difficult. Surface application of the lime will not be very effective because of lack of movement downward. Adequate tillage to incorporate the lime appropriately, however, destroys any surface residue and may interfere with the no-till system. Injection by some means is not very effective because, again, lime does not move. Acidity will be corrected in the injection zones, but other parts of the soil will still be acid. The best compromises usually include using tillage every few years to place the lime correctly, or to apply it on the surface and accept very slow correction.

Reducing Soil pH

For most agricultural crops, the reduction of high pH values does not provide enough additional yield to pay for the treatment in most situations. However, for some high-value crops, elemental sulfur or gypsum can be used to lower soil pH by dissolving the lime. The amounts can be determined by soil testing procedures and may vary from 1 to 10 tons per acre. Elemental sulfur is usually more effective than gypsum. The requirements in application are the same as for lime. The material must be fine, mixed with the soil to be treated and applied well before the effect is needed.

Sample Questions

1. Would a soil with pH of 8.5 be acidic, neutral, or basic?
2. What effect does soil acidification have on plants? High pH soils?
3. What plants are most intolerant of acid soils?
4. A field has a pH of 4.5. Does the pH need to be increased or decreased for optimum plant growth? If the buffer pH is 6.0, how much lime should be applied per acre?

[Top](#)

THE SOIL SURVEY REPORT

One of the best sources of information about soils is the Soil Survey Report. In Nebraska, a report is available for each county with a couple of exceptions in which two counties are combined in a single report. These reports have been produced by USDA - Natural Resources Conservation Service (formerly, Soil Conservation Service) on the basis of field surveys over a

period of years. Thus, the currency of the reports varies. The format of all the reports is very similar. A few reports have sections not included in others. In this lesson, only the common features will be included.

Learning Objectives

1. Define soil survey, parent material, soil profile, soil map units, map symbol, soil association, and soil series.
2. Locate information found in different divisions of the soil survey.
3. Utilize the soil survey to locate a soil map using a legal description.

Definitions

- Parent material - the geologic material from which soils form. These include bedrock, loess, glacial till, alluvium, and others.
- Soil profile - a vertical section through the soil showing the soil layers or horizons. The horizons are designated by subscripted letters. They are described in many common references.
- Soil map units - the basic units of soil mapping. They are often called simply "soils". The mapping unit name is made up of the soil series name, the soil class, the slope, and may include other designations relating to wetness, erosion, topographic position, depth or others.
- Map symbol - a short group of letters and numbers denoting a map unit on a soil map.
- Soil association - a group of soil map units or "soils" found near each other.
- Soil series - a group of map units which have features in common. The soil series name is usually the name, or is derived from the name, of a place.

Divisions of the Soil Survey Report

Use any County Soil Survey Report to locate these Divisions.

(**Note:** County survey reports can be obtained from the Agriculture Stabilization Committee (ASC) or your County Extension Office)

- The table of contents.
- The index to the soil map units. A list of map units and their symbols.
- Summary of tables.
- A general description of the county and how the map was made.
- General soil map units or soil associations. In this section are described the soil associations.
- Detailed soil map units. Most of the detailed information about the map units are found in this section. This is the first of three main sections of the report.
- Use and management of the soils. This section describes in a general way how the soils can be managed with regard to several uses. Where appropriate, it refers the reader to one or more tables.

- Soil properties. Here engineering data are explained. Again, it includes references to tables where appropriate.
- Classification of the soils. Here the soil series are described. For each series the parent material and an example of the soil profile showing the horizons are given.
- Formation of the soils. A short description of how the soils of the county were formed.
- References.
- Glossary. Definitions of commonly used terms.
- Tables. The second major section of the report. A search for information is likely to end up in these tables.
- The soil association map (colored).
- Index to Map Sheets. Most searches for information begin here. This sheet also includes the soil map legend and a list of the map units with their map symbols.
- The soil maps. This is the third and last major section in the report. They are numbered in the upper right or left corner to correspond with the large shaded numbers on the Index to Map Sheets.
- Some reports contain a second Index to Map Sheets at the end.

Locating a Soil Map from a Legal Description

- The legal description will give the town, range, and section numbers and a subdivision of the section. Example: S 1/2, NW 1/4, T 6 N., R 14 W., Sec. 18, Kearney County, Nebraska.
- Turn to the index to Map Sheets.
- Find the intersection between the town and range designations. Find the township in which this intersection lies. It is 6 squares (miles) by 6 squares. The upper right corner square will contain a '1', the upper left corner, a '6', the lower left corner, a '31', and the lower right corner, a '36'.
- Find the section by counting through the sections according to the scheme shown elsewhere on the page.
- Now look at the shaded gray lines that surround your area and the shaded gray number they enclose. This is the map number.
- Turn to the map. Confirm that this is the right map by looking at the town and range designations on the side and top of the map. Find the section by looking at the section numbers printed on the map.
- Using any additional location indications from the legal description, further refine your location. The map symbols of interest can now be found.

Locating information

- The first step is to locate the land of interest through the procedure above if the legal description is known, or by observation of known points on the Index to Map Sheets. In the latter case, the last 3 procedures above will help locate the appropriate map and find the map symbols.
- Some information is given in the section Detailed Soil Map Units. Examples are the Land Capability Class, the Range Site Classification, and the soil parent material.

- If the information is not found there, go to the Summary of Tables. Look through the list to find the item of information you want and the table in which it is located.
- Then turn to that table, and with the map symbol or its included series name, find the information you want.

Sample Questions

1. What is the map symbol for the Holdrege silt loam soil?
2. Is the Holdrege soil good for buildings with basements?
3. How many different soil horizons are found in the Holdrege soil?
4. What is the average annual rainfall in Kearney?
5. What is the predominant soil map unit in the NW 1/4, NW 1/4, T 6 N, R 14 W, Sec. 10 Kearney County, Nebraska?
6. County, Nebraska?

[Top](#)

SOIL EROSION

Soil erosion is a concern around the world. This concern is based on loss of productive soil as well as the pollution of lakes and streams by soil particles that may have pesticides absorbed on them. To the land user erosion effects ditches, sediment deposition, dust storms, and crust development.

Water erosion is most prevalent in eastern Nebraska while wind erosion is most prevalent in western Nebraska. However, both types of erosion can occur anywhere in the state.

Learning Objectives

1. Differentiate between geologic and accelerated erosion.
2. Describe four (4) types of water erosion.
3. Locate values for each of the six (6) factors affecting soil loss by water and calculate soil loss by water and calculate soil loss using the Universal Soil Loss Equation.
4. Describe the five (5) factors that affect the amount of soil lost by wind erosion.
5. Describe three (3) types of wind erosion.
6. Identify methods to control wind erosion.

Impact

Erosion has been occurring for millions of years. It is responsible for the leveling of mountains, and development of the Great Plains, valleys, river flats, foothills, and deltas. Famous attractions created by erosion include the Badlands in South Dakota and the Grand Canyon in Arizona. Chimney Rock in western Nebraska is another example. These processes that take millions of years are called geologic erosion.

When erosion occurs at a faster rate it is called accelerated erosion. This is usually associated with agriculture. Barren fields are susceptible to the action of water and wind.

Water Erosion

Water moves downhill and when soil particles move with the water it is called water erosion. The process by which soil is eroded away involves two steps - detachment and transportation.

Detachment refers to the loosening of soil particles from the soil surface. Raindrops are the primary cause of detachment. Raindrops hit the soil with tremendous energy breaking down aggregates and dislodging or detaching particles. Running water can also dislodge particles with its cutting action.

Transportation is the process by which detached soil particles are moved to other parts of the field or into waterways. This action may include floating, rolling, and splashing. In all cases, soil has been suspended in water and moved along with it.

Water erosion has been classified into different types depending upon the action involved. They include splash, sheet, rill, and gully.

Splash - Soil is moved with the water that splashes up when raindrops hit the soil surface. With this action soil particles move only a very small distance with each splash; however, through the course of a rainstorm a single soil particle can be moved quite a distance.

Sheet - Soil flows with runoff water and is moved rather uniformly from all portions of the soil service.

Rill - Water moving with sheet erosion can concentrate into miniature flow paths that look like small irregular channels. These tiny channels are called rills.

Gully - Rills come together and concentrate the water flowing in them to form larger flow paths. Moving water then gains energy and cuts into the soil. These large channels are called gullies.

Universal Soil Loss Equation

Many aspects of an agricultural field influence the actual amount of soil erosion that may result from a rainstorm. Vegetation, soil type, topography, and conservation practices also enter into the equation. In an effort to better understand the interrelationship among these different considerations, research soil scientists developed the USLE - Universal Soil Loss Equation.

$$A = R \times K \times L \times S \times C \times P$$

where

A = soil loss in tons per acre per year

R = rainfall factor

K = soil erodibility factor
L = slope length factor
S = slope gradient factor
C = crop management/soil cover factor
P = conservation practice factor

For each factor, many different considerations are incorporated into a numeric value.

Rainfall effects. Total rainfall, its intensity, and the time of year when it occurs all affect erosion. Of these, intensity has the greatest influence. The harder rain falls the most likely soil particles will be detached.

Soil effects. High infiltration capacity and stable aggregates both help to retard erosion. The major soil properties affecting erosion then are texture, organic matter, structure, and permeability.

Slope effects. Both slope length and slope gradient influence the rate at which water moves downhill. Steeper slopes promote runoff. Longer slopes allow moving water to gain momentum.

Crop management/soil cover effects. Anything that protects the soil from raindrop impact is accounted for in this factor. Grass, weeds, crops and other vegetation all intercept rainfall. Plant residue on the soil surface can also intercept rain. Thus, vegetation, dead or alive, is very important in controlling erosion because when it intercepts raindrops, soil is not detached.

Conservation practice effect. These include any practice that alters and slows down the flow path of runoff water. Such practices include contour tillage, contour planting, contour strip cropping, and terracing.

Calculations Tables and graphs have been developed to make the calculation of soil loss fairly simple. Use the Nebraska Extension Circular "Universal Soil Loss Equation: A Handbook for Nebraska Producers" to locate the following information.

- R factor - developed for different areas of the state. Determine the R value for Northeast Nebraska including Cedar and Knox Counties.
- K factor - developed for different soils in the state. Determine the K value for a Moody silt loam soil.
- L and S factors - developed for different combinations of slope steepness and length. These factors are frequently combined into a single numerical value. Determine the LS factor for a field with 8% slope and a slope length of 300 feet.
- C factor - developed for different cropping sequences and crop residue levels. If a two year rotation of corn and soybeans is considered, C-values for corn and soybeans must be averaged. Determine the C factor for continuous no-till corn.
- P factor - developed for contouring and terracing. Determine the P factor for contour planting.

These are the "tools" to calculate soil loss due to water erosion. Soil loss for this combination of factors is xxx ton acre per year.

$$A = R \times K \times LS \times C \times P$$

Whenever any six values in the equation are known, it is possible to solve for the other.

Wind Erosion

Soil is usually picked up and blown along with the wind during dry weather. The worst case of wind erosion occurred in the Great Plains in the 1930's. Barren fields and overgrazing of rangeland lead to wind erosion.

Like water erosion, wind erosion is controlled by the processes of detachment and transportation. Wind hitting soil particles is abrasive and causes particles to detach. As more soil is carried with the wind it becomes even more abrasive, thus accelerating erosion. Rapidly moving soil particles can also separate particles from aggregates and soil clods. Once dislodged, the soil can be transported by three mechanisms.

Types of Wind Erosion

Saltation Soil particles bounce or leap across the land and are never more than about 1 foot off the ground. This is the most important mechanism of wind erosion because it is so prevalent.

Surface Creep Soil particles roll or slide along the ground. Saltation encourages surface creep because the bouncing action helps to push other particles along the ground.

Suspension Soil particles are moved horizontally along the ground and then upward into the air. This visible form of wind erosion reflects our usual concept of wind erosion; however, it usually accounts for only a small portion of wind erosion. Turbulent winds can carry particles a few feet to several miles up into the atmosphere and hundreds of miles horizontally.

Wind Erosions Considerations

Any number of things influence the extent of wind erosion on agricultural lands. Fives of these have been shown to be most important.

Wind velocity and turbulence. The rate at which the wind moves is very important, especially wind gusts. Soil can be detached and moved at wind speeds as low as 12 miles per hour.

Soil surface condition. Several conditions make the soil more or less susceptible to wind erosion. Stable surfaces of dry clods and aggregates or crusts are more resistant to the abrasive action of the wind. Size is also important. Soil particles or aggregates about 0.1 mm in diameter are more susceptible to wind action than larger or smaller sizes.

Soil moisture Soil particles, when wet, are held together by very strong forces and resist erosion by wind. Wind provides a lot of drying at the soil surface. If the wind is sustained over a long period of time, soil will become dry enough to be eroded.

Soil physical condition Wind erosion is less severe when the soil surface is rough. When wind hits a rough surface it is slowed down. A rough surface may be created by tillage or by the presence of residue on the soil surface.

Vegetation Growing vegetation or standing crop residue provide the greatest soil protection. Winds are slowed as they move through vegetation. Plant roots also help to bind soil particles together so they are larger in size and more resistant to wind damage.

Control Measure for Wind Erosion

The considerations mentioned above provide great insight into options on controlling wind erosion. Whenever the soil can be kept moist, damage will be lessened. In the semi-arid dryland regions like western Nebraska, crops may be grown on an alternate year basis. During summer fallow, the off-crop year, several tillage operations may be performed which expose the soil to wind. Alternatives to traditional summer fallow may be fewer tillage operations - stubble mulch; and controlling weeds with chemicals rather than tillage - chemical fallow.

Stripcropping and alternate strips of crop and fallow aid in reducing wind velocity near the soil surface, especially when strips are perpendicular to the prevailing winds. Vegetative barriers and tree windbreaks or shelterbelts help to reduce wind velocities and trap moving soil. Vegetative barriers are usually permanent strips of tall grasses planted at intervals across a field. Windbreaks are usually at the edge of the field.

Identify each of the following examples as geologic or accelerated erosion:

- erosion by water following a mountain path
- deepening of a waterway as it approached a river
- water running down rows of a newly planted field
- wind erosion from land that has been recently graded for a subdivision
- wind movement of sand dunes in the desert

Sample Questions

1. What term describes the process of soil particles being dislodged by raindrops?
2. What characteristics separate the four different types of water erosion? Give an example of each.
3. Locate an R, K, LS, C and P factor using the booklet in front of you.
4. If 5 ton per acre per year were allowed on a field, and $R = 150$, $K = .3$, $LS = .7$, $P = 1$; what is the
5. C value needed?
6. What soil and vegetation considerations influence the C-factor?
7. How is soil transported by wind?

8. Define the three types of wind erosion? Which is most important?
9. How can wind erosion be controlled?

[Top](#)

IRRIGATION

There are many different facets of irrigation that could take up an entire course. These materials will only address the specific issues of irrigation scheduling, fertigation and chemigation.

Learning Objectives

1. Define irrigation, irrigation scheduling, fertigation, and chemigation.
2. Identify different sprinkler and land irrigation systems.
3. Understand and utilize the check-book approach to schedule irrigation.
4. Differentiate between fertigation and chemigation and describe conditions for their use.

Irrigation

The practice of applying water to a field to supplement rainfall for the purpose of improving plant growth is called irrigation. In crop production, it can be applied in many different ways.

Sprinkler - Water is applied through pipes and sprayed above or within the plant canopy. Sprinkler systems vary greatly but all achieve the same goal. Common systems include center pivot, wheel line, linear move, hand move, and water guns.

Land - Water is applied to the soil surface at a designated location and then allowed to flow over the land. Much more water is applied with these systems as compared to sprinklers. Common systems include furrow with gated pipe or siphon tube, and flood.

Irrigation Scheduling

The goal of irrigation is to supply the plant with water needed for plant growth. Irrigation can be most efficient if it is applied in a timely manner and in a quantity needed to bring the soil water content up to field capacity. If water is applied after the soil reaches the permanent wilting point, plants may have already been stressed. If excess water is applied, runoff or leaching will occur.

The technique of irrigation scheduling was developed to address these two issues. The concept is to "schedule" irrigation so that it is timely and sufficient to allow the soil to reach field capacity. Several different techniques have been devised for scheduling. The check-book approach is used most often as it is simple and fast.

There are five (5) specific steps to scheduling by the check-book approach:

Evaporation Soil water is absorbed by the plant. This water is ultimately transpired into the atmosphere. To duplicate this process, a wash tub full of water can be placed near a field. The

evaporation of water from the tub is almost equivalent to the transpiration from the plant. Measure the height of water in the tub after it has been filled. Measure the height again after several days. The difference between the two readings is the water use. When divided by the number of days between measurements, it becomes the water use rate.

$$(\text{Water height}_1 - \text{water height})_2 / \text{Days} = \text{water use rate}$$

When the tub is initially filled with water the height may be 12 inches. Ten days later it is 10 inches. The water use rate is 0.20 inches per day. Over the course of a growing season the water use rate can vary from near zero to about 0.33 inches per day. The evaporation for the wash tub is also called pan evaporation.

Plant-available water This terminology and calculation were illustrated in the "Soil Water" module.

Plant-available water per soil profile This terminology and calculation were also illustrated in the "Soil Water" module.

Water status This determination is based on the evaporation and plant available water per profile (PAW). Consider that the soil profile was at field capacity when you filled the wash tub. At that time, the plant available water in a 5 foot soil profile would have been 4.2 inches. A total of 2 inches of water has been used, based on the evaporation pan. The water remaining in the soil that can be used by the plant is 2.2 inches.

$$\text{PAW} - \text{water use} = \text{Water remaining}$$

Days to irrigation This value allows us to plan for the next irrigation. It is determined by dividing the plant available water remaining in the soil profile by the water use rate. With 2.2 inches remaining in our soil profile and a water use rate of 0.2 inches per day, irrigation water should be applied 11 days after the second evaporation pan reading was taken.

$$\text{Remaining PAW} / \text{Water use rate} = \text{Days to irrigation}$$

Under actual growing conditions, these measurements would be made every few days to adjust for the changes in the water use rate as the crop grows.

Irrigation amount It is essential to know the amount of water to apply so that under- and over-irrigation do not occur. The amount of irrigation water to apply is the same as the water used from the soil profile since the last irrigation. If all the plant available water has been used by the crop, then the irrigation amount is equal to the plant available water in the soil profile. If less water has been used, the irrigation amount will be the difference between the plant available water in the profile and the water remaining in the profile.

$$\text{PAW} - \text{water remaining in the profile} = \text{Irrigation amount}$$

Fertigation

This practice involves the application of fertilizer in irrigation water. It is most efficient and controlled in sprinkler systems but can also be used with some land systems. Fertilizer is dissolved or suspended in water to form a concentrate. This fertilizer concentrate is then slowly mixed with the irrigation water and applied to the field.

Often times it is used to apply nitrogen during the growing season. The need for late applications of fertilizer is determined by leaf tissue testing.

Chemigation

Chemigation is similar to fertigation except that pesticides are applied. This technique should be used with sprinkler systems because of its increased potential for environmental contamination and toxicity. Again, chemicals are dissolved or suspended to form a concentrate which is then mixed with irrigation water.

Sample Questions

1. How is water applied in sprinkler irrigation systems?
2. What is the goal of irrigation?
3. Calculate the water use rate and water status for a field.
4. There is 1 inch of plant available water remaining in a soil profile and the crop is using 0.33 inches
5. of water a day. How many days are there before you have to irrigate?
6. Why would fertilizer be applied through an irrigation system?

[Top](#)

SOIL and WATER POLLUTION

Pollution of our soil and water resources has accelerated since World War II because of new technology to produce fertilizers and pesticides and to farm more intensively and because of political decisions. In recent years, some effort has been made to reduce agricultural pollution; however, much of the responsibility falls to individual producers. If 100 producers take steps to prevent pollution and one producer pollutes, our resources will, and have, become polluted.

Learning Objectives

- Define pollution, organic compounds, inorganic compounds, organic waste, and salinity.
- Describe the five (5) kinds of pollutants.
- Understand the conditions which promote pollution.
- Describe the hydrologic cycle and mechanisms by which water can become polluted.
- Compare and contrast measures used to reduce pollution.

Our environment affects everyone. Agricultural chemicals that leave fields in southeast Nebraska have been found in Kansas. Soil eroded from productive Nebraska lands has helped to create the Mississippi Delta in Louisiana. Topsoil blown or eroded by water into lakes and streams can

cause algal blooms because of phosphorous loading and kill fish because of pesticides. Wind-blown soil and grain dust puts particulate matter into the air causing respiratory problems for agricultural workers and other citizens in towns and cities.

Pollution Hazards

Both soil and water can become polluted. In addition, soil itself can be a pollutant. Soil and water become polluted when undesirable substances are placed in them. While some environmental contamination is truly caused by accidents, most is due to negligence and ignorance. Knowledge, then, is one key to pollution prevention.

Soil interacts with pollutants in four different ways. They can be adsorbed onto the surface of soil particles, leached, undergo chemical reactions, or be decomposed by microorganisms. In some situations, the pollutants may be altered so that they are no longer hazards; while in other situations the pollutants can persist for months or even years.

Water can be contaminated with dissolved, suspended or solid materials. Dissolved materials move readily with water while suspended and solid materials may have limited ability to move because of their size. Runoff and leaching are instrumental in water pollution.

Pollutants

Many different pollutants exist in, on, and around the farm. Many are also present at seed and chemical dealerships as well as at storage facilities. These pollutants take on many different forms. In general, pollutants are classified into five groups.

Pesticides These are organic compounds used to control pests such as diseases, weeds, and insects. The storage, transportation, handling, mixing and loading, and application of pesticides all present pollution hazards. The release of any of these compounds into the environment in a manner other than its intended use can cause contamination. Spills, improper disposal of containers, over-application, and misapplication are among the most common sources of pollution.

Inorganic Pollutants Inorganic compounds and elements are abundant. They include substances that are not organic. Lead in a truck battery and mercury in a thermometer are common; but when the battery corrodes or is left in a junk pile or when the thermometer breaks they become pollution hazards. Other pollutants include copper, zinc, arsenic, and nickel. Proper disposal and reduction in the use of materials containing inorganic compounds can markedly reduce potential hazards.

Organic wastes These wastes come from feedlots, food-processing plants, and urban and industrial settings. They include manure, poultry litter, paunch and carcasses, and sludge. When these materials are exposed, rain may wash organic material and nitrates into waterways; with wind they may become air-borne. Odors from these wastes or their decay products can easily pollute the air. Many of these materials are applied to soils for disposal and nutrient utilization. They should be applied to the soil during the time of year when the potential for pollution is

minimized. Field conditions such as slope and terracing, residue cover, crop rotation, proximity to water, etc. are also considerations for environmentally safe application.

Salts Salts create a condition known as salinity. Because of their widespread occurrence they are considered separate from other inorganic pollutants. This has been a problem since our earliest civilizations on Earth. Salts are present in soils and in water. Water causes salts to move in soil and can also add additional salt to soils. Over-irrigation can cause the accumulation of salts in the plant rooting zone. Poorly drained and poorly vegetated soils may concentrate salts near the soil surface because salts move upward from the lower soil profile as evaporation occurs. Some soils naturally have a very high concentration of salts. Extremely salty soils are easily recognized by their white coating on the surface soil.

The routine application of manure or sludge high in salts can increase the soil salt content to levels that will prevent crop growth. Salty manure results from the force feeding of salt in formulated feed rations.

The practice of summer fallowing, mentioned earlier also contributes to salinity. In years when no crop is growing, rainfall can leach salts downward and laterally to a fairly shallow area or a downslope position. Here, as water evaporates, salts are left on the soil surface. Throughout Montana and the Dakotas many of these areas have developed and are called saline seeps. Several saline areas are also visible in western Nebraska on crop and range land.

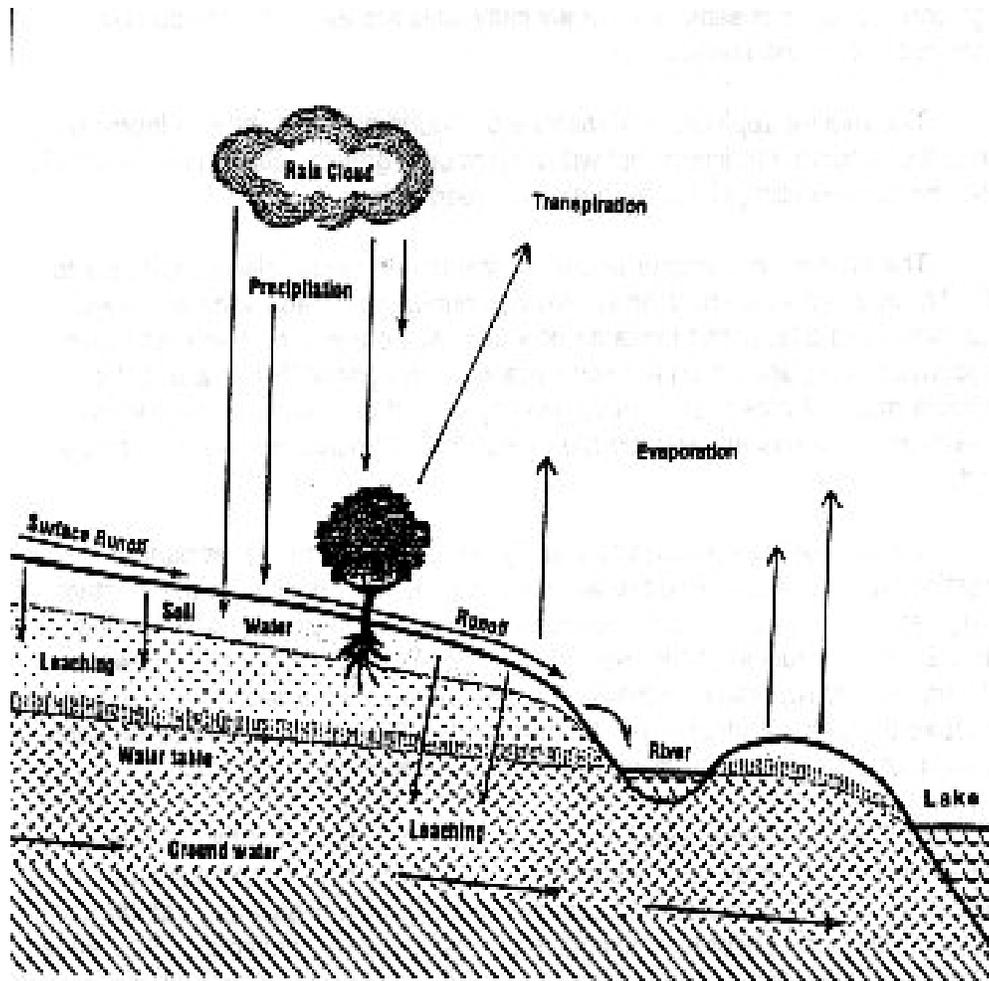
Salinity can be minimized by applying only the required amount of irrigation water and checking the water's salt content. Testing the salt content of sludge and manure can aid in management decision to prevent salt loading. Eliminating or reducing salt in feed rations can also reduce the salt content of manure. Cropping practices that keep vegetation growing allow soil moisture to transpire through the plant rather than evaporate from the soil surface or leach. Consequently, salts do not move toward the soil surface.

Soil On a national basis, soil is the No. 1 pollutant of our waterways. Soil, once eroded, ends up in waterways or on lands other than its site of origination. Streams and lakes become filled with soil. Spawning habitat for migratory fish may become unusable if too much soil has collected. Suspended soil can decrease the amount of light reaching the streambed and allow undesirable organisms to grow. Municipalities that use river water must separate out soil as well as chemicals and bacteria from the water before it is suitable for drinking. Keeping soil from eroding is the only prevention for these problems.

Water Pollution

Water can become contaminated anytime it interacts with dissolved, suspended or solid materials. The movement of pollutants in localized bodies of water can easily contaminate other water. All bodies of water and their movement are part of the global hydrologic cycle (Fig. 5).

Figure 5. The hydrologic cycle (From Applying Pesticides Correctly, NE Cooperative Extension).



Water in the form of rainfall or irrigation impacts the soil surface. This water can then runoff along the soil surface or infiltrate the soil. Water that runs off may enter a ditch, waterway or small stream. These conduits eventually connect with rivers, large streams, lakes, reservoirs, ponds, or oceans.

Water that has infiltrated the soil may evaporate from the soil surface, be absorbed by plants and transpired, or leached below the root zone. Water that leaches will move downward to a water table or deeper to the groundwater aquifer. Within the water table or aquifer, water may move laterally until it reaches an outcropping, such as a river, lake, or shallow spot of soil.

Pollutants may be moved with water throughout the hydrologic cycle except evaporation and transpiration. The chemical makeup of most pollutants prevent them from being vaporized into the air. As a result these materials remain in the soil.

Sample Questions

1. What are the major differences between pesticide and organic waste pollutants?
2. How do salts contaminate the soil?

3. Draw the hydrologic cycle and label the different forms of water flow according to their ability to
4. transport dissolved, suspended, or solid pollutants.

[Top](#)