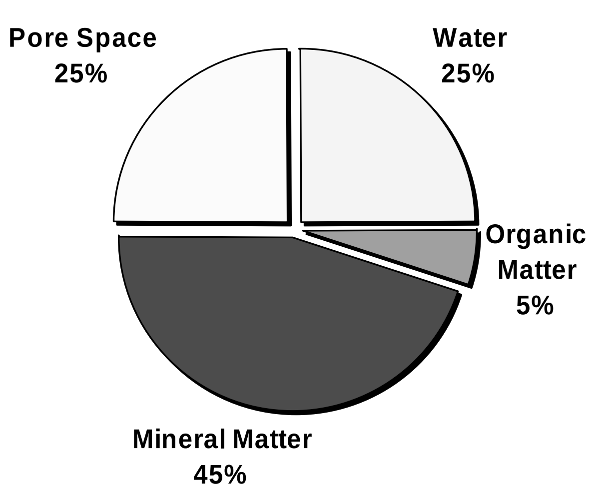
SOILS, SOIL CHARACTERISTICS AND SOIL MANAGEMENT

Introduction

The success of many civilizations has been determined by the quality of their soil resources. Furthermore, most civilizations have remained great only as long as they have properly managed the soil. Many productive soils have been worn out by depleting the fertility and allowing excessive erosion. Modern day use of fertilizer can help replenish fertility, but good soil management is still important to maintain high productivity.

Soils differ greatly in their ability to produce agricultural crops. Our soils have developed from a diversity of materials and under a wide range of environmental conditions. This chapter will discuss soils and factors affecting their productivity.

Fig. 1 Approximate volume composition of soil.



What Is Soil?

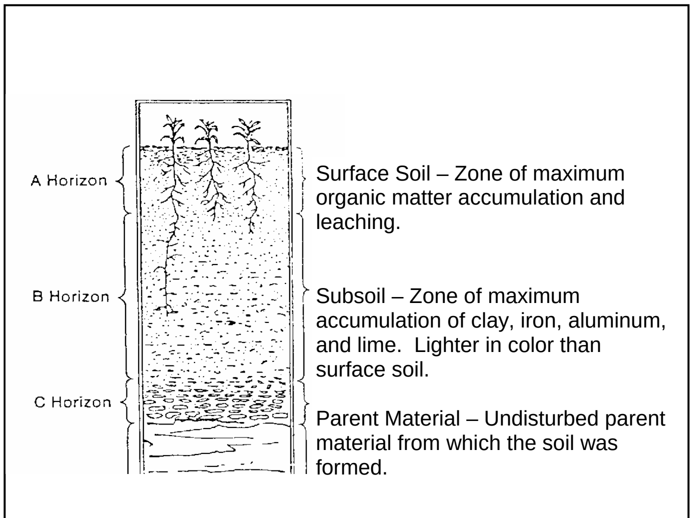
Soil is the upper weathering layer of the solid earth surface in which plants growand is a mixture of minerals, organic matter (humus), air, and water (Figure 1). An ideal soil is about 50% solids consisting of mineral and organic material. The organic portion consists of residues of plants, animals, and other living organisms. Levels vary, but in most Great Plains soils, levels of less than 1% to 5% on a weight basis are typical. Under optimum conditions for plant growth, about half of the pore space is filled with water, leaving the remainder of the pores filled with air. This mixture of mineral and organic material, water, and air provides the environment for root growth. Soil compaction reduces pore space, soil aeration, and permeability which restricts root growth and nutrient uptake.

Soils vary in their chemical, physical and biological characteristics. Because of these inherent differences in characteristics, soils have different use capabilities. They respond differently to various cropping, tillage, fertility, and irrigation practices. Soil scientists use the inherent characteristics of soils to give them distinct, identifying names. They use the same characteristics to group soils into land use classes. Successful farmers learn to use this information to their best advantage. Soils are like people in that we must know them thoroughly in order to understand them; in order to understand which practices will enhance their worth—their productivity.

There are 17 different nutrient elements that are essential for plant growth; of these, 14 are derived primarily from the soil. Soil also provides a place to store water and gives support for plant roots.

The term, soil profile, is used to describe a vertical cross-section of the soil from its surface down into the parent rock or earth materials from which the soil was formed. Soil scientists have divided the soil profile into horizons.

The soil has three major horizons (Fig. 2).



“A” horizon is the top layer of the soil in which organic matter has accumulated from plant and animal residues and from which clay and chemical elements have been leached into lower layers. The “A” horizon, then, is the leached layer of soil.

“B” horizon is the middle layer of soil into which leached materials are deposited from the “A” horizon. This horizon is characterized by its higher content of clay and minerals; by its color; and by its structure or arrangement of soil particles into distinct aggregates; i.e. angular, blocky, columnar shapes. The “B” horizon is the layer of accumulation; the subsoil.

“C” horizon—the undisturbed parent material from which the soil was formed. Later we will discuss the influence of different parent materials on soil formation.

Factors Involved In Soil Formation

Soil is produced by soil forming processes acting on materials deposited or accumulated by geological activity. The characteristics of the soil at any given location are determined by five factors of soil formation:

1. The climate under which the soil material accumulated and existed since its deposition or accumulation.
2. The physical and mineralogical composition of the parent material.
3. The ecology (plant and animal life) on and in the soil over the time of formation.
4. The relief or slope of the land.
5. The length of time the forces of soil formation have acted on the soil material.

Each of these five factors will be discussed briefly because an understanding of their relationships to each other governs our classifications of soils.

The interactions of these factors determines the kinds of soils formed.

Climate: Three climatic factors – precipitation, temperature, and wind – have all acted to help change soil material into a soil profile. These factors have caused the three principle types of weathering processes – physical, chemical and biological – to take place. The processes of weathering are all inter-related.

Moisture from rainfall and other sources enters the soil, dissolves soluble materials and transports those materials downward in the soil. It permits plants to grow and to contribute organic matter to the soil. As the moisture moves downward, it carries fine particles of soil material and minerals with it and deposits then in “B” horizon (subsoil). Moisture also allows the soil organisms to increase in number and activity. These organisms help by changing decaying plant material to soil organic matter.

Variations in wind and in temperature from season to season affects the soil in several ways. Hot summer winds evaporate moisture rapidly. Alternating cold and warm temperatures in winter, freezing and thawing, break up the soil aggregates and change the soil structure. Winds also blow particles of soil material from one area to another and, thus, modify the texture of the surface layer. Large particles or aggregates are caught up by the wind and bounced along the surface. Where these large particles are deposited, they disturb the fine particles, causing them to rise, caught by the wind, and carried into the air. They are often deposited many miles away.

As a general rule, we can expect most acid soils requiring lime to occur in humid regions receiving in excess of approximately 30" of annual precipitation (eastern Kansas). Most potassium deficient soils occur in the same region. Rain has leached through many soil profiles, removing significant quantities of calcium and potassium.

Typically, lime and potassium needs are generally lower in the western parts of Kansas. As annual precipitation falls below 20", free lime is often present in surface soils. In these drier regions, higher rates of evapotranspiration encourage upward movement of soil water which reduces leaching of nutrients. The high pH often found in these soils favors iron and zinc deficiencies in crops.

<u>Parent material:</u> Whatever the character and manner of geological formation of parent materials from which soils are formed- volcanic, marine, colluvial, sedimentary, etc. – they are classified principally by the manner in which they were transported to the place where the soil has actually been formed. You will hear the following terms applied to parent materials of soils:

- Sedentary. Those soils formed from parent geological materials that have not been moved from the place in which they were first formed.

- Colluvial. Those soils formed from rock debris accumulated at the foot of cliffs or steep slopes.

- Alluvial. Soils formed from parent materials washed into place by running water.

- Glacial. Soils formed from glacial drift materials brought into place by glaciers.

- Outwash. Soils formed from great masses of mulit-textured parent materials washed into place by water. The outwash plain of the Rocky Mountains, for example, extends from the mountains almost to Russell, Kansas.

- Loess. Soils formed from fine-textured (silt and clay) materials transported into place from long distances by wind action.

- Eolian. Soils formed from coarser textured soil materials (sands) that were first transported by water and then reworked within a relatively small area by wind.

Parent materials exert a great influence upon the properties of the soil because of the differences in the physical and chemical composition of the original geological materials and because of differences in what happened to these materials as they were moved to the location at which the soil was formed.

<u>Vegetation</u>: Plants and animals aid in the soil forming process. The roots and tops of plants decay and add organic matter to the soils. Burrowing animals and earthworms mix the soil material and move it from one layer to another. Microorganisms break down organic matter, as well as the minerals and rocks. Plants are the primary source of organic matter that causes the dark color of soils.

Vegetation influences the kind of soil developed, in that plants vary in types of root system, size, and nutrient composition. Soils formed under trees are greatly different from soils formed under grass even though other soil forming factors are similar. Trees and grass vary considerably in their rooting habits, and in the amount of various elements taken up by roots and deposited in or on top of the soil. Trees are light feeders of bases (calcium, magnesium and potassium), thereby allowing bases to be leached from the soil. Grasses have a higher requirement for bases and thereby return the bases to the surface soil. Soils formed under trees are usually acid, while soils formed under grass are basic. Climate, of course, dictates to a great degree the type of vegetation that occurs .

<u>Slope</u>: Slope of the land (relief) influences the formation of soils through its effects upon drainage, runoff, erosion, and vegetation. Because of more runoff and erosion, and less water within the soil for plant growth, soils on steep slopes form definite profile characteristics

much more slowly and less distictly than soils on more level topography. We say such soils are young and immature. Thus, the action of the other soil forming factors (climate, vegetation, plant material, and time) are modified by the slope of the land.

Time: The length of time required for the formation of a soil depends largely upon the other factors of soil formation. In parent material consisting of weathered rock, a much longer period of time is required for a soil profile to develop than in a thick deposit of outwash sediment. A soil profile develops more quickly in areas where weathering is extensive than in areas of low rainfall. In some soils more time is required for a soil profile to develop than in others because the parent material is resistant to leaching or is susceptible to erosion. Soils in the floodplains of present streams tend to be the youngest from the degree of profile characteristics because of the frequent deposition of materials

Soil Microorganisms

Each spoonful of arable Kansas soil contains billions of living microscopic organisms. Multiply this by the number of spoonfuls of soil in an acre and you have figures that are astronomical (Table 1).

This seething mass of microorganisms constitute 3 to 5 tons per acre-foot of soil that a farmer sustains beneath the surface in addition to the crop that he grows above the ground. If the microorganisms beneath the surface do not have adequate food the crop above the ground may suffer from competition for mineral nutrients and be more susceptible to disease.

The microorganisms are almost all in the top three feet of soil, largely concentrated in the upper few inches. Newly leveled land will take several months to several years to build back the microorganism population.

"Microorganisms eat at the first table." They are in contact with almost every particle of soil. The majority of the microorganisms obtain their food and energy by breaking down complex organic substances manufactured by higher plants and animals. Without their activity, man probably could not survive, since dead plants and animals would soon choke the earth's surface.

Various kinds of organisms grow best under quite different conditions. Most bacteria prefer well-drained, slightly acid to alkaline soils with moderate temperatures and good aeration. Fungi prefer acid soils and algae are found near the surface of the soil where light and water are available. While most microorganism groups depend on organic matter for food and energy, several types obtain their energy by oxidizing inorganic elements such as sulfur and nitrogen. A few organisms can live in poorly drained soils and in the absences of free oxygen.

The decomposition of organic matter in the soil by microorganisms completes a vital cycle in the plant world. The plant grows and absorbs nutrient elements from the soil, matures and dies. By microbial breakdown of the dead plant, these plant food elements are released and again become available for use by a new generation of plants. Without this decay process, most of the carbon in our universe would become locked up in complex plant and animal tissue, because the amount of available carbon dioxide in the atmosphere is quite limited. In the process of organic matter decaying, various acids are formed in the soil. These may react with mineral compounds containing vital plant food elements (phosphorus, calcium, magnesium, potassium, etc.) making them more soluble and available to growing plants.

During the process of organic matter decay, an organic colloidal material is produced which helps to cement the finer soil particles into larger granules. A soil which is granulated in this fashion is said to have good structure and is often described as being "mellow" or easy to work. When it rains, the water soaks into a granulated soil instead of running off the surface.

Organic matter decay by soil microbes is a continuous process of vital importance, and fresh organic residues must be continually added to the soil if the benefits of this complex process are to be realized over long periods, hence, the recommendation for returning residue to the soil whenever feasible.

Soil organisms perform both beneficial and detrimental functions in the soil. Without microorganisms to decompose organic residues, these organic materials would accumulate indefinitely. Microbial decomposition of organic matter also releases many nutrients for reuse by plants. Nitrogen, phosphorus and most other essential nutrients are converted from a plant-unavailable, organic form to a plant-available inorganic form by soil microorganisms via a process termed mineralization. Additionally, bacteria called *Rhizobia* are responsible for nitrogen production in root nodules on legumes and mychroriza are microorganisms associated with plant roots that can improve nutrient availability and uptake.

On the detrimental side, microorganisms such as fungi and nematodes are responsible for many plant diseases while many soil insects damage crops.

Fertilizer generally has a positive effect on soil microorganisms by providing needed plant nutrients and subsequently increased grain and crop residue yields. This is equally true for anhydrous ammonia applications to cropland. While the application of anhydrous ammonia will temporarily reduce populations of microorganisms and in the relatively small volume of soil in the ammonia band, populations quickly increase above original levels in a very short time.

<u>Biological inoculants and activators.</u> Soil biological activators are marketed with claims of increasing the activity and number of soil microorganisms, or adding new and beneficial microorganisms to the soil. With few exceptions, these products are not beneficial. The Kansas Soil Amendment Law requires products intended to improve the physical, chemical or other characteristics of the soil or improve crop production (with exceptions for fertilizer, lime and pesticides covered under other laws) must be registered with the Kansas State Board of Agriculture

Subsoil Influence on Soil Fertility

Even though most soil samples for soil tests are taken from the surface soil, subsoil fertility can contribute significantly to a crop's nutritional requirements.

While most soils become less fertile with depth, a few actually contain higher levels of P and K in the subsoil Mobile nutrients such as nitrate-nitrogen and sulfate-sulfur can accumulate below the surface horizon requiring deep sampling for accurate soil tests.

Table 1 Organisms in top foot of soil.

Organism	Number/gram soil	Typical Weight/acre-foot soil
Bacteria	1 Billion	750
Actinomycetes	15 Million	1,100
Fungi	1 Million	1,700
Protozoa	1 Million	300
Algae	100,000	250
Yeasts	1,000	---
Worms and Insects	---	900

T.M. McCalla, Neb. Ag. Exp. Sta. Research Bulletin, 1959

Characteristics Affecting Management

Soil means different things to different people. The farmer, the housewife, the engineer, the geologist, and the soil scientist put different interpretations on the measurable properties of soils. In this discussion we are interested in soil differences as they influence fertility and yield potentials. Some of the soil characteristics in which we are most interested in this regard are:

- Surface and subsoil texture
- Slope
- Surface soil color, organic matter content
- Drainage and permeability
- Soil depth and water storage
- Soil pH
- Cation exchange capacity
- Bulk density

Slope: Under dryland conditions where rainfall is limited, slope exerts more influence than any other soil characteristic in determining soil management practices. In considering slope influences we think of:

- Surface drainage
- Rate of erosion and build-up of organic matter
- Rate of water runoff and droughtiness
- Loss of surface applied fertilizers
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Surface soil color and organic matter content: Crop rotations and their effect on soil organic matter are not stressed today as they were 20 years ago. Organic matter content is still an important indicator of:

- The rate at which soils warm up
- The amounts of organic nitrogen, phosphorous and other nutrients present
- The ability to maintain tilth and infiltration rates
- Reaction with certain herbicides

Drainage and permeability: These two soil properties are often ignored in dryland areas when management decisions are made. Yet as we increase irrigation, use of heavier farm machinery, and seek higher yields they often become limitingfactors. Knowledge of drainage and permeability often tell us:

- The surface water and/or runoff status of the soil
- The movement and/or leaching of plant nutrients and pesticides
- Air relationships within the soil
- Possible droughtiness

Depth of root zone and available water storage capacity: Soil fertility specialists pay attention to these two characteristics of sols. Farmers often ignore them. They are important because they are a measure of:

- The amount of plant nutrients a soil can retain
- The basic fertility stature of the soil

Bulk density. This is the weight of a given volume of soil in relation to the same volume of water. Even the experts often overlook this soil property when evaluating soils. Consequently very few of our soils have data recorded for bulk density. Bulk density tells us some things about the soil that no other measurement can:

- It is a measure of compaction and plow pan formation
- It indicates probable root distribution and growth problems
- It is another measure of permeability and aeration

Heavier equipment and larger farms result in tillage decisions that increase the chance for soil compaction. When evaluating tillage research, the term bulk density will often be used to estimate differences in compaction.

Bulk density is the weight of a unit volume of soil, including any air space and organic materials. The average soil bulk density for a cultivated loam is 68 to 87 lb/cu. ft. or 1.1 to 1.4 g/cu. cm.

Soils that are compacted will have higher bulk density. For good growth, bulk densities should be below 87 lb/cu. ft. for clays and 98 lb/cu. ft. for sands.

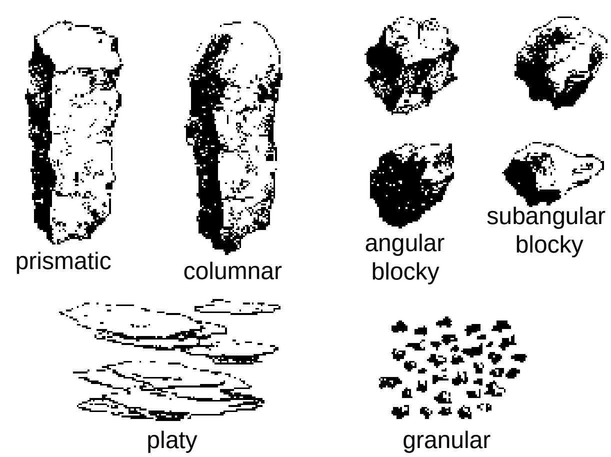
A fertile soil is not necessarily a productive soil since it may have properties that restrict plant growth. The productivity of a soil will vary with its physical and chemical properties and the environment where it occurs. Fertilizer recommendations should consider the yield potential of the soil plus a realistic yield goal. Important soil properties affecting productivity include:

No soil is ideal for crop production in all these characteristics, but the dryland soils of western Kansas are better in many respects than almost any other soil in the world. Lack of adequate rainfall is the most limiting factor on many of these soils.

Soil structure Soil structure refers to the arrangement of the various individual soil particles into units called aggregates. The size, shape, and stability of these aggregates affect soil porosity, permeability, drainage, resistance to crusting, and soil tilth. Organic matter or humus contributes to good soil structure by acting as a bonding agent which holds soil particles in stable aggregates such as granules. Soils that are low in organic matter tend to crust and form clods when tilled because the soil aggregates break down easily. We can improve or destroy soil structure through management decisions which affect crop rotation, tillage, compaction, and erosion. Excessive sodium levels in alkali soils can result in poor soil structure.

Soil Porosity and Permeability *Porosity* refers to the total pore space in the soil and may vary from 30% to 60% of the soil volume. *Permeability* refers to the ease with which water, air, and plant roots move through the soil. A heavy clay soil may have high porosity but low permeability. Permeability of water can range from 0.5 in./hr. on clay soils to over 10 in./hr. on sands. High permeability results in less run off of water and nutrients, but more leaching. A balance of large pores for good intake and movement of air and water and small pores for storage of water is important. Porosity and permeability depend on the texture, structure, and organic matter in the soil. They are impaired by soil compaction.

Figure 3 Soil structure examples



Properties of Soil Clays

The chemical reaction between cations in the soil water and clays in the soil has been called the second most important reaction that occurs in nature. The most important reaction is photosynthesis through which plants take carbon dioxide from the air, water from the soil, energy from the sun and manufacture simple sugars. They are able to do this because of their green coloring matter called chlorophyll. Man has yet to duplicate this reaction in the laboratory.

The composition and reactions of soil clays are very complex but there are certain basic principles and practical applications, which can be expressed rather simply. Dr. Roscoe Ellis, former soil chemist at Kansas State University, is mainly responsible for working out the simplified explanation for soil clay reactions presented in this write-up.

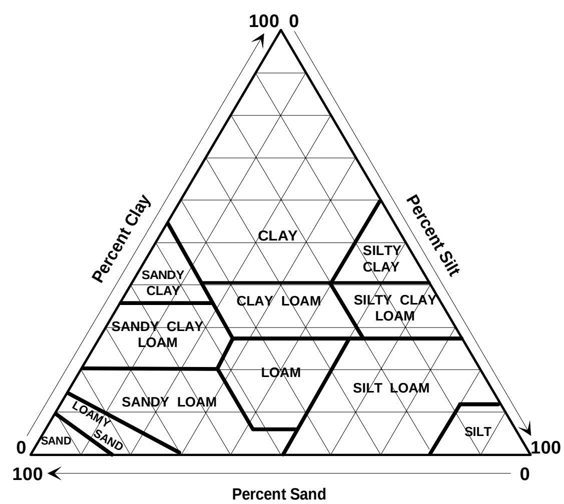
In reading this account of the basic principles of clay reactions in the soil, please keep in mind that this knowledge is not going to suddenly change the kind of soil you have or the ways you have learned over the years for handling them. It will, however, let you know why certain practices work well and others do not.

There are several reasons why we need to know more about the relationship of soil clays to fertilizer applications and water use. The concern about pollution from excess use of nitrogen has already been widely expressed. The same concern exists regarding the use of pesticides. Ten to twenty tons per acre per year applications of manure cause no problems, but the 100 to 200 tons per acre per year applications that occur around feedlots and other confinement facilities is another matter. An increasing challenge, is the necessity for waste disposal from large cities. Chicago, for example, is piping wastes down state in Illinois and applying them to farmlands. Knowledge of soil clays and their capacity to adsorb these wastes is absolutely necessary if we are to avoid ruining the land for agricultural purposes.

Surface and subsoil texture. Soil texture is the term used to describe the relative proportion of different soil particles sizes. A soil, of course, contains many different size soil particles ranging in some cases from boulders to those so small they can be seen only with a microscope. The proportion of different size particles in a soil is very important in determining the physical and chemical properties of a soil.

The texture of the soil, whether a silt loam, silty clay loam, or sandy loam, is determined by the amount of sand, silt, and clay in the soil. With experience, it is possible to determine soil texture by ribboning the soil between the fingers. However, for accurate determinations, the amount of sand, silt, and clay sized particles in a soil are determined in the laboratory. Once the percent of the three separates is known, soil texture is determined by the use of a "textural triangle" (Figure 4).

Figure 4 Soil textural triangle



The three sides of the triangle represent increasing or decreasing percentages of sand, silt, and clay. By drawing lines through the known percentages (point at which the three lines intersect), a soil texture name can be given to the soil.

Size of soil particles is expressed as their diameter in millimeters. A meter is 39.2 inches so a millimeter (mm) is 1/1000 meter or .0392 inches. Soil textures are divided into four groups; clay, silt, sand, and gravel

Clay particles are very small in size and, therefore, there are many more particles in a given weight of clay than of silt or sand. Likewise, clay has many times the surface area in a given weight compared to silt or sand. Because of this great surface area, clay per unit weight exerts a far greater influence on the chemical and physical properties of soils than does silt or sand. The kinds of influences will be brought out under later discussions of pH; base exchange; reactions of fertilizer nutrients in the soil; water movement in the soil; etc.

We can summarize by saying that surface and subsoil textures indicate:

- Approximate clay content
- Erodability
- Water infiltration rate
- Moisture permeability
- Moisture holding capacity

The texture of a soil is described in terms such as coarse to fine, light to heavy, or sandy to clayey. These terms can have different meanings for different localities and can even vary from person to person. For this reason a classification system has been established which places soil texture in 1 of 12 textural classes. This system, devised by the USDA, is used throughout the United States and in many other parts of the world.

Loam is a common term referring to a general mixture of sand, silt, and clay in which no one of the three size groups predominates. Loam soils generally have better physical properties than sandy or clayey soils. If the soil textural name ends in sand, it contains at least 70% sand and less than 15% clay. If the name ends in clay, the soil contains at least 35% clay particles.

How do we know the texture of a soil? The most accurate method of determining soil texture is performed in the laboratory. Many farmers can determine the texture of soils in a field by referring to county soil survey reports. In most counties in the United States, soil maps have been made showing the soil name and texture as well as other soil information. The two important solid fractions of soils are organic and the inorganic materials. Soil clays are part of the inorganic part of the soil and may make up from almost 0 to as much as 45 percent or more of the soil's weight. Studying the properties of clays is very difficult because of the small size of the clay particles. Soil scientists separate the soil particles into three size groups.

Sand is the term used for soil particles larger than .002 inch in diameter. These particles can be seen by the naked eye. Most of us have some experiences with feeler gauges in setting tolerances in motors and, thus, have some idea about the thickness of something that is .002 inch in diameter. Sand feels gritty to the touch. The largest particles and, when dominant, yield a coarse-textured or sandy soil. Sandy soils are frequently called light soils because they are easily worked.

Sand particles contribute little to soil fertility and do not attract or hold much water; thus very sandy soils are usually droughty and infertile. However, a certain percentage of sand-sized particles can be desirable by contributing to better aeration, drainage, and tilth. Quartz is the most common mineral composing sand particles.

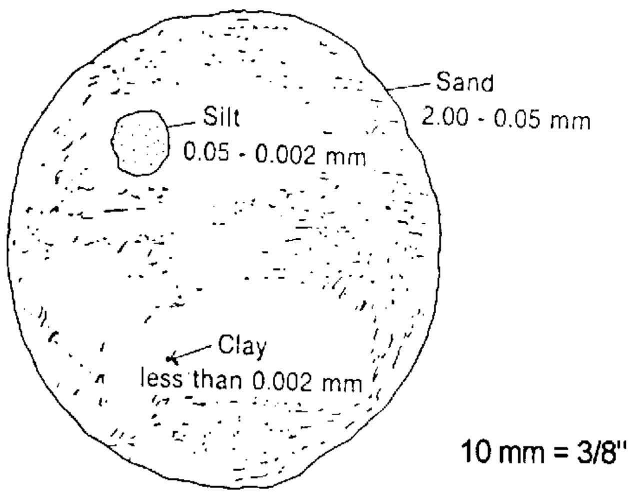
Silt is the term used for soil particles that range in diameter between .002 and 1/12,500 inch. Most silt cannot be seen as individual particles but does feel silky or velvety when moistened and rubbed between finger and thumb. These particles are smaller than sand but also contribute little to soil fertility. Silt is on the order of 25 times the diameter of clay particles and possesses less than 5% of the surface area. Silt may be composed of quartz or of the more chemically active minerals that compose the clay fraction.

Clay is any soil particle that is less than 1/12,500 inch in diameter. These particles are too small to be seen with an ordinary microscope, but can be seen by an electron microscope. Because of their size they are quite difficult to study. Much of what we have learned about them has been found out over a long period of time using X-ray analysis. We know much about their composition; how they influence the chemical and physical properties of soils; and why this is so. Clays are made up of very small particles that cannot be seen with the naked eye, but collectively exhibit a tremendous surface area. The surface area of the clay particles in an acre-furrow slice of a typical Midwest soil is approximately equal to the surface area of the continental United States. Clay particles have about 1,000 times the surface area of an equal weight of sand.

The surface of clay particles possess negative electrical charges which are responsible for the ability of soil to retain certain nutrients in a form available to plants.

A high percentage of clay is a characteristic of fine-textured soils that are often termed heavy because they are more difficult to till.

Figure 5 Comparative size of sand, silt and clay



Kinds of clay. We know that the kind of clay in a soil makes a big difference on how it reacts to fertilizer applications and to the storage of water. There are more than two dozen distinct clays in soils but they may be classified for purposes of simplicity into three main types: Kaolinite, Montmorillonite, and Illite.

Kaolinite clay may comprise as much as 10-15 percent of the total clay in some Kansas soils. The Dakota Sandstone area has a bed of highly kaolinitic clay in one part of the state. The Dakota Sandstone outcrops from Washington County south and west to about Great Bend. The rolling hills west of Salina are of Dakota Sandstone. If you have traveled Interstate 70 you might have noticed the white layers in the roadcuts east of the junction of I-70 and K-156 northeast of Ellsworth. These layers are kaolinite. Kaolinite usually occurs where there is heavy annual rainfall and fairly high annual temperatures. This tells us that central Kansas back in geological time had a different climate than it does now.

Montmorillonite clay is the predominate clay in Kansas soils. In most Kansas soils the clay is more than two-thirds montmorillonite. You may know this clay better by the names “Bentonite” or “Driller’s Mud.”

1. They have a high tendency to shrink on drying and swell when wet. They are sticky when wet. We call them “gumbo” soils if the total clay content is high. They should not be worked just after a rain or when quite dry.

2. Water permeability tends to be slow. Irrigation sets need to be for a much longer time than for kaolinite clay soils. They tend to puddle if worked too wet. Surface sealing can be a problem. The puddling or “plow-pan” forming process can be illustrated by putting water between two panes of glass. You can’t pull the panes apart but they will slip easily. When this slipping happens in montmorillonite containing clay soils the structure is destroyed. Plow pans are formed. Thus, structure can only be restored by freezing and thawing; wetting and drying; by grass and legume roots; and by the incorporation of residues and manure to the soil. It is often a slow process. Care must be taken, then, not to till these soils when they are wet and sticky.

3. Because of their high cation and water holding capacity and slow permeability, montmorillonitic clay soils don’t leach like kaolinitic clay soils. Winter application of fertilizers, if surface erosion is controlled, becomes a practical time saving practice. This high cation holding capacity allows the

winter application of anhydrous ammonia, when soil temperatures are below 50^oF.

4. Also because of the high water holding capacity of montmorillonitic clay soils, they are not as droughty as kaolinitic clay soils. Crops grown on them can go much longer between rains or irrigations. Montmorillonitic clay soils also react much differently to the presence of alkali or saline conditions.

This is of great importance in the management of irrigated soils high in soluble salts or in the use of irrigation water containing appreciable amounts of salts. For example, if the amount of sodium attached to the internal surfaces between the clay lattices amounts to somewhere between 10 and 20 percent of the total cations present in the soil, the soil will puddle (deflocculated) just like it does when tilled too wet. However, the condition is much more difficult and expensive to correct.

The puddling occurs because the sodium ion attracts large amounts of water forcing the clay lattices to swell apart until the cation positive charge can no longer hold them together. The result is a puddled soil which is almost impossible for water to penetrate. Tilth is so poor it is very difficult to make good seedbeds. Because of the puddling and high salt content, plants can't take in water so the soils become droughty even though the soil may be nearly saturated. Oxygen relationships in these soils are disturbed to the extent that proper root development and function is prevented. The roots can't take in plant nutrients even though they are present in ample amounts.

Other cations besides sodium can cause this chemical puddling of soils. However, the effects are not as marked or as difficult to correct. Potassium and ammonia, for example, will cause the puddling if they exceed more than 30 percent of the total cations on the internal surfaces of the clay.

Illite clay is predominately formed by the weathering of mica minerals. It usually makes up smaller portions of the clay in Kansas soils but imparts important characteristics where it does occur.

Usually it does not make up more than 50 percent of the total clay. However, where it is present it contributes some important properties to the soil. Illite is formed principally from the decomposition of mica minerals. Mica is high in potassium so the internal surfaces of illite are highly saturated with potassium. Illite has some of the properties of both kaolinite and montmirillonite. It has a fairly high cation exchange capacity and water holding ability. Like kaolinite it is not sticky when wet and has good tilth. Much of the good tilth of western Kansas soils comes because of the illite clay in them.

One problem occurs occasionally in western Kansas that may be due to the presence of illite clay. Farmers have complained that they sometimes do not get a response from anhydrous ammonia when it is applied. But they do get responses later in the year or during the next crop growing season. One explanation for this might be that the illite clay was expanded enough when they anhydrous was applied to take the ammonia in between the lattices. Quick shrinking might have locked the ammonia in. Later in the year increased moisture (or freezing and thawing over the winter) expands the clay and releases the ammonia for delayed plant use.

Some areas of southeast Kansas provide us with good illustrations of the effects of different soil clays on management practices. One of the soils, Summit silty clay loam, is a "gumbo". It is quite high in montmorillonite clay. It is extremely hard to work either wet or dry. Another soil in the same areas, Newtonia silty clay loam, has only a small amount of montmorillonite clay. It has very few physical problems.

Table 2   Soil Textural Class Estimated by Hand-Feel Method

Soil Textural Group	Soil Textural Class	Feel
Coarse to Very Coarse (>70% Sand)	Sand, Loamy Sand	Feels gritty, does not ribbon or leave smear on hand.
Moderately Coarse	Sandy Loam	Feels gritty, leaves smear on hand, does not ribbon, breaks into small pieces.
Medium	Loam, Silt Silt Loam	Feels smooth & flour-like, does not ribbon, breaks into pieces about ½" long or less.
Moderately Fine	Sandy Clay Loam Clay Loam, Silty Clay Loam	Forms ribbon that breaks into pieces about ¾" long, sandy clay loam will feel gritty.
Fine (>40% Clay)	Sandy Clay, Silty Clay, Clay	Forms long, pliable ribbon more than 2" long; sandy clay will feel gritty.

Soil Moisture-Relationships

The relationship between soil moisture, plant nutrient availability and crop growth is important. Some interacting effects are:

- Satisfactory crop growth and yield depends on adequate available soil moisture.
- Moisture influences soil temperature.
- Soil water affects the activity of soil organisms.
- Plant nutrient uptake requires adequate soil moisture.
- Too much water in the soil means insufficient oxygen for proper root development and function.
- Soil moisture levels affect tillage operations.
- Movement of soluble nutrients and pesticides are in soil solution.

To understand these and other relationships we need to answer to such questions as: What is soil moisture in terms of supplying plant needs? How much moisture can soils hold? How much of this is available to plants? How does water move in the soil? The purpose of this discussion is to help answer some of these questions.

<u>Kinds of soil moisture</u>. For purposes of relating soil moisture to crop growth and other relationships, soil scientists have grouped soil water into four classes:

- *Gravitational water*- sometimes called "free water." This is the water in the soil which occupies the larger pores (or holes) and drains away under the influence of gravity. It occupies the space normally occupied by air in a well balanced soil-water-air relationship. If this water drains away too slowly, injury to the plants may result.
- *Capillary water*_ This is the water which is held by surface tension forces as films around the soil particles, in angles between them and in capillary pores. Water moves slowly in the capillary pores from the thicker to the thinner films. A soil holding the maximum amount of water it can retain against the force of gravity is said to be at its *field capacity*. Maximum soil compaction occurs at 80-100% of field capacity. When soil is saturated, pore space is totally filled with water which resists .
- *Hygroscopic water* – This is the water held very tightly in a thin film around the soil particles. It is held so firmly that it can move only in the form of vapor. The moisture remaining in air-dry soil is usually regarded

as hygroscopic water. It is unavailable for plant sue.

- *Water vapor* – This is the water in the form of vapor which occurs in the soil atmosphere. It is not generally important to plant growth and development. However, it may be an important means of desert plants survival. It can also be involved in the recovery of plants overnight after they have wilted under hot, dry conditions.

Some Soil-Water Definitions

A few additional terms have been, or will be, used which, for better understanding of later discussions, should be defined at this time. The definitions given here are not as technical as used by soil scientists but should explain the terms.

- *Field Capacity*: This is the soil moisture content after the gravitational water has drained away and capillary water movement has become very slow. Most soils are at their field capacity within from a few hours to 2 or 3 days after a rain or irrigation.

- .*Wilting Point* . When the water films have been reduced by evaporation or root absorption to the point that plants wilt, the moisture level is said to be at the *permanent wilting percentage*.. Water is still present (10 - 15% of the soil's weight), but plants cannot pull it away from soil particles fast enough to prevent wilting: The moisture content of the soil at the time when the leaves of plants growing in the soil first become permanently wilted.

- *Readily Available Moisture*: The readily available water is usually considered to be included in the range from field capacity down to the wilting point. It is water available for plant use.

- *Capillary Pore Spaces*: The pore spaces between the soil particles small enough to hold water against the force of gravity. This occurs because of the attraction between the water and the surface of the soil particles.

- *Capillary Movement of Water*: The capillary pores in the soil actually connect with each other in such a way that a series of small tube-like connections are formed. The movement of water, horizontally and vertically, through these tubes is called capillary movement. Fine textured soils have many more capillary pores than sandy soils and, thus, a much greater capillary water supply.

- *Infiltration Rate of Water*: This is the term used to describe the movement of water into the soil from the surface. It is a very important factor in determining how much of a given rainfall event goes into the soil and how much will be lost by the runoff. The rate of infiltration decreases rapidly in most soils after only a few minutes exposure to rainfall. Most irrigators notice that I decreases over time within an irrigation as well as from the first irrigation in the spring until the last in the fall. This is caused by the dispersion of large soil aggregates by raindrops and by the packing of small aggregates between the larger ones by the surface flow. The rate at which infiltration decreases on sands, especially under sprinkler irrigation, is a source of much surprise to some irrigators. The best remedy for poor infiltration is the incorporation of organic matter into the surface of the soil.

- *Soil Permeability*: This is the term used to describe the rate at which water moves downward once it gets into the soil. If subsoil textures are too clayey, rate of movement may be so slow that little water can get into the soil during a rain or irrigation.

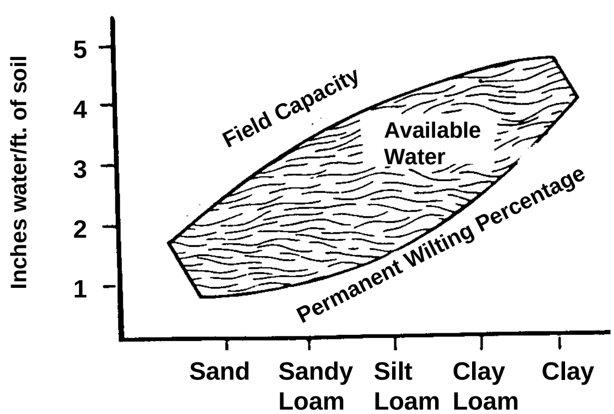
Soil texture affects the ability of soil to hold water against the force of gravity. Water is held in a film around soil particles. The attraction between water and clay-sized particles is so strong that plant roots have difficulty extracting water from the inner portion of the film. However, the outer portion of the water film is readily extracted by plants.

The best soils for storing soil moisture are medium-textured loam soils containing adequate levels of organic matter that allow rapid water penetration yet contain sufficient clay to hold water.

Sandy soils hold less water than clays, but clays may not necessarily provide plants with a better supply of moisture. Soils with a high clay content are easily compacted and water infiltration is slower than on sands. Thus a sand may absorb and hold more moisture from an intense rain than a clay if runoff loss is high. In addition, a higher percentage of the moisture attracted by clay is held too tightly for plants to extract it

Figure 6 illustrates how water-holding capacity is related to soil texture. In a silt loam soil holding 3.5" of water per foot of depth, approximately 2" is available to plants. Sandy-textured soils may contain an inch or less of plant-available moisture per foot. A fine to medium textured soil can hold 8" to 12" of available moisture in the top 5' or nearly half the annual requirement to grow a crop of corn or sorghum.

Figure 6 Water holding capacity as affected by soil texture



Obviously our interest in soil moisture and its movement is practical in nature, such as: How much water will soils hold that plants can use? What influence does depth of root penetration and feeding have on soil moisture available to the crop? How much is the infiltration and permeability rates of my soils? Is the soil moisture capacity of my soil high enough to make summer fallowing profitable? How about the same thing in regards to irrigation? Is there danger of leaching of soluble plant nutrients like nitrates? How much irrigation water can I apply without causing leaching? The following tables of data give at least partial answers to some of these questions.

Crop use of water

Crops are heavy users of water, some being more efficient than others. About 99 percent of the water taken up by plants is lost again through their leaves into the air by "transpiration." On the average, plants take up about 100 tons of water for each 2 tons of dry matter produced, or a ratio of about 50 to 1. For example, a corn plant will take up as much as 50.8 gallons of water, of which 50.0 gallons is lost through transpiration and only 0.8 gallons is retained in the plant (Advances in Agronomy 14, 1962).

In general, fertilizer applied at recommended rates increases the ability of crops to utilize soil moisture. Proper liming and fertilization improves water use efficiency in several ways. Higher yielding crops provide more cover, use sunlight more efficiently and shade the soil surface better to decreased evaporation losses. More vigorous root systems on well-fertilized crops are able to spread through the soil to a greater extent, grow deeper, and utilize more of the available moisture in the soil. By increasing crop produced, yield per acre-inch of water used is increased, even though total water use by the crop may be no greater (Table 5).

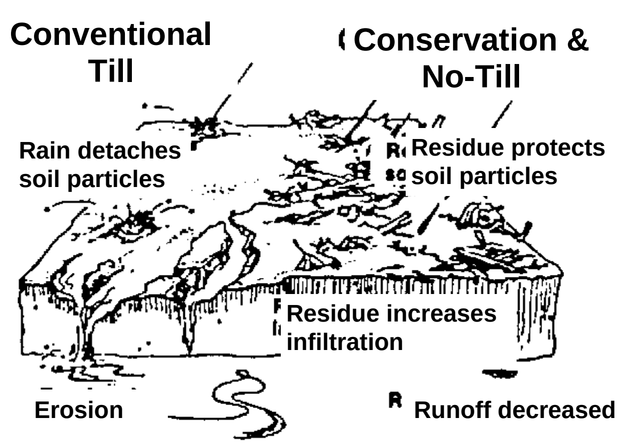


Table 3 Approximate rooting depth and major feeding zone of plant roots

Crop	Rooting Depth	Major Feeding Zone
Wheat	4-6 ft.	80% in top 3 ft.
Corn	4-7.5 ft.	75% in top 2 ft.
Grain Sorghum	4.5-6 ft.	75% in top 3.5 ft.
Alfalfa	20 ft. +	50% in top 3.5 ft.
Bromegrass	5.5-6.5 ft.	75% in top 3.5 ft.

Weaver, Root development of field crops

Table 4 Moisture holding capacity and permeability of several Kansas soils.

Soil Type	Depth Inches	Available Water inches/foot of soil	Permeability Inches/hour
Harney silt loam	0-7	2.2	0.2-0.3.
	7-18	2.2	0.2-0.3.
	18-26	2.2	0.1-0.2
	26-60	2.2	0.2-0.4
Richfield silt loam	0-6	2.2	0.2-0.4
	6-34	2.2	0.2-0.4
	34-60	2.2	0.2-0.4
Pratt loamy fine sand	0-70	1.4	2.0-5.0
Wymore silty clay loam	0-6	2.6	0.2-0.6
	6-26	1.6	0.06-0.2
	26-60	2.3	0.2-0.6
Parsons	0-14	2.4	0.6-2.0
	14-60	2.2	< 0.06

From county Soil Surveys

Table 5   N Fertilizer Effect On Water-use Efficiency

Crop	N Rate	Yield	Water Used	Water Use Efficiency
	Lb N/A	Lb/A	Inches	Lb Yield/inch Water
Bromegrass	0	1,420	28.0	51
	40	2,360	27.4	86
	80	2,840	27.6	103
	160	4,000	27.3	147
Corn Forage	0	6870	15.6	442
	120	10,630	13.8	772

Viets, Plant Food Review, 1964

Movement of moisture in the soil

Dr. Walter H. Gardner, Washington State University, has put together an excellent illustrated discussion on how water moves in the soil under different conditions. It demonstrates the importance of soil and irrigation water management if favorable soil moisture relationships are to be maintained at all times. The following is a reproduction of Dr. Gardner's material:

"Under unsaturated conditions, water moves into soil in all directions in response to attraction of particle surfaces for water and cohesive forces between water molecules which result in water occupying the small pores. Gravity acts on the water to cause slightly greater movement downward, but the absorptive forces of the soil dominate."

"Water introduced from an irrigation furrow moves laterally as well as downward. However, if the wetting front encounters a layer of coarse sand, movement of the wetting-front is stopped temporarily. If the soil above the sand continues to receive water until it becomes nearly saturated, water will move into and through the sand layer. When the sand layer is water filled it transmits water readily. Thus, the sand layer can act much the same as a check valve, stopping flow until the soil above becomes very wet and then allowing water to flow through."

"Sands or gravels underlying finer soil materials behave much the same as does the sand layer discussed above. When the soil above the sand or gravel layer becomes very wet, water can move in."

"Water is able to move into a hard pan or clay pan from a coarser soil material, but the rate of movement through such a layer is slow because of the resistance to flow encountered in extremely fine pores. Thus, even though such layers readily become wet they can seriously check deeper penetration of water. Water tables often build up over such hard pans or clay layers."

"Water does not flow readily from fine soil pores into larger ones unless the soil is very wet. Here, coarse aggregates formed from the same soil create a layer of large pores. Water moves readily into the coarse aggregates but the diminished number of fine pores and contacts between aggregates result in reduced flow rates since water cannot move through large pores until the soil becomes very wet."

"Where large pores connect directly to a source of free water, water flows readily. However,

where the large pores are not in contact with free water they do not fill and contribute nothing to the flow."

"Water moves more readily through sandy soil than through loams and clays. This can be illustrated by applying water to columns made up of different soil textures. However, when the same amount of water is applied to each of the materials it may be seen that the clay soil holds more water than the loam or sandy soil."

"Water applied rapidly to a hilly soil with poor infiltration properties runs off and collects in the low places where it gradually soaks in. Thus, the soil in the hill is not wet deeply. However, when water is applied slowly over a long period of time so that run-off is prevented the soil in the hill is also wet deeply."

"Straw or crop residues, if turned under in layers through plowing, act much like coarse sand layers in impeding the downward penetration of water. However, if straw or organic matter is mixed with the soil they help maintain open and porous conditions which favor the rapid intake of water."

"A vertical channel filled with straw or other organic material and maintained open to free water at the surface will help to transmit water deep into the soil. However, if such a channel is covered with soil it does little or no good in transmitting water."
"Soluble materials such as fertilizers like nitrate-nitrogen move readily with moving water. Where water flow is vertically downward these materials likewise are carried downward. The small amount of spreading that takes place because of diffusion and dispersion can be demonstrated by putting a water soluble dye on the fertilizer before applying it to the soil. Where water is added at a point within the so that water flow is radial, the dye-traces likewise move radially."

"When water is applied to soil in furrows much of the flow is essentially radial as can again be demonstrated with dye-traces. In this case, water and soluble materials move up into the hill between furrows as well a downward. In the region between furrows when the wetted fronts join the rate of water flow decreases and some accumulation of soluble materials can occur as may be observed by the pattern of dye-traces."

Soil Erosion and Runoff

Soil erosion has detrimental effects on soil productivity, surface water quality and profitability and sustainability of farming. Loss of topsoil, the most productive portion of the soil profile, is essentially irreplaceable in the short term. Farmers have reduced cropland erosion significantly by using soil-conserving practices such as crop residue management, contour tillage, strip cropping, and land retirement into programs such as CRP and vegetative buffer strips. The following table illustrate the effect of these practices on soil erosion over a 10 year period (NRCS)

Erosion Type	Soil Loss (billion tons/year)	
	1982	1992
Water	1.7	1.2
Wind	1.4	0.9
Total	3.1	2.1

<u>Water Erosion</u> There are three types of water erosion-- *sheet, rill and gully*. Sheet erosion occurs when soil is eroded as a uniform, thin layer across a slope. As sheet erosion continues, numerous shallow gullies (rills) randomly occur causing rill erosion. With increased rainfall duration and intensity, runoff volumes increase and concentrate in small ravines termed gully erosion. While gully erosion is most noticeable and dramatic, greater topsoil deterioration is caused by less noticeable rill and sheet erosion. The universal soil loss equation (USLE) and a similar version for wind erosion are used to estimate soil loss.

These equations are used to develop management guidelines that will help reduce erosion below a tolerable level (T). Both equations use various soil, site and management characteristics to estimate potential soil loss.

For water erosion, the USLE is specifically designed to measure water-induced rill and sheet erosion.

The equation is :

A = R x K x LS x C x P

Where:

A = Average soil loss from a field (tons/acre).

R = Rainfall/runoff factor. Based on the amount of rainfall and the rate of runoff. Determined by intensity and duration of rainstorms.

K = Soil erodibility factor. Based on the soil type's susceptibility to erosion. K values consider the percentage of silt and very fine sand, the percentage of organic matter, soil structure and permeability. K values are highest for soils high in silt. Lower K values are assigned to sands with low runoff and soils high in clay that resist detachment.

L = Slope length factor. Soil loss per unit generally increases as slope length increases.

S = Slope steepness factor. An increase in slope means significant increases in soil loss. The L and S factors are often grouped into one factor known as the topographic factor (LS) which combines slope length and steepness.

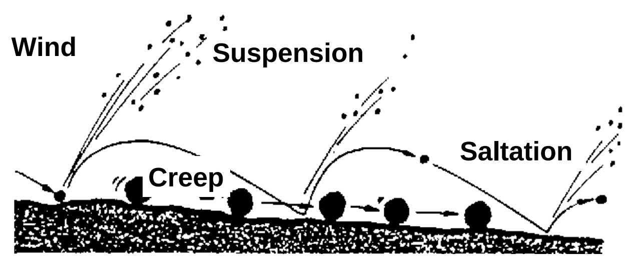
C = Crop cover and management factor. This factor accounts for cropping sequence, time between canopies, presence of crop residue, and surface roughness. This factor differs regionally according to the timing of rains with seasonal harvest.

P = Conservation practice factor. This value is based on the ratio of soil loss on a field with certain tillage practices to soil loss on a field with certain tillage practices to soil loss under straight row plowing up-and-down the slope.

<u>Wind Erosion</u> Wind erosion occurs throughout most of the United States, but is of greatest concern in the Great Plains. Wind erosion causes economic loss through soil removal and crop damage. Seedlings and small plants can be damaged by the abrasive movement of fine soil particles.

Wind erosion can erode soil particles by:

- *saltation* which is the movement of soil particles by a series of short hops which hit and loosens more soil particles
- *soil creep* or the rolling or sliding of smaller soil particles along the soil surface.
- *suspension* of soil particles in the air where they can travel from a few feet to thousands of miles.



The wind erosion soil loss equation is similar to the and uses soil, climate and farm management factors to estimate soil loss.

The equation is: E = IKCLV

Where:

E = Average soil loss due to wind erosion (tons/acre)

I = Inherent erodibility factor of a particular soil. Is based on the percentage of coarse-sized soil particles greater than 0.84 mm in diameter.

K = Ridge roughness factor. Flat unridged surfaces are more susceptible to wind erosion, provided that ridged rows are oriented at right angles to the prevailing wind direction.

C = Climatic factor. It includes average wind velocity, surface soil moisture and temperature measurements.

L = Measure of the unsheltered distance across a field in the direction of prevailing wind. A windbreak protects a soil downwind for a distance at least 10 times its height and 3-5X upwind.

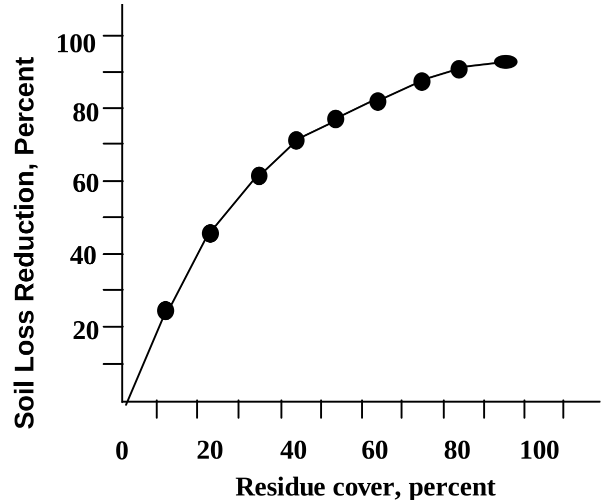
V = Vegetative cover factor. Considers the kind, quantity, and orientation of crop and/or residue cover.

Soil properties, climatic history and other research information are used to determine values for these factors. Factors that are exclusive to a field's size, soil type, and location are used for guidelines of what cropping and tillage practices can be used to keep the estimated soil loss below the "T" value. Furthermore, terraces and windbreaks can reduce a soil loss.

Adoption of high residue farming techniques have been used to control soil erosion. These systems reduce or eliminate tillage and maintains residue cover. This residue decreases the possibility of soil particle detachment and transport by either wind or water. Additionally, crop residues can help maintain organic matter levels and soil structure. These soil properties increase permeability, maintain aggregate stability and consequently reduce potential soil erodibility. Crop residue cover effectively reduces erosion. Residue coverage of 20 to 30% will reduce soil erosion by 50%.

Water and Nutrient Runoff Nutrient runoff into surface waters such as streams, rivers, lakes and eventually into ocean waters is a major concern that affects nutrient management planning. Nitrate nitrogen in drinking water has health concerns. Nitrogen and phosphorus can cause plant and microbes such as algae growth to flourish (eutrophication). If growth is excessive, oxygen levels in water are reduced

Figure 7 Effect of residue cover on water erosion



which can have adverse effects on all aquatic life.

Conservation practices to reduce water runoff from agricultural fields help reduce movement of nutrients into surface water. Vegetative buffer or filter strips around field borders and near water inlets can remove sediment, increase water infiltration and reduce runoff. Filter strips are less effective at reducing nutrient *leaching* into waters.

Soils Summary

The yield potential on any soil depends on a number of factors of which fertility and fertilizer use is only one. All of the above soil properties combine to determine the ultimate suitability of a soil for growing crops. In order to establish a sound, economical fertilizer program, it is necessary to understand the factors that affect production potential. It is not practical to fertilize for a 175-bushel-per-acre corn yield goal on a field where poor drainage limits yield to less than 100 bushels unless tile is installed. It is not economical to fertilize for a 80-bushel-per-acre wheat yield if the subsoil is gravel at 18" and yield potential is but 30 bushels. On the other hand, many soils have the yield potential to utilize higher rates of fertilizer. The discussion of soils and soil productivity in this section is intended to give a better understanding of soil factors affecting efficient fertilizer use.

Using Soil Surveys

Using Soil Surveys

County soil surveys provide information that can be used in developing fertilizer and pest management programs. Information that can be found in most soil survey report includes:

- Soil texture, slope, erosion class, depth, parent material.
- Water holding capacity, permeability, drainage problems, and potential for flooding.
- Subsoil characteristics such as sand lenses, impermeable layers, bed rock or high water tables limiting crop yields.
- Suitability for cropping and estimated yield potential.
- Suitability for woodlands, windbreaks, building sites, septic tanks, landfills, roadfill, ponds, recreational sites.

The scale of most soil survey maps is: 4 inch = 1 mile(each 640 acre section is 4” X 4”).

Approximately how many acres are in the field marked in the SW corner of this section?

Soil mapping units: Expressed on the map as symbols, for example,162D2 is a Downs silt loam with9-11% slope and moderate erosion where:

The *first number* (162) designates the soil type (name & texture of the surface soil), i.e. Downs silt loam.

Some older soil surveys use a letter or symbol rather than numbers.

A soil series is a group of soils with the same name but texture can vary i.e. Downs loam, Downs silt loam, etc.

A *capital letter* following the number indicates the slope class in percent or the change in elevation in feet/100 feet of horizontal distance. If there is no letter the soil is relatively flat, i.e. (0 - 2% slope).
The letter B represents moderate slope and each subsequent letter designates steeper slopes. The slopes given below are approximate and vary by state:

A = 0-2% slope	B = 2-5% slope.
C = 5 -9% slope.	D = 9-14% slope.
E = 14-18% slope.	F = 18-25% slope.

A *final number* indicates the degree of erosion:
2 = moderate erosion
3 = severe erosion.