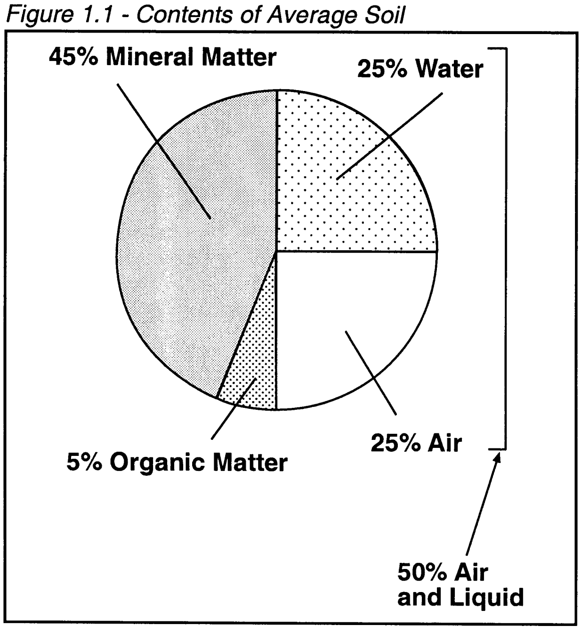
Lesson 1: Soil Composition

Soil scientists define soil as a living, naturally occurring, dynamic system at the interface of air and rock. The soil is considered "living" because it is full of living organisms such as roots, animals, insects, fungi, and bacteria. Equally important is organic matter, the decaying remains of plants and animals. Soil is "dynamic" because it is constantly changing. Natural elements such as temperature and rainfall are continually affecting and changing the soil as do the actions of living organisms and organic matter. These components work together in the soil "system," the thin, outer layer of the earth's surface. Soil forms at this "interface" of air and rock in response to the forces of climate and organisms (chemical changes) acting on the parent material (rock) over a period of time. It can take a thousand years for just 1 inch of soil to form, making it critical that soil is managed properly for the benefit of future generations.

Soil Components

Soil consists of minerals, organic matter, water, and air. The solid materials, mineral and organic matter, comprise about half of average soil (Figure 1.1), in a concentration of 45% mineral matter and 5% organic matter. Water and air complete the other 50% with each contributing approximately 25%, depending on how wet the soil is at the time. When water is added to soil, the air is driven out. As soil dries out, it contains more air.

Figure 1.1 - Contents of Average Soil

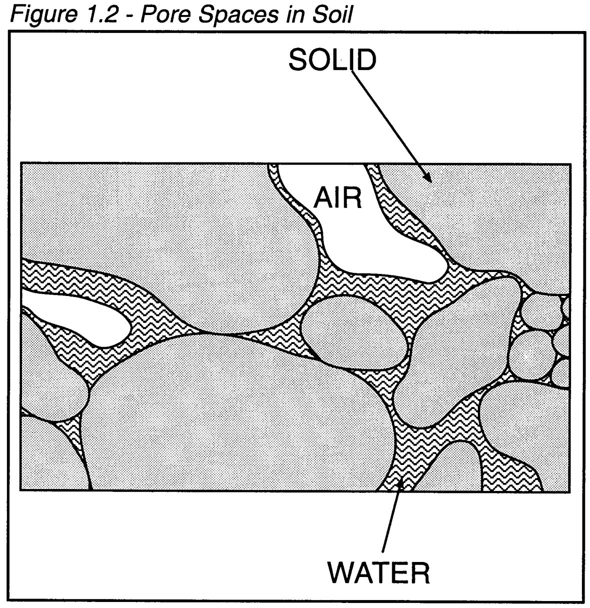


Mineral matter is inorganic material (rock) in soil and consists of three types of particles: sand, silt, and clay. Sand particles are the largest and range in size from .05 mm to 2 mm. Silt particles are smaller and range in size from .002 mm to .05 mm. Clay particles are the smallest and are less than .002 mm in size. The combination and amount of these three mineral particles determine the soil's ability to retain water and nutrients.

Organic matter is dead and decaying plant and animal material. Most soil organic matter found in crop fields is from the leaves, roots, and stems of plants. Biosolids (sewage sludge) can be spread on fields to increase soil organic matter levels. Some crops such as alfalfa are grown as green manure and plowed into the soil to accomplish the same results. All of these sources of organic matter provide essential nutrients for plant growth.

Mineral and organic matter solids fit loosely together forming pore spaces, or openings (Figure 1.2). The size of the pore spaces is determined by the size of the mineral particles in the soil. Sand particles create large pore spaces whereas clay has very small pore spaces. These pore spaces are filled with water and air.

Figure 1.2 - Pore Spaces in Soil



Water alone determines if soil can maintain plant life. The primary function of water in soil is to dissolve soil minerals, moisten plant roots, and provide a solution for plants to absorb essential nutrients. Three types of water are found in soil: gravitational, capillary, and hygroscopic.

Gravitational water percolates, or moves down, through the soil through pore spaces. It ends up as ground water below the soil surface. Capillary water is held by the soil above the water table by adhesion, or capillarity attraction, of soil particles. It is free to move from one soil particle to another. This water is the most readily available for plant use. Hydroscopic water forms a thin film around individual soil particles. It does not move about. This is the water that remains after the gravitational and capillary water have been removed. It exists in the driest soils but is unable to be absorbed by plants.

Air contains carbon dioxide and oxygen critical for plant photosynthesis and respiration. The ability of air to move in and out of soil is important in providing oxygen for healthy root growth. Rain fills the soil's pore spaces with water and air refills the pore space as the water is absorbed or drains away. Air occupies most of the soil's pore spaces in excessively dry, arid regions with sandy soils. The absence of air in water-holding clay soils or flooded fields reduces plant growth. Plants grow best when air and water levels in the soil are balanced.

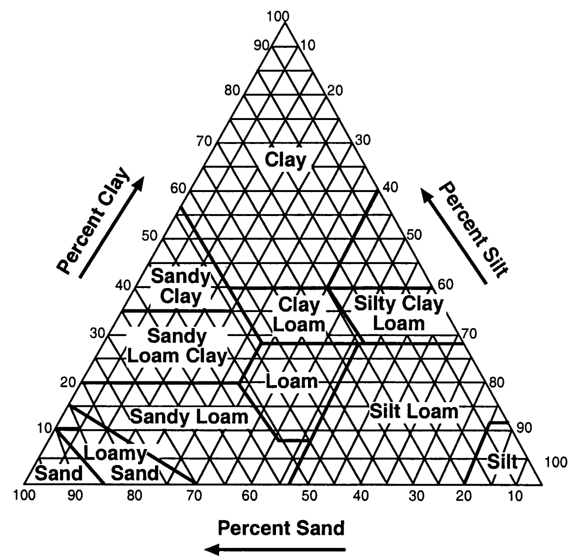
Soil Texture's Effect on Water-holding Capacity and Fertility

The relative proportions of individual mineral particles are referred to as soil texture. Soil texture is grouped in classes determined by the weight percentage of sand, silt, and clay in a soil. The USDA Soil Textural Triangle is used to classify soils. When sand, silt, and clay are in balanced amounts as shown in Figure 1.3, loam soil texture is created. Soil texture can be determined by a laboratory analysis or from a field estimate, which is working a small amount of soil between the fingers and thumb in a ribbonlike fashion.

Soil texture directly affects the amount of water a soil will hold due to differences in the sizes of soil particles. As noted earlier, water enters the soil through pore spaces and is held on the surfaces of soil particles. Fine clay particles have much more surface area per volume of soil than sand, with silt falling somewhere in between. Therefore, small soil particles hold more water than large ones.

Soil fertility (the amount of available nutrients for plant growth) is also affected when one particle is

Figure 1.3 - USDA Soil Textural Triangle



overly abundant in soil. As water percolates down through the soil, it carries with it dissolved nutrients. This nutrient-filled water is held on soil particles by surface tension. The force holding the water is closely related to the total surface area of the soil particles. Because the volume of small particles has more total surface area than the same volume of large particles, small particles exert a greater holding force. The larger pore spaces surrounding large particles quickly become filled with the nutrient-rich water. Due to the lack of surface tension of the large particles, the pore spaces are easily drained by gravity, and nutrients pass through the soil too quickly to be absorbed by plants. Likewise, water-holding, fine soil particles keep nutrients from plants by trapping them in the surrounding smaller pore spaces.

Sandy soils are made up of mostly coarse particles surrounded by large pore spaces. Water moves quickly through sandy soil giving it a low water-holding capacity and leaving it less fertile.

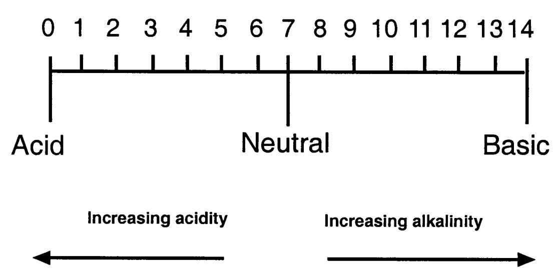
The very small pore spaces surrounding the multiple soil particles result in clay soils having a high water-holding capacity. In addition, when the small pores become filled with water, the lack of aeration limits plant root growth. Clay-type soils tend to swell when wet, reducing pore sizes even more and holding water so tightly that nutrients within the water are not easily available to plants.

Silty soils have a mixture of particle sizes and pore spaces. The qualities of silty soils range from the upper limit of clay to the lower limit of very fine sand. With this variation of particle sizes, silty soils have the best water-holding capabilities. Water drains gradually down through the soil, making silty soils more fertile because plants gradually absorb needed nutrients.

Soil pH and Nutrient Utilization

Soil pH (potential hydrogen) is the measure of acidity or alkalinity of the soil. A scale of 0 to 14 is used to express the concentration of hydrogen (H+) and hydroxide (OH-) ions as shown in Figure 1.4. Neutral pH (or pH 7) occurs when the concentration of H+ and OH- ions is equal. Neutral pH is neither acid nor alkaline. When the concentration of H+ ions increases, the pH is lower (acid, 0 - 9), and when the concentration of OH- ions increases, the pH is higher (alkaline, 7.1 - 14). Missouri soil pH ranges from 4.5 to 8.4.

Figure 1.4 - The pH Scale

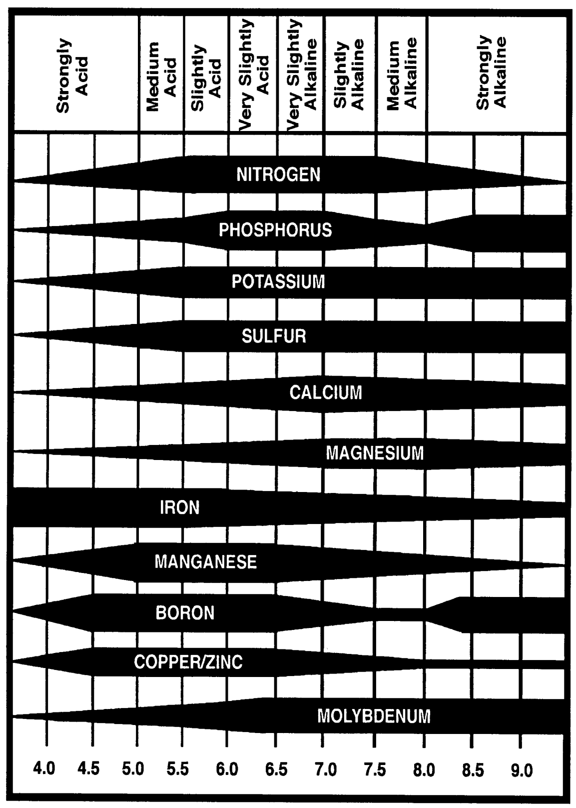


The pH scale. Common soil pH values range from about 3.8 to 8.2.

Plants require large amounts of available nutrients for growth. The ability of a soil to hold and exchange important nutrients to plants is known as the cation exchange capacity (CEC). Cations, or positive-charged ions, are attracted to negative-charged soil particles (especially clay). This is the same principle of attraction seen in magnets; the negative pole is attracted to the positive pole. Cations, such as potassium (K+), calcium (Ca+2), and magnesium (Mg+) can leave soil particles and be replaced by cations held in soil solution (soil water). Nutrients in solution are the most available for plant use. To obtain a soil's CEC, a soil test must be performed. Refer to Chapter 7 of the *Soil Science Student Guide* for detailed information on calculating the CEC.

Soil pH directly affects the CEC of a soil. For example, strong acidic soils high in H+ ions will generally have a low CEC of the positive-charged nutrients potassium, calcium, and magnesium. A crop such as corn that prefers a more basic (alkaline) soil will display nutrient deficiencies because it cannot use the potassium, calcium, and magnesium in the acidic soil. Soil acidity is caused by leaching (the removal of bases by water percolation), or the absorption of base nutrients by growing plants. Growing plants require large amounts of base nutrients; therefore, the depletion of calcium can be one of the greatest causes for increased acidity. The soil is unable to release important nutrients if the soil is too acidic or too alkaline. By knowing the pH of a soil, it can be determined if a neutralizing agent, such as lime, is needed to maintain the correct balance of nutrients for the optimum growth of a particular crop. The soil pH can generally be raised to any desired level by applying lime (calcium carbonate, or $CaCO_3$). Figure 1.5 lists several plant nutrients and how the pH level of the soil determines the availability of those nutrients.

Figure 1.5 - Soil pH Governs Nutrient Release



Soil pH Governs Nutrient Release
Acidity or alkalinity (pH) controls relative to nutrient availability.

Each growing crop has a preferred pH level. Most crops grow and produce the best in soils with a pH range of 5.0 to 7.5. Soils with a pH outside this range may inhibit the absorption of nutrients by growing plants. For example, legumes require more neutral soils (pH 6.8 – 7.3), whereas corn, small grains, and grasses prefer slightly acidic soils (pH 6.0 – 6.8). The pH level needed for individual crops can be determined only by a soil test.

Summary

Soil is composed of 45% mineral matter, 5% organic matter, and 25% each of water and air. Mineral matter consists of sand, silt, and clay particles. Organic matter consists of dead and decaying plant and animal material. Mineral and organic matter fit together, forming pore spaces that hold water and air in soil. The primary function of water in the soil is to dissolve soil minerals, moisten plant roots, and provide a solution for plants to absorb essential nutrients. The ability of air to move in and out of the soil is important in providing oxygen for healthy root growth.

Soil texture is the relative proportions of the individual mineral particles sand, silt, and clay. Soil texture directly affects the soil's water-holding capacity and fertility. Silty soils have a mixture of particle sizes and pore spaces that give them the best water-holding capabilities and fertility levels.

The acidity and alkalinity of soil are determined by the pH (potential hydrogen) of a soil. The pH scale ranges from 0 to 14, with 7 considered neutral, 0 acidic, and 14 alkaline (basic). Plants require large amounts of nutrients made available through cation exchange capacity (CEC). Soil pH directly affects the CEC of a soil. The pH of a soil is important in determining if a neutralizing agent is needed to maintain the correct balance of nutrients for optimum plant growth. Applying lime can raise the pH. Each growing crop has a preferred pH level; most crops grow and produce best in soils with a pH range of 5.0 to 7.5.

Credits

Biondo, Ronald J. and Jasper S. Lee. *Introduction to Plant and Soil Science and Technology.* Danville, IL: Interstate Publishers, Inc., 1997.

Lee, Jasper and Diana L. Turner. *Introduction to World AgriScience and Technology.* Danville, IL: Interstate Publishers, Inc., 1994.

Minor, Paul E. *Soil Science* (Student Guide). Ed. Barbara Rosenfeld. Volume 27. Columbia, MO: Instructional Materials Laboratory, 1995. Chapters 4 and 7.

Sopher, Charles D. and Jack V. Baird. *Soils & Soil Management.* 2nd ed. Reston, VA: Reston Publishing Company, 1982.

Lesson 2: Soil Types and Limitations

Soil morphology is the composition, or makeup, of soil. The composition includes the texture, structure, consistence, color, and other physical, chemical, and biological properties of the soil. Soil surveys and soil survey books give extensive information about the soil morphology in a given location. This information is used by individuals, organizations, and government agencies to determine suitability of land tracts for farming, industry, and recreation. It is important to understand how soil morphology affects crop management decisions for farms, ranches, and woodlands.

Identifying Soil Types

The soil resources of Missouri are classified, mapped, and interpreted through county soil surveys. The published soil survey book contains maps of the locations and extent of important soils in each county. Each soil is described by its chemical and physical properties; classified by a national classification system; and interpreted for agricultural, engineering, recreational, and urban uses.

Soil surveys are made by soil scientists who examine aerial photographs to determine relationships among soil colors, native vegetation, and topography. Over time, soils develop special characteristics that help scientists predict the location of different soils. Scientists also examine soils by walking the landscape to gather additional specific data.

The published soil survey maps contain soil and road boundaries, water features, township sections, and cultural features such as schools and farmsteads. The survey also contains information about each soil, including interpretations helpful for selecting the best use and management practices. State residents may obtain free copies of county soil survey reports from the local soil and water conservation district or Natural Resources Conservation Service offices.

When using a soil survey book to determine soil types for a given location, choose a site to research. Good examples include a specific field, farm, or homestead. Once a site is determined, its location can be found on the Index to Map Sheets, which is in the center of the survey book before the soil survey sheets. This map shows the county townships by section and number. The number of the township corresponds with the soil survey sheets in the back of the book and shows an aerial view of the desired site. Explanations for the symbols listed on the soil survey sheets can be found in the Index to Map Units section in the front of the book or on the back of the Index to Map Sheets.

The General Soil Map is a color-coded map located adjacent to the Index to Map Sheets that shows the soil association groups for the county. Each association group has a distinctive pattern of soils, drainage, and relief (elevations in land surface). A description of these soil groups can be found toward the front of the book in the General Soil Map Units section. This section provides information useful in planning the use and management of large areas. It also explains the soil classification of each soil type within the association group. The Detailed Soil Map Units section provides descriptions of each individual soil type in the county and is also useful in determining the suitability and potential of a soil for specific uses. The Tables section provides additional data regarding specific land uses for each soil type. All of these maps, descriptions, and tables, as well as other general and historical information on the county, are provided to the public to make good land use decisions.

Limiting Factors for Crop Selection and Growth

Soil properties that limit a soil from producing crops are known as limiting factors. Many limitations or hazards exist for individual soil types. These can have devastating effects on crop production.

Seven limitations are identified in Table 2.1 and have been generalized for statewide use to satisfy state soil-judging contest requirements. Slope, erosion, available water capacity (AWC), surface drainage, internal drainage, rock fragment content (gravel, cobbles, channers, or flagstones), and surface stoniness are all hazards or limitations that affect crop selection and growth. These seven are considered the most significant and easiest to evaluate on a small site. Individual soils may have more severe or specific limitations noted in the soil survey book.

Table 2.1 - Guide to Determining Hazards or Limitations for Cropping

Possible Hazard or Limitation	Soil Characteristics That Indicate a Hazard or Liability
Slope	All land slopes longer than 90 feet and/or in excess of 2 percent slope
Erosion	Any eroded area where the upper 6-7 inches is either mixed topsoil and subsoil, mostly subsoil, or has gullies
Available water capacity (AWC)	Less than 10 inches of available water in the upper 60 inches of the profile
Surface drainage	High-water table less than 2 feet and nearly level with depressional spots, and sloping areas below seep spots
Internal drainage	High-water table of less than 3.5 feet
Rock fragments (volume upper 10 inches)	Greater than 15%
Stoniness (surface)	Large rocks less than 100 feet apart

Slope is the incline of the land. Percentage of slope is the vertical distance divided by horizontal distance, then multiplied by 100. Slopes less than 3% are considered an asset; those over 3% are considered a liability. Slope characteristics are the gradient, the length, the shape, and the aspect. Slope gradient is the steepness of the land surface. Operation of farm equipment and irrigation becomes more difficult on steeper slopes. The slope length will affect erosion. A long slope allows runoff water to gather more volume as it flows over the surface and increases erosion. The shape of the slope will also affect erosion. The shape is classified as linear, concave, or convex. Slope aspect refers to the effects of temperature and sun exposure on the soil and is dependent on compass direction.

Erosion is the wearing away of the land surface by water, wind, ice, or other geological agents. There are three main types of water erosion: sheet, rill, and gully. Sheet erosion is the detachment of soil particles by flowing water and is usually caused when rain hits wet soil. After soil particles are detached, they can be floated into rills and gullies and transported into low places or off the field. Rills are small steep-sided channels where runoff water concentrates. Gullies are miniature valleys where water usually runs only after rainfall and unlike rills are obstacles to farm machinery. *(For a more extensive explanation of soil erosion, see Lesson 6 of this unit.)*

Available water capacity (AWC) is the soil's capacity to hold water. It is commonly expressed as inches of water per inch of soil. Soils with low or very low available water are considered a liability.

Surface drainage is the runoff, or surface flow of water, from an area. Surface drainage is needed on all poorly drained soils regardless of their classification, soils that are nearly level in slope with depressional areas, or soils on sloping areas below seepy areas.

Internal drainage (depth to high-water table) is the rate at which internal free water leaves the soil to allow aeration. Gravitational water must move out of the profile quickly so the roots can obtain adequate aeration. Internal drainage is classified on seven levels: excessive, somewhat excessive, well, moderately well, somewhat poorly, poorly, or very poorly. Rock fragments are rock or mineral fragments with a diameter of 2 mm or more such as gravel, cobbles, or boulders. Rock fragments affect the amount of irrigation water the soil can absorb.

Stoniness refers to soil in which rock fragments 10 to 24 inches (25 – 60 cm) in diameter are exposed at the surface. Stoniness is evaluated according to the percentage of the soil surface covered by detached stones. Stony soil interferes or even inhibits tillage. Five general classes are as follows: not stony, stony, very stony, extremely stony, and rubbly. *(Refer to IML's* Soil Science Guide*, Chapter 11, for a review of these classes.)*

Summary

Soil surveys are developed by soil scientists who examine aerial photographs to determine relationships among soil colors, native vegetation, and topography. They also examine the soils by walking the landscape to gather additional specific information. This information is then compiled into soil survey books available to the general public. Guide pages assist the reader in understanding the information in the soil survey books.

The information found in soil survey books describes capabilities, limitations, and hazards that exist in the soil in a specific location. The most significant factors for cropping are land slope, erosion, available water capacity, surface drainage, internal drainage, content of rock fragments, and surface stoniness.

Credits

Biondo, Ronald J. and Jasper S. Lee. *Introduction to Plant and Soil Science and Technology*. Danville, IL: Interstate Publishers, Inc., 1997.

Minor, Paul. *Soil Science* (Student Guide). Ed. Barbara Rosenfeld. Volume 27. Columbia, MO: Instructional Materials Laboratory, 1995. Chapters 11 and 12.

Soil, Plant, and Crop Science (Teacher Edition). Oklahoma Department of Vocational and Technical Education. Stillwater, OK: Curriculum and Instructional Materials Center, 1996.

Lesson 3: Soil Testing

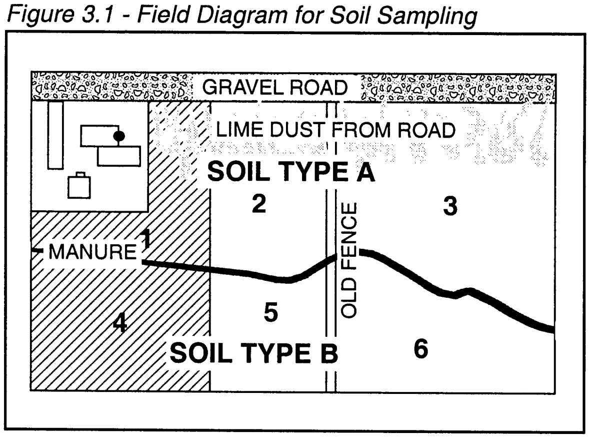
Soil fertility levels vary in fields due to size, soil type, crop management, fertilizer, or limestone history. Likewise, soil properties can vary over short distances, resulting in differences in plant growth, crop yield, and quality. Therefore, it is important to obtain a soil sample representative of the field, garden, or lawn to be planted in order to appropriately apply fertilizer.

Obtaining a Soil Sample

Traditional methods of obtaining a soil sample recommend testing an area of 20 acres or less. Research shows areas larger than 20 acres do not provide enough uniformity and the data collected is too burdensome to make good farming practice recommendations. Variation is naturally caused by climate, topography, parent materials, vegetation, time, and human influences. To account for variability, soil samples should be taken from different soil types within the test area. As stated in Lesson 2 of this unit, soil types for a given location can be found in the county soil survey book. Testing should be done on areas where different crops have been grown, various soil surface textures are present, and on wet or eroded production areas. Avoid taking soil samples from areas not representative of the entire field such as driveways, dead furrows, road edges, old barn lots, and severely wet or eroded areas where production is not feasible.

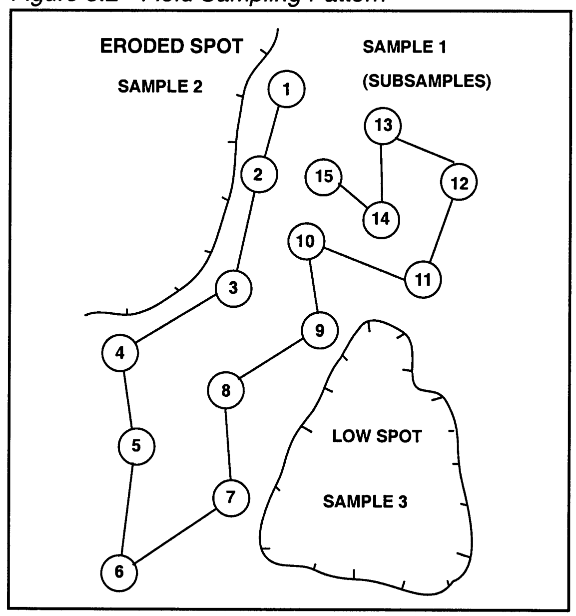
Figure 3.1 illustrates a field diagram for traditional soil sampling. The field was originally two 20-acre tracts with a fence and tree row between each tract. In this example, separate samples should be taken for changes in soil type, crop history, and manure applications to provide an accurate soil fertility map of the field.

Figure 3.1 - Field Diagram for Soil Sampling



University Extension personnel recommend taking an average of 15 to 20 samples from each soil type or special area. This will reduce variation and allow for the correct amount of fertilizer to be applied based on the average fertility of the field. Figure 3.2 shows a random, zigzag sampling pattern used to obtain a representative soil sample. These subsamples are mixed together thoroughly and a composite sample (about 1 pint) is taken from the mixture and sent for analysis along with soil from sample areas 2 and 3 as shown in Figure 3.2.

Figure 3.2 - Field Sampling Pattern



All soil tests should include the top 7 inches of topsoil obtained through the use of an auger, probe, or spade. Samples from all the areas of the field should be mixed thoroughly, air-dried, placed in a small bag or box, labeled, and taken to a testing facility. University Extension personnel recommend taking soil samples annually and preferably in the fall or spring under moist soil conditions. It is best to sample when the acreage is lying fallow.

Many of the same criteria are used for taking soil samples for use with Global Positioning Systems (GPS) except for a few points. GPS uses satellite technology capable of locating the exact location in a field from which field data was gathered. Mapping software will divide the field into sectors, or grids. Refer to Figure 3.3. A typical sector is 2 1/2 acres. One sample, which consists of 8 to 10 core samples 5 to 10 feet apart, should be taken every 2 1/2 acres. The exact location is tracked to

Figure 3.3 - Sampling Soil for Satellite Technology

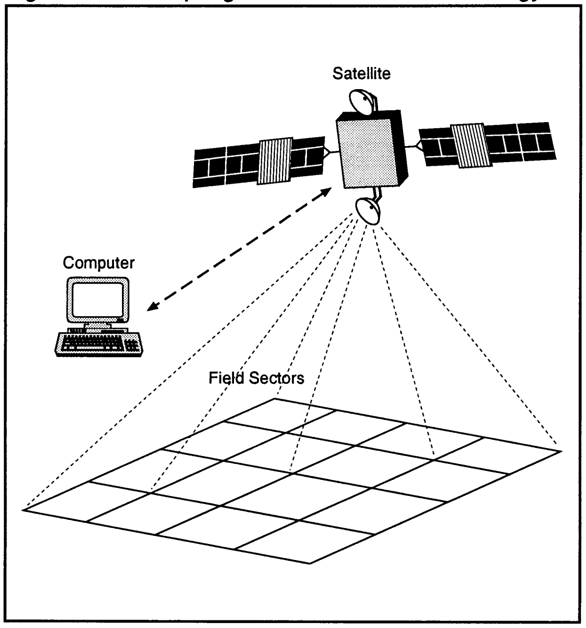
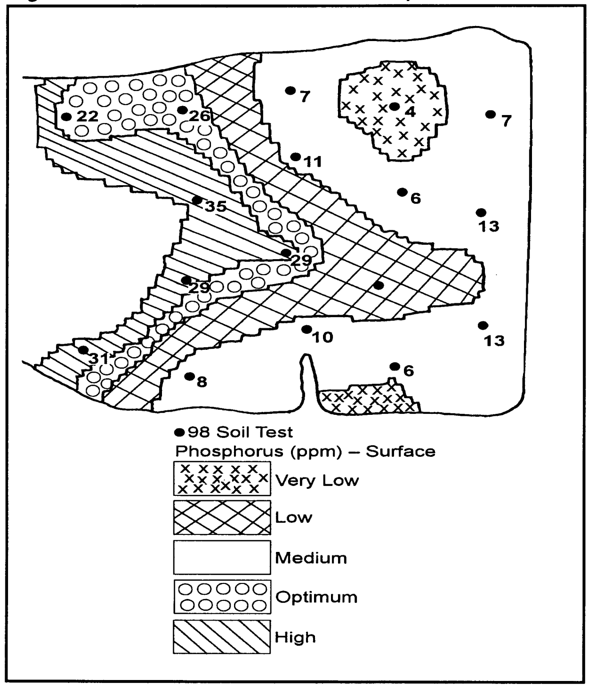


Figure 3.4 - Results of GPS Soil Sample



correspond with the location on the mapping software. The software will develop an application map for the entire field.

If a producer were to take the same 20-acre plot from a traditional soil sample and compare it with a 20-acre plot using GPS, the results could vary tremendously. Figure 3.4 shows the results of a soil test for phosphorus using the sampling technique for GPS. Note the detailed variances from very low to high in this 20-acre plot. A traditional soil sample, which takes samples throughout the plot and then mixes them together, would show the same phosphorus recommendation throughout the 20-acre plot.

Testing Soil Samples

Soil samples can be tested at University Extension Centers, fertilizer dealers, or private testing laboratories. A small fee is charged for the analyses. The majority of all soil testing is conducted by University Extension Centers or local, independent laboratories because of the necessary working knowledge of local soil types. It is better to have soil tested at an independent laboratory than by a fertilizer dealer to ensure objectivity and accuracy. Wherever a soil test is evaluated, the producer needs to feel confident that the results are reliable. Added production costs, possible crop losses, and even environmental damage from over- or underfertilization based on a bad soil test report can be devastating. Recommendations should always be made by a trained official to guarantee the reliability of the soil test.

Soil samples are tested for acidity, phosphorus, potassium, calcium, magnesium, and organic matter. The results will provide recommendations for the amount of limestone, nitrogen, phosphate, and potassium to be added to the soil. Tests are also available for sulfur, zinc, iron, manganese, copper, and salt content.

When testing for acidity levels, laboratories will use either a salt pH measurement or a water pH measurement. The University of Missouri Soil Testing Service uses a salt pH measurement. Most of the time, the water pH reading is about 0.5 unit higher than the salt pH reading. For example, if water pH is about 6.0, salt pH might be 5.5.

Key Parts of a Soil Test Report

A soil test report will include six parts: field information (field name, sample number, acres, last crop), soil test information, rating, nutrient requirements (cropping options, yield goal, pounds per acre), limestone suggestions, and special notes. This information is needed to make good management and fertilizer recommendations to

Figure 3.5 - Soil Test Report for a Soybean Field

OUTREACH & EXTENSION
UNIVERSITY OF MISSOURI
LINCOLN UNIVERSITY

Soil Test Report

Soil Testing Laboratory
23 Mumford Hall, MU
Columbia, MO 65211
Phone: (573) 882-0623

or

Soil Testing Laboratory
P.O. Box 160
Portageville, MO 63873
Phone (573) 379-5431

FIELD INFORMATION		
Field ID A1 SOIL	Sample no. 1	
Acres 22	Last Limed UNKNOWN	Irrigated NO
Last crop 115 SOYBEANS		

Serial no. P9039	Lab no. 18793
Area 15	County 010 Region 3
Submitted 11/18/98	Processed 11/24/98

Soil sample submitted by:

This report is for:

JOHN DOE
RURAL ROUTE 1, BOX 1
CENTERTOWN, MO

SOIL TEST INFORMATION				RATING (Very Low / Low / Medium / High / Very High / Excess)
pHs	(salt pH)	6.3		*************************
Phosphorus	(P)	86	lbs/a	**********************************
Potassium	(K)	428	lbs/a	******************************
Calcium	(Ca)	5071	lbs/a	****************************
Magnesium	(Mg)	568	lbs/a	*************************
Sulfur	(SO_4-S)	6.0	ppm	********************
Zinc	(Zn)	1.3	ppm	*************************
Manganese	(Mn)		ppm	
Iron	(Fe)		ppm	
Copper	(Cu)		ppm	

Organic Matter	2.9 %	Neutralizable acidity	1.0 meq/100g	Cation Exch. Capacity	16.6 meq/100g
pH in water		Electrical Conductivity	mmho/cm	Sodium (Na)	lbs/a
Nitrate (NO_3-N) Topsoil	ppm	Subsoil	ppm	Sampling Depth Top	Inches Subsoil Inches

NUTRIENT REQUIREMENTS

Cropping options	Yield goal	N (Pounds per acre)	P_2O_5	K_2O	Zn	S
103 CORN (GRAIN)	140 BU/A	155	0	20	0	0
115 SOYBEANS	40 BU/A	0	0	20	0	0
119 WHEAT	60 BU/A	95	0	20	0	0
103 CORN (GRAIN)	140 BU/A	155	0	20	0	0

LIMESTONE SUGGESTIONS	
Effective neutralizing material (ENM)	0
Effective magnesium (EMg)	0

Your sample has an estimated pH in water of 6.8.
The cation exchange capacity of this soil would suggest very low potential for sulfur response. Monitor the crop by plant analyses for potential need for sulfur.
Nitrogen requirements may be reduced by 30 pounds per acre for the first crop following soybeans. Not applicable for wheat.
Soils testing high in P or K should be retested annually to determine when maintenance fertilizer should be applied.

correct or maintain the desired balance of nutrients for the intended crop. Additional information regarding a specific test for other nutrients may be included if requested. Soil test report formats may vary due to differences in laboratories and their testing procedures. Figure 3.3 is an example of a soil test report on a soybean field from the University of Missouri Outreach and Extension Service.

Interpreting Soil Test Results

In order to interpret an individual soil test, all six components of a soil test must be evaluated. The Field Information section allows the producer to know exactly which field was tested. General information should include a field name, sample number, size, and previous crop planted.

Table 3.1- Determining Fertilizer Needs from Nutrient Ratings (MU G09112)

Rating						Probability of response to fertilizer
Very low	Low	Medium	High	Very high	Excess	
****						very high
***********						high
*********************						medium
********************************						low
***						none
**						none

The Soil Test Information section is the primary component of the soil test and provides the results of the sample analyzed. The salt pH indicates the level of active soil acidity. Missouri soils maintained at a salt pH between 5.5 and 7.0 provide a favorable environment for helpful microorganisms and root development. Phosphorus results are expressed in pounds of elemental P per acre. It is a measure of the relative availability of phosphorus for plant growth, not the total amount of phosphorus in the soil. Potassium results are expressed as pounds of exchangeable K per acre and estimates the potassium available to the growing crop. The calcium measurement is used to calculate cation exchange capacity (CEC) and is not based on the actual soil test calcium level. Calcium seldom limits crop growth in Missouri soils. Magnesium application based on a medium rating is not likely to increase yields in row crops and small grains but may improve forage quality. When sulfur is needed, 10 to 20 pounds per acre is suggested for row crops, small grains, and alfalfa. Most other forages in Missouri do not require sulfur. Zinc application is likely to increase corn and grain sorghum yields in Missouri; however, zinc is recommended for small grains and alfalfa only when the soil test is less than 0.5 ppm. Field research has not shown a need for applications of iron, manganese, or copper in Missouri. Organic matter estimates the potential nitrogen release to a crop throughout the growing season and determines proper herbicide application. The cation exchange capacity is a calculation of the exchangeable calcium, magnesium, potassium, and hydrogen measured by the soil test.

The Rating section of a report interprets the information provided in the Soil Test Information section. Each rating indicates the probability of a yield increase from fertilizer application for each nutrient tested. Table 3.1 shows how the probability of yield increases from fertilizer drops as the soil test ratings rise. For example, a Very Low or Low test indicates that crops would likely respond to the addition of the appropriate fertilizer. However, there are no economic advantages to applying fertilizer to soils testing Very High.

The Nutrient Requirements section of a soil test contains three parts: cropping options, yield goal, and pounds per acre. Cropping Options are the crops the producer is considering planting in the sampled location. If a producer is unsure, different crop option scenarios are available from University Extension personnel. The Yield Goal is the number of bushels per acre the producer needs to harvest from the field in order to be profitable. This goal should be based on soil type, field history, fertility level, irrigated versus nonirrigated land, and economic considerations. Pounds per Acre lists the fertilizer recommendation for the crops and yield goals intended. Recommendations are given for nitrogen (N), phosphate (P_2O_5), potassium (K_2O), zinc (Zn), and sulfur (S) for the number of pounds of each to be applied per acre on the field. Following these suggestions, a producer can attempt to meet yield goals as well as improve the soil's fertility over time.

The Limestone Suggestions section is used to indicate the amount of limestone needed to raise the pH level to the desired level for the intended crops listed under cropping options. This recommendation is always for the crop requiring the highest pH range and is reported as pounds of effective neutralizing material (ENM) per acre. The amount of lime needed is calculated by dividing the ENM by the amount of ENM per ton of fertilizer guaranteed by an agricultural lime supplier. For example, if a soil test ENM fertilizer recommendation was 1,450 pounds per acre and the dealer guarantees 400 pounds ENM per ton, then the amount of lime needed per acre equals 3.63 pounds (1,450 lb./acre ÷ 400 lb.ENM/ton = 3.63 lb.).

ENM Suggestion	÷	EMN Guaranteed	=	Lb. of Lime Needed per Acre

1,450 lb./acre ÷ 400 lb. ENM/ton = 3.63 lb.

Special Notes are sometimes posted at the bottom of the soil test report to aid in interpreting results and to list additional recommendations.

Summary

Soil samples should be taken in an area of 20 acres or less to increase the chances for an accurate soil fertility rating. Variations are caused by climate, topography, parent materials, vegetation, time, and human influences. Separate samples should be taken from each soil type or special area in order to obtain the average fertility of the soil. It is recommended that yearly soil samples be taken under moist soil conditions.
University Extension Centers and private soil testing laboratories will test soil samples, and a trained official will provide recommendations. Adding the wrong amount of fertilizer as a result of an inaccurate soil test can add to production costs and cause crop losses.

A soil test report includes information about the field tested. The soil test information section provides results on salt pH levels, phosphorus, potassium, calcium, magnesium, sulfur, zinc, organic matter, neutralizable acidity, and cation exchange capacity. The rating section of the soil test report indicates the probability of a yield increase from fertilizer application for each nutrient tested. The nutrient requirements include cropping options the producer can choose from, along with the yield goal and recommended pounds per acre of fertilizer for the intended crops. The Limestone Suggestions section indicates the amount of limestone needed to raise the pH to the desired level. Interpretations and recommendations are sometimes posted in the Special Notes section.

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Lesson 4: Fertilizing Soils

Nutrients are removed from the soil through cultivation, topsoil erosion, and harvesting crops. The continuous use of soil without replenishing the essential nutrients will lead to lower crop productivity. Fertilizers applied to the soil will increase fertility and provide a means of maintaining high fertility levels. With improvements in technology, fertilizer manufacturers have developed concentrated high analysis fertilizers that provide more nutrients per ton of fertilizer. Producers, in turn, see higher crop yields and profit.

Fertilizer Types

All fertilizers can be categorized as three basic types: mineral, organic, or chemical (inorganic). These fertilizers are applied to soils to supply the required level of essential nutrients needed for optimum plant growth, yield, and nutritional quality. The following paragraphs list the advantages and disadvantages of using each type.

Mineral fertilizers are rocks containing nutrients that are ground up and applied to soil. Rocks contain mineral nutrients that are vital to healthy soil. However, most minerals dissolve slowly in soil and their usefulness as a fertilizer is limited. They are typically applied after harvest with fall tillage operations, making them available for spring-planted crops. Mineral fertilizers can also be added with spring or double-crop tillage operations, to build up nutrients for future crops. Minerals are seldom found in a pure state. The two most common minerals found in Missouri are limestone and phosphate rock.

Limestone is an example of a multi-element mineral fertilizer. It is mainly used to neutralize soil acidity but is also a good source of calcium, magnesium, and sulfur. Ground limestone, or calcium carbonate (CaO_3), is the most commonly used type of liming material. Other limestone materials used to correct magnesium and sulfur deficiencies are magnesium carbonate ($MgCO_3$) and magnesium sulfate ($MgSO_4$).

The most common form of phosphorus in nature is phosphate rock (PO_4). Rock phosphate is the basic material used in nearly all phosphorus fertilizer. Phosphate rock does not dissolve easily in liquids; therefore, it is processed into more soluble fertilizer sources. Finely ground phosphate rock can be applied to soil but is used only on soils with a definite phosphorus shortage. It should be used only on acidic soils (pH below 6.0) and it should be applied at rates three to five times greater than those of other more soluble phosphate fertilizers.

Organic fertilizers are plant or animal tissues that have become waste materials. Plant residue; animal manure; bone, cottonseed, and soybean meal; and biosolids (sewage sludge) can all be recycled and used as fertilizers. Table 4.1 gives the nutrient content found in these organic fertilizers except plant residue. As plant residue is worked into the soil, it breaks down slowly and returns nutrients to the soil, thus reducing the need to add nutrients as determined by soil tests.

Table 4.1 - Nutrient Content of Some Organic Fertilizers

Percent of Nutrient Content Per Pound of Organic Fertilizers			
Organic Material	**% of N**	**% of P**	**% of K**
Cattle Manure	0.5	0.25	0.5
Sheep Manure	1.4	0.5	1.25
Swine Manure	0.5	0.25	0.5
Poultry Manure	1.5	1.0	0.5
Horse Manure	0.7	0.25	0.7
Bone Meal	4.0	23.0	0.0
Cottonseed Meal	6.0	2.5	1.5
Soybean Meal	7.0	1.2	1.5
Biosolids (sewage sludge)	3.0	2.5	0.4

The nutrients from organic fertilizers are obtained slowly by plants as the material decays. These slow-releasing nutrients are less likely to cause root damage because salts do not build up in the surrounding soil. In addition, organic wastes are long lasting and a great source of the live bacteria needed to convert natural soil minerals and chemical fertilizers into useable forms for plants. Organic fertilizers do have disadvantages; they are low in the major nutrients, the material is bulky, and the exact amount of fertilizer applied is sometimes difficult to measure. However, organic fertilizers are considered more natural than chemical fertilizers and continue to be used by producers as they have been for thousands of years.

Since chemical (inorganic) fertilizers were first widely used in the middle 1900s, crop yields have greatly improved. Some chemical fertilizers may be mined but many are manufactured from a nonliving source. The most common chemical fertilizers are formulations of nitrogen (N), phosphorus (P), and potassium (K).

Nitrogen fertilizers applied to soils include anhydrous ammonia, urea, ammonium nitrate, ammonium sulfate, and sodium nitrate. Phosphorus is applied as ammonium phosphate, superphosphate, or in fertilizer mixes containing finely ground phosphate rock. The most common fertilizer element, potassium, is applied as potassium chloride (sometimes known as potash).

Chemical fertilizers generally have a higher proportion of useable nutrients than mineral or organic fertilizers. (See Table 4.2.) These nutrients are more soluble and therefore immediately available for plant use following application. They are easier to measure, making application of the exact amount of a specific nutrient possible. Chemical fertilizers, however, are more costly and errors in application can damage crops and the environment.

Forms of Fertilizers

Mineral and chemical fertilizers can generally be purchased in four forms: (1) fluid fertilizers, (2) pressurized liquids, (3) dry fertilizers, and (4) slow-release fertilizers. The form of fertilizer a producer uses will be dictated mostly by what form is available, cost, available application equipment, individual producer practices, and current weather conditions.

Fluid fertilizers There are two main categories: (1) true liquids and (2) suspension fertilizers. The nutrients in true liquids are completely dissolved and can be sprayed or dribbled directly on soil or plant surfaces, injected into the soil, or mixed with irrigation water. Suspension fertilizers are mixtures of liquids and finely divided solids in which the solids do not settle rapidly and can be redispersed easily by agitating to give a uniform mixture. Suspension fertilizers are applied to the soil surface. Most nitrogen fertilizers are prepared in fluid form. Powdered forms of phosphorus and potassium fertilizer compounds are also soluble enough to be mixed with water and used as fluid fertilizer. Potash is typically applied as a suspension fertilizer. It is becoming common practice to apply herbicides along with the liquid fertilizer to reduce trips across the field.

Table 4.2 - Nutrient Content of Some Chemical Fertilizers

Percent of Nutrient Content per Pound of Chemical Fertilizers			
Inorganic Material	**Nitrogen**	**Phosphorus**	**Potassium**
Nitrogen Sources			
Anhydrous Ammonia	82	0	0
Urea	45	0	0
Ammonium Nitrate	33.5	0	0
Ammonium Sulfate	21	0	0
Sodium Nitrate	16	0	0
Phosphorus Sources			
Ammonium Phosphate	11	48	0
Diammonium Phosphate	34	0	0
Superphosphate	0	20	0.2
Potassium Sources			
Potassium Chloride	0	0	60
Potassium Sulfate	0	0	50
Potassium Nitrate	13	0	44

Pressurized liquids are applied by injection directly into the soil from tanks. Pressure in the tank forces the liquid through chisels that are pulled underground. When the liquid reaches the soil it adheres to the soil moisture. Anhydrous ammonia, the most common nitrogen fertilizer, is sold as a pressurized liquid. Biosolids from lagoons and treatment plants are generally applied using pressurized spray or gravity-fed equipment designed for such purposes.

Dry fertilizers are applied mechanically and absorbed into the soil through rainfall. They generally are the most economical and are available as powders, granules, or prills. Prills are formed by hot liquid fertilizer flowing through a cooling tower where they are formed into a round pellet and coated with a conditioning clay. The clay slows moisture absorption from the air and reduces caking (forming into hardened clumps). Ammonium nitrate is supplied as dry prills. Nitrogen is considered to be the most common fertilizer used in granular form. Dry fertilizers can also be mixed with liquid and applied as a fluid fertilizer.

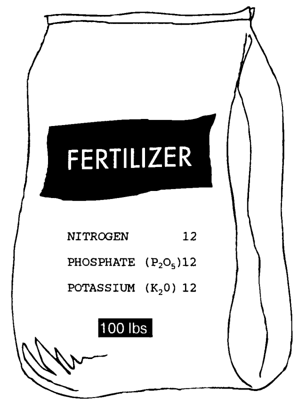
Slow-release fertilizers contain nutrients that dissolve into the soil solution slowly. They are available in dry or liquid form. The time period for this form of fertilizer to become available for plant use generally ranges from several weeks to a few months. Slow-release fertilizers are most commonly used in horticulture or vegetable production.

Obtaining Fertilizers

Chemical fertilizers used on cropland are typically obtained in large, bulk quantities from agriculture supply centers or dealers. The fertilizer mixture required is determined from the results of a soil test performed on the cropland. To help explain the breakdown of the primary macronutrients used in large quantities, it will help to determine how the chemicals in a 100-pound bag are broken down.

The three primary macronutrients, nitrogen (N), phosphorus (P), and potassium (K) are seldom found in sufficient levels for crop production and must be supplied by fertilizers or manure. Complete commercial fertilizer mixtures must contain all three nutrients. The proportions of nitrogen, phosphorus, and potassium are known as the fertilizer grade and are expressed on a bag of fertilizer as the percentages of the contents of the bag by weight. Therefore, a 100-pound bag of fertilizer (Figure 4.1) with a grade of 12-12-12 contains 12% nitrogen, 12% phosphorus, and 12% potassium. The nutrients are always listed in the same order (N, P, and K) and the listed percentage is guaranteed by the manufacturer.

Figure 4.1 - Contents of a Bag of Commercial Fertilizer



Actual Plant Nutrient Percentages for 12•12•12 Fertilizer

Nitrogen	12 lbs.
Phosphorus	5.76 lbs.
Potassium	7.2 lbs.
Inert Materials	75.04 lbs .

Multiplying the total amount of fertilizer (100 pounds) by the percentage of each ingredient will provide the total pounds of each active ingredient. Therefore, 100 (total pounds of fertilizer) x 0.12 (percent of nitrogen) = 12 pounds of nitrogen. The amount of phosphorus and potassium is also 12 pounds each. The phosphorus (P) in a bag of fertilizer is actually an oxidized phosphate (P_2O_5). One of the most widely used phosphates is diammonium phosphate, which contains only 48% phosphorus. Likewise, a common source of potassium is potassium chloride (KCl), which contains only 60% potassium. (Note: Many commercial fertilizers use the old term for potassium (K_2O) to list the potassium content even though there is actually no K_2O compound in the fertilizer.)

To determine the actual amount of phosphorus and potassium applied from a bag of fertilizer, multiply the percentage of each by 0.48 and 0.60, respectively. The actual phosphorus contained in the 100-pound bag in Figure 4.1 is 12 x 0.48, or 5.76 pounds and the actual potassium is 12 x 0.60, or 7.2 pounds. If a producer were to use this bag of 12-12-12 fertilizer on an acre field, he or she would be applying 12 pounds of nitrogen, 5.76 pounds phosphorus, and 7.2 pounds of potassium per acre. The remaining materials in the bag of fertilizer (75.04 pounds) are other elements that act as carriers of the nutrients. Fillers and conditioners also make up a small percentage of the contents.

Most forms of fertilizers can be purchased from a local agriculture supply center. The mixing and spraying of fertilizers are highly technical skills needing correct calculations. Supply centers have trained personnel who can prepare the fertilizer mix according to the results on the soil test. Some supply centers may have personnel who can apply fertilizers to producers' fields. Many materials are hazardous and require specialized equipment, clothing, and gear to maintain individual and environmental safety. Producers may find added benefits in time, safety, and liability by paying for application services. If a producer chooses to transport and apply chemical fertilizers, then a license to do so must be obtained and records must be maintained as determined by state law.

An alternative source of mineral fertilizer, such as limestone, can be purchased from a local quarry. However, the producer would generally need to have the equipment to apply this type of fertilizer because most quarries do not offer this service.

Organic fertilizers can be found in producers' barnyards, livestock waste pits or lagoons, or at a local sewage treatment facility. If the producer is not a livestock producer, neighboring producers may have ample supplies. Again, special equipment such as manure spreaders, pumps, and hoses are needed to perform applications of dry or liquid organic fertilizers. Like chemical fertilizers, wastewater from pits, lagoons, and treatment facilities is considered hazardous material. Producers must secure licensing to transport it and must comply with any state regulations required to apply organic fertilizers.

Application Techniques

Fertilizers can be applied to soils in a number of ways. Most often they are applied using spray equipment attached to a tractor, tillage implement, or airplane. Fertilizers should be applied so that growing plants can use the nutrients efficiently, there is little or no injury to the plants, and the process is done quickly and economically. The methods for fertilizer application include broadcasting (spreading), soil injection or knifing, banding, starter, side- or top-dressing, foliar, and fertigation.

The broadcasting method is done by spreading dry fertilizer evenly over the surface of the soil prior to planting using mechanical equipment or aircraft. Broadcasted fertilizer, especially lime, is used on fallow fields before planting and may be disked or mixed into the soil to increase the nutrient breakdown process. Spreading solid animal waste on crop fields before tillage is considered broadcasting, but when it is spread over pastures or hay fields it is referred to as top-dressing.

Soil injection or knifing is another method of fertilizer application used before or during planting. Anhydrous ammonia must be injected directly into the soil because ammonia evaporates quickly. Other liquid fertilizers have been injected with success, but due to the specialized equipment required many producers still use other methods. Injection is developing into a preferred option to apply liquid manure because it reduces odor and maintains air quality, a growing issue with large-scale livestock production.

Banding places dry fertilizers directly into the soil about 2 inches to each side of and below the seed. This method is used extensively for row crops during planting. The placement of the fertilizer is far enough away to avoid damaging the seed but close enough that the young roots can find the band of fertilizer. Starter applications apply fertilizer in a band 1 or 2 inches from one or both sides of the seed and below only at planting time. This method of application is commonly used on corn and cotton to stimulate early growth. Starter fertilizers normally contain only the necessary amounts of nitrogen, phosphorus, and potassium to aid plant growth. They are applied as either dry or liquid materials.

Side-dressing is performed by placing fertilizer in bands about 6 to 8 inches from the row of growing plants. This method is very common in row crops such as corn, cotton, and vegetables when additional nitrogen is needed. Dry or liquid fertilizer is placed directly into the soil on one or both sides of the plants. Sometimes the crop is cultivated to mix the fertilizer into the soil. In other situations, the fertilizer is placed on top and carried into the soil by rain or irrigation water. Side-dressing fertilizers in sandy soils may be used to minimize leaching during both planting and cultivation operations. Caution must be used to avoid damaging plant roots, stems, and leaves when side-dressing.

Top-dressing is a surface application method where dry or fluid fertilizer is broadcast lightly over close-growing plants. It is the most common method for applying nitrogen fertilizer to wheat, small grains, hay fields, pastures, and lawns. Rainfall dissolves dry fertilizer and soaks it into the soil. Nitrogen is often top-dressed due to its ability to penetrate the soil easier than other nutrients.

The foliar method is the application of liquid fertilizer directly on the foliage or leaves of plants. Soluble nutrients are broadcast on growing plants for rapid utilization. This method has been used to correct iron and manganese micronutrient deficiencies in certain field crops. Foliar applications have caused severe burning of leaves if sprayed too heavily. This method is not recommended to supply the nitrogen, phosphorus, and potassium needs of plants.

Fertigation is the application of fertilizer in irrigation systems. Liquid fertilizers are normally used, although dry fertilizers may be dissolved and dispersed by the system. Various metering devices are available to distribute the desired quantity of fertilizer into the irrigation water. The type of irrigation system (open ditch, grated pipe, or sprinkler) will dictate the type of fertilizer used.

Time of Application

The time of fertilizer application depends on the soil temperature, air temperature, moisture, crop to be grown, and nutrient applied. Nutrients, particularly nitrogen, are very susceptible to losses that render them unavailable for plants if not applied under appropriate conditions. Missouri's four seasons provide opportunities to apply fertilizer at the most beneficial times.

Soil temperature affects the rate (speed) of chemical activity generally by the indirect effect on microorganism activity in the soil. Microorganism activity, in turn, is responsible for organic matter breakdown, nitrification, and denitrification. Nitrification begins slowly, just above freezing, and continues to increase as soil temperature increases up to about 85°F. Rates decrease at temperatures above 85°F.

The amount of moisture between time of fertilizer application and plant utilization will affect the efficiency of the applied material. Nitrifying bacteria remain active in very dry conditions but are inactive in waterlogged soils. Soils with sufficient moisture to grow crops will have the optimum moisture level for normal nitrification. Saturated soils do not contain enough oxygen for nitrifying bacteria. If water stands on the soil for only 2 or 3 days during the growing season, much of the nitrate nitrogen can be lost by denitrification. Phosphorus is more available to plants when soil moisture is at high levels. Excess moisture prohibits oxygen, limits root growth, and reduces phosphorus uptake.

The type of crop to be grown may determine a specific time for fertilizer application. A single application of primary nutrients is usually satisfactory for most fast-growing annual crops, such as corn, grain sorghum, and soybeans. However, split applications of nitrogen, one in the spring and one in the fall, may be desirable for perennials, cool-season grasses such as fescue and bromegrasses, and warm-season grasses such as Bermuda grass.

The plant nutrient applied, as well as its source, may also influence the application time. Mobile nutrients, such as nitrates and sulfates, are more susceptible to leaching losses than phosphates or potassium. Nitrogen applied in the ammonia form must be nitrified before leaching or denitrification can occur. Nitrogen efficiency is improved when applied near the time plants are growing rapidly. Limestone may be spread at any time of the year when the soil is firm enough to support the spreading equipment and when crops do not interfere.

Producers need to consider the soil temperature, moisture, crop, and nutrients when choosing the most favorable season for application of fertilizer. Fall application of nitrogen is susceptible to leaching loss under conditions of adequate rainfall. However, the texture of the soil, average fall and winter temperatures, and the nitrogen carrier all influence possible leaching losses. Application of any nitrogen materials in the fall to sandy soils is normally discouraged. Coarse-textured soils allow more rapid percolation of water than do clay soils. Anhydrous ammonia is an excellent material recommended for use in fall applications in most locations in Missouri. When applied to soils of medium to heavy texture, the nitrogen remains in the ammonium form and resists leaching until converted to the nitrate form. If applied after the soil temperature is below 50°F at a depth of 4 inches, the conversion to nitrate is relatively slow and of little consequence. Fall application of phosphorus and potassium is relatively safe in most areas. These elements are rather immobile and the chances of leaching losses are quite small. Soil texture and fall or winter precipitation will have little influence on the losses of these nutrients.

Winter application of fertilizer is normally slow during this period. Plow-down applications and anhydrous ammonia application can continue until the ground freezes. In some areas, these methods of application continue throughout the winter.

Spring application is the most popular period for applying fertilizers. Broadcast applications for plow-down or disk-in on row crops, preplant applications of anhydrous ammonia for row crops, and starter applications for spring small grains or row crops are commonly applied at this time of the year. Many producers find it more desirable to apply fertilizer prior to this period so that they can concentrate on seedbed preparation and crop planting.

Summer applications of fertilizer are mainly confined to providing supplemental amounts of plant nutrients not applied previously. Side-dressing with nitrogen during irrigation applications is normally used.

Calculating Application Rates

Most fertilizer application rates (also called spread rates) are calculated in pounds per acre, except for lime. The spread rate for dry chemical fertilizer is determined by dividing the total pounds of fertilizer materials to be applied by the total acres to be fertilized. When fertilizer is purchased from and applied by a local agricultural supply center or dealer, the spread rate is listed on the bill of sale. If producers are applying their own fertilizer, the spread rate is necessary to calibrate application equipment. The application rate of liquid organic fertilizers is regulated by state and federal laws and the producer must be familiar with the regulations before application.

Lime is the only fertilizer that requires measuring based on a rating system. The rating system measures the ability to reduce soil acidity and is referred to as ENM (effective neutralizing material). The ENM of agricultural limestone is determined by the purity of the material used and its fineness. A producer can call an agricultural lime dealer at a quarry to find out the local ENM per ton of agricultural lime.

Lime is always applied in pounds of ENM per acre. Soil test results make liming recommendations in pounds of ENM per acre. To determine the amount of lime needed in tons per acre, divide the ENM value from the soil test by the ENM of the limestone. For example, if a soil test ENM fertilizer recommendation was 1,450 pounds per acre and the dealer guarantees 400 pounds ENM per ton, then the amount of lime needed per acre equals 3.63 pounds as shown below.

1,450 lb./acre ÷ 400 lb. ENM/ton = 3.63 lb.

A pound of ENM is a pound of ENM, regardless of the source of liming material. For example, say the soil test recommends 1,200 ENM. A limestone dealer says he has 400 ENM lime. Dividing 400 into 1,200 will equal 3 tons of that limestone per acre needed to satisfy the lime requirement. If another limestone dealer had 600 ENM lime, only 2 tons per acre of that lime will be needed to satisfy the field requirements. Producers should use the least expensive source per pound of ENM for their management systems.

Summary

Mineral fertilizers, organic fertilizers, and chemical (inorganic) fertilizers can be applied to soils to supply the nutrient elements needed for maximum plant growth. The two most common mineral fertilizers are limestone and phosphate rock. Organic fertilizers are plant and animal tissues that have become waste materials. The most common chemical fertilizers are nitrogen (N), phosphorus (P), and potassium (K). Chemical fertilizers have more useable nutrients than the other types but are more costly and can damage the crop if not applied correctly.

Fertilizers are available as fluids, pressurized liquids, dry, and slow release, which is available in either dry or liquid form. When choosing the form to use, the producer must consider the form available, cost, available application equipment, current weather conditions, and preferred practice of the individual producer.

The primary source for purchase of fertilizers is the agricultural supply center. They have trained personnel who can mix and apply the fertilizers. Commercial fertilizer mixtures contain proportions of nitrogen, phosphorus, and potassium as indicated by a soil test. Mineral fertilizers may be obtained from quarries. Barnyards, livestock waste pits and lagoons, and sewage treatment facilities can also provide organic fertilizers.

The primary factors affecting the time of fertilizer application are the soil temperature, moisture, crop to be grown, and nutrients applied. The soil temperature and moisture levels need to be at an appropriate level for the fertilizer to be efficient. The crop grown may require a single application or split applications during the fall and spring. The nutrient may be susceptible to leaching and denitrification if soil conditions are not appropriate. The spring season is the most popular time for fertilizer application. In most parts of Missouri, the fall season is a good time to apply anhydrous ammonia, phosphorus, and potassium.

Application rates for dry chemical fertilizer are determined by dividing the total pounds of fertilizer material to be applied by the total acres to be fertilized. Application rates for lime require measuring on a rating system referred to as the effective neutralizing material (ENM). The ENM of lime measures its fineness and purity. Lime is applied in pounds of ENM per acre. Divide the ENM per acre suggested on the soil test by the guaranteed ENM per pound to determine the pounds of lime needed per acre.

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Lesson 5: Soil Management Practices

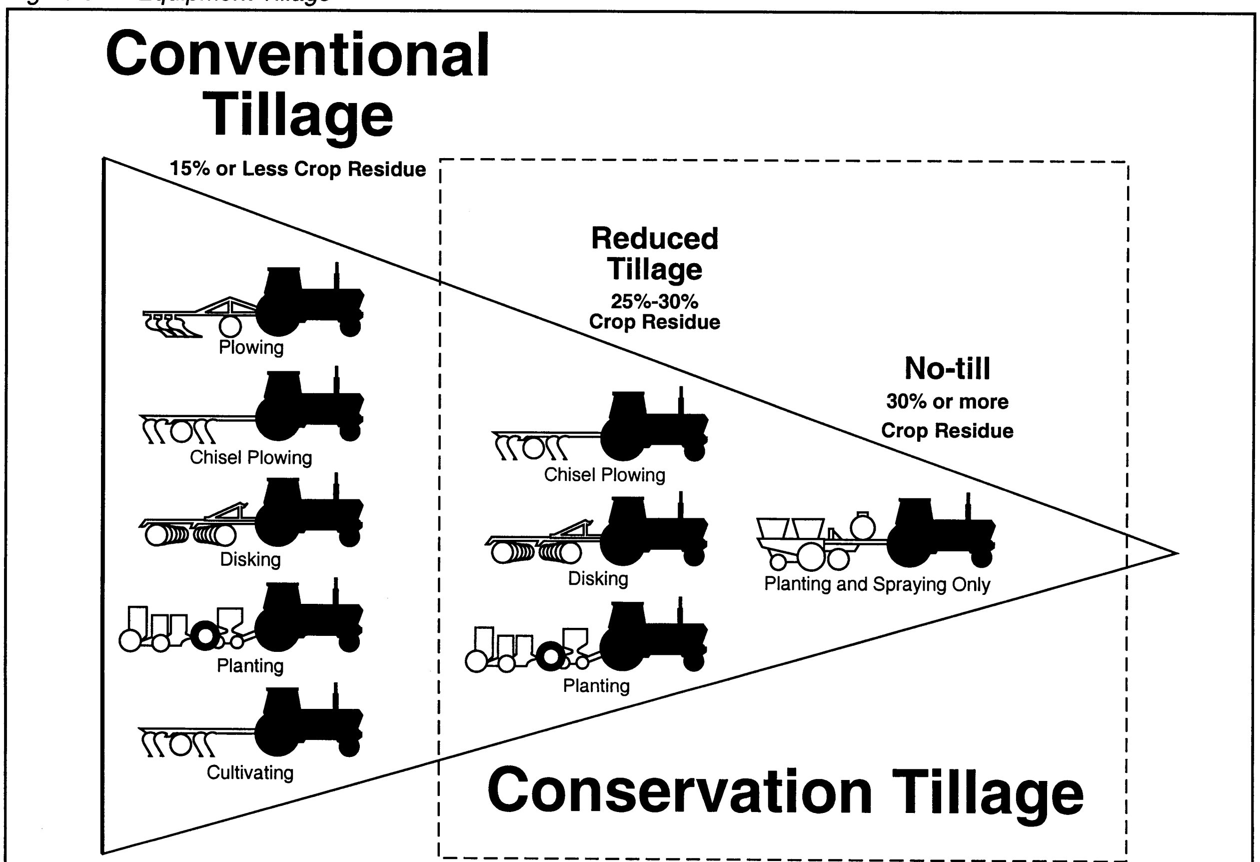
Soil is a precious natural resource. With increased farm production, the earth's soil supply is being slowly depleted. Alternative soil management practices have been tested and implemented to reduce the problem. However, to ensure the productivity and profitability of cropland, producers must continually seek ways to control soil erosion and maintain soil fertility. A key aspect of this is knowing the advantages and disadvantages of different tillage and planting methods and understanding how each of these affects the soil. With this knowledge, producers can select soil management practices that enhance and protect the soil.

Tillage Methods

Tillage, the act of moving soil particles or cultivating the land, is important in the establishment of a good crop stand. Tillage is used to prepare a suitable seedbed, eliminate weed competition, and improve the physical condition of the soil. Crop residue left on the surface of the soil acts as a protective blanket that improves surface water quality, increases the diversity of plant and animal life in a field, and reduce soil erosion. Thus, tillage practices are defined or distinguished by the level of crop residue left on the soil surface. Practices are classified as either conventional or conservation tillage. As shown in Figure 5.1, conventional tillage maintains crop residue levels of less than 15% on the surface due to the number of mechanical operations needed to plant the crop. Conservation tillage maintains crop residue levels of at least 30% because fewer operations are used to plant the crop. However, conservation tillage may be broken down into another component referred to as reduced or minimum tillage. This type of tillage will generally have a residue level between 15 and 30%.

Conventional tillage is the practice of tilling the soil using a moldboard plow, disk, or chisel plow to

Figure 5.1 - Equipment Tillage



Adapted from *Fundamentals of No-Till Farming,* American Association for Vocational Instructional Materials, Athens, Georgia.

prepare the seedbed. The method completely inverts the soil leaving the surface soil clean and smooth and promoting organic matter oxidation, the mixing of oxygen with soil to speed up the breakdown process. Conventional tillage was once the primary tillage practice in the United States, and many producers located in areas of minimal soil erosion continue to use this method.

There are several advantages to this system: (1) the machinery is familiar and widely available, (2) it is adaptable to a wide range of soil and crop conditions, (3) it allows for weed control by cultivation throughout the growing season, and (4) soil warms faster when soil residues are incorporated. Disadvantages of conventional tillage are (1) increased fuel and labor costs, (2) high erosion risks, (3) reduced organic matter, and (4) occurrence of soil compaction due to increased field traffic.

Conservation tillage is any tillage and/or planting practice designed to reduce soil erosion caused by wind or water. By minimizing soil disturbance and maintaining crop residue levels, conservation tillage increases soil organic matter and greatly reduces soil erosion. Conservation tillage acres are generally concentrated in the Midwest and Northern Plains where years of intensive farming have depleted soil resources.

Numerous conservation tillage methods provide various advantages and disadvantages; however, all forms provide a number of advantages over conventional tillage methods. Conservation tillage (1) reduces soil erosion 50 to 90% depending on the tillage practice, (2) increases water infiltration and conserves soil moisture, (3) reduces sediment runoff from reaching streams and lakes, and (4) reduces production costs with fewer trips across the field and less equipment maintenance. The disadvantages are (1) more cost is incurred with increased dependence on herbicides and specialized equipment, (2) current equipment may need modification, (3) amount and types of fertilizers and chemicals applied require specific timing and sequencing of field operations, and (4) planting time is generally delayed due to moist conditions and a cool soil temperature from the added crop residue. The most common methods of conservation tillage used in Missouri are no-till, mulch-till, and ridge-till.

The no-till method is the least disruptive form of conservation tillage. This method leaves the soil undisturbed before and after planting except for a narrow seedbed that is prepared by using a planter or drill that disturbs no more than 10% of the surface. By leaving the soil surface covered with crop residue from the previous year, soil losses from water and wind erosion are reduced, soil moisture is conserved, equipment and fuel expenses are reduced, and planting time is shortened. The no-till system requires skillful management and may cause soil compaction in the upper soil zone. A producer may encounter a greater variety of insect, disease, and weed problems because control depends upon the effectiveness and timing of limited chemical applications. Planting may be delayed because of lower spring soil temperatures and greater moisture under heavy residue. Strip-till is a specialized form of no-till that is increasing in popularity in northern Missouri. This method uses a narrow 2-inch strip cultivated in a row by a rototiller, an in-row chisel, or other row cleaner. The crop seed is planted during this tillage operation.

The mulch-till method disturbs the entire surface of the soil using tillage tools such as the chisel plow, field cultivator, or disk. The primary goal is to increase crop residue and protect soils from excessive erosion with decreased tillage and other soil-disturbing activities. More than 30% of the soil surface is covered with crop residue. Weeds are controlled by herbicides or cultivation. Mulch-till maintains sufficient crop residue to reduce surface erosion while incorporating a percentage of the crop residue into the soil. The practice applies to many types of soil, presents an easy transition from conventional tillage, and increases soil roughness and filtration. Mulch-till also allows for surface-applied fertilizer and pesticides. Some disadvantages are similar to conventional tillage: increased fuel and labor costs and more field traffic causing soil compaction. Also, some residue is buried, limiting erosion-reducing potential.

The ridge-till method has soil pushed into ridges between rows. Ridges are preserved and rebuilt during cultivation and planting that is done on the same ridge year after year. (Conventional tillage is used the first year to build the ridges.) The ridge-till method is useful on flat ground to aid in water drainage. The seedbed is prepared with sweeps, disks, or other row cleaners. Weeds are controlled by both cultivation and herbicide usage. A significant reduction in erosion is possible by ridge-till because soil sediment and crop residue are channeled into the furrow, reducing planting interference and allowing ridges to warm up and drain faster. The added residue also helps support tractors in wet spots while still providing an ideal seedbed on the ridge. General conservation benefits include reduced evaporation and increased moisture, reduced weed pressure and soil compaction, and food and shelter for wildlife. Disadvantages include the need for special planters and attachments; wheel adjustments on applicators, tractors, and combines; and equipment turning on end rows.

An additional tillage practice referred to as subsoiling is used throughout the state except for the northeast and southwest sections. Subsoiling involves breaking up the compacted subsoil layer to help root growth extend into more fertile soil. The process requires heavy-duty equipment, additional fuel, and time but has proven beneficial when growing root crops such as potatoes. Subsoiling can be used in a no-till system because it does not disturb the topsoil. It is typically used during spring tillage but can also be used after harvest.

The tillage practice that a farmer chooses will depend on costs, location, soil type, crop, and other site-specific factors. Tillage costs money not only for equipment, but in fuel, labor, and maintenance of equipment. Reducing the number of tillage operations and tillage depth can minimize these costs. Producers needing technical assistance to select the best tillage method can contact several sources including the Natural Resources Conservation Service (NRCS), University Cooperative Extension and Outreach, The Conservation Technology Information Center, or their local soil conservation district office. Some local district offices may even have equipment available for rent.

Planting Methods

After choosing a tillage practice, the seedbed should be prepared and the field readied for planting. The planting method must then be selected to cut a seed slot at the proper depth, deposit the seed at the desired spacing, and cover the seed for germination. There are several planting methods available, but the most commonly used by producers in Missouri are row, drill, broadcast, and aerial.

With row planting, seeds are evenly spaced in parallel rows. Crops such as corn, grain sorghum, soybeans, cotton, and vegetables are planted in rows to allow for tilling of weeds and reduced herbicide costs. Rows can range from ultranarrow to wide depending on the equipment available, crop needs, and size of the seed. Seed germination rates are highest when planting in rows because the seedbed is ideal and the seed is placed in direct contact with the soil. A disadvantage to row planting is increased days until the leaves develop and provide a canopy to protect moisture levels in the soil. Also, plant population counts are limited due to spacing requirements between plants and rows.

Drilling places seeds in narrow rows at high population rates and gives a better plant distribution. Under conventional tillage methods, intensive tillage and seedbed preparation is necessary. Specialized no-till equipment can be used without tillage. Small cereal grain crops such as wheat, oats, and alfalfa are most often planted with this method. Soybeans, grain sorghum, and rice can also use the drill method. When using the drill method, attachments can be used to place fertilizer at the same time, saving time and trips across the field. Planting seeds by the drill method makes mechanical cultivation impossible and therefore increases the dependence on herbicides. A major advantage to drilling crops in ultranarrow rows is that the crop canopy (upper extended leaf-covered stems) grows together faster and limits sunlight to weeds growing below. This benefit is significant enough to reduce herbicide use. Also, most growers feel that narrower rows reduce the weed pressure and save moisture.

Broadcast planting involves scattering seeds in a random pattern across the top of the soil. This method is usually the cheapest, provides for faster canopy, helps in preventing erosion, and controls weeds. Seeds may be broadcast with a variety of equipment including pulled and hand-held seeders. Crops generally broadcast-seeded are grasses and legumes used to improve hay and pasture crops, and some small grains. Light tillage is often used to cover seeds with a thin layer of soil on conventionally tilled fields but is seldom used with conservation tillage. Poor germination may occur due to inferior seed to soil contact as well as limited crop selection due to seed size. This will result in uneven plant distribution.

Aerial planting involves randomly scattering seeds across the top of the soil by an airplane or helicopter. It is merely a specialized broadcasting method. This method is used when the soil is too wet to till or plant by traditional methods, when the area is too rough, or where obstacles exist that hinder the use of surface equipment. It is commonly used to plant rice in flooded fields.

Effects of Tillage and Planting Methods on Soil Structure

The structure of the soil can be greatly improved or destroyed depending on the tillage and planting method selected by a producer. The soil's physical condition is affected by many factors including crop residue, soil compaction, and moisture levels. Each of these factors directly impacts the others.

Crop residue has good and bad effects on soil structure. Although it reduces erosion, residue insulates the soil, which makes it cooler and wetter. It also shifts the physical properties of the soil to a more natural state, leaving it with higher concentrations of nutrients, pesticides, and organic matter. These can in turn lower soil pH, adjust population levels of beneficial and harmful insects, and increase the roughness of the soil surface.

Soil compaction from farm equipment traffic results in soil with smaller pores and fewer channels, which reduces water infiltration. This causes greater surface wetness, more runoff, and a longer drying time. Figure 5.2 shows how soil moisture affects compaction depth. A given load and tire size cause much deeper compaction on wet soil than dry. In the past, sod-forming crops such as alfalfa and clover were usually included in crop rotations and provided greater support at the soil surface than bare soil. The trend toward continuous row cropping has eliminated sod-forming crops and therefore encouraged current soil compaction problems.

Compaction is directly affected by field machine weight, tire size, and tire inflation pressure. Machines weighing up to 30 tons not only cause compaction near the surface but also at depths unreachable by tillage. All tillage and planting systems, except aerial, require some field traffic. Choosing a tire pressure that will cause the least damage and trying to reduce field traffic are key to controlling soil compaction. Testing equipment, as shown in Figure 5.3, is available to determine how severe and how deep the compaction layer is.

Figure 5.2 - Effects of Soil Compaction

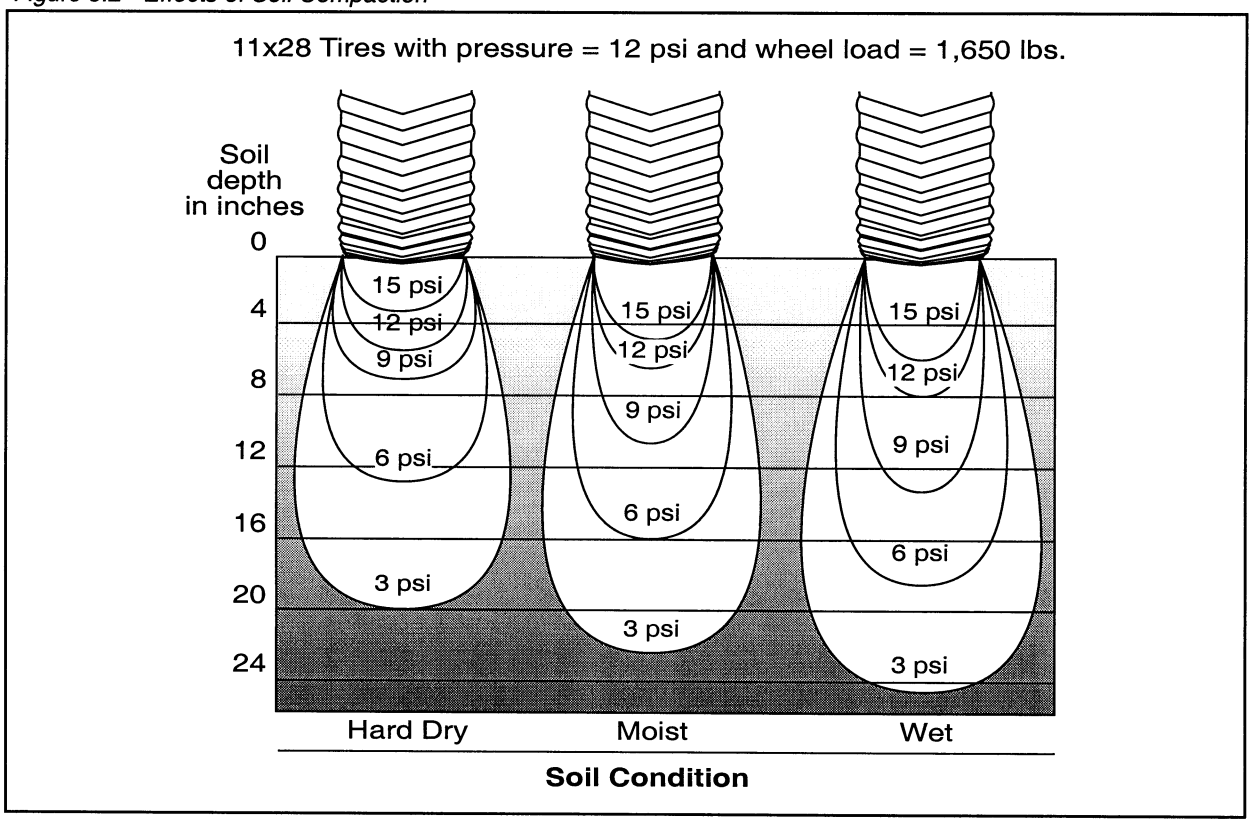
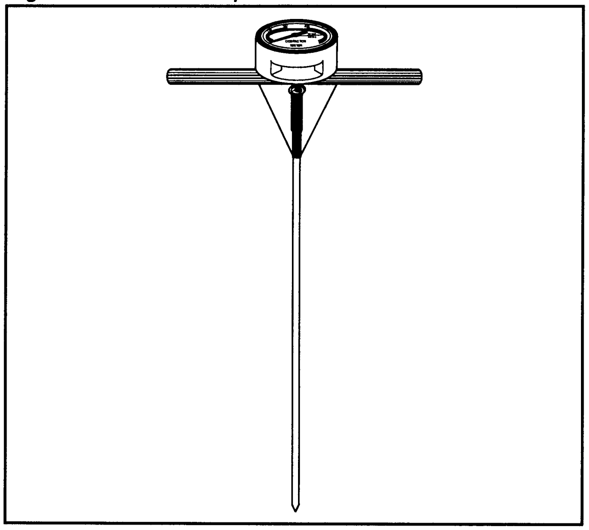


Figure 5.3 - Soil Compaction Tester



Additionally, tilling and harvesting should be avoided when the soil is wet. Soil moisture levels are affected by the amount of crop residue, the degree and depth of soil compaction, and the drying that occurs from turning over soil during tillage. Soil temperatures increase 10^0F to 15^0F in the spring during mid-afternoon at a depth of 1 inch, increasing evaporation and further reducing soil moisture levels.

Crop Rotation

Crop rotation is growing different crops in recurring succession on the same land. Crop rotations may be multiple crops in one year (six radish crops in one growing season) to multiple crops over many years (12 crops in a sequence of 18 years). Crop rotations in Missouri may commonly include corn, soybeans, wheat, oats, grain sorghum, meadow, alfalfa or other legumes, vegetables, cotton, or rice in the Bootheel region.

By rotating crops, producers can limit competition from weeds for soil nutrients. Fields planted to the same crop every year may experience severe infestations of specific weeds. This often leads to increased usage of herbicides. Crop rotations through normal tillage requirements will keep weed infestations in control and increase nutrient use for the crop.

The organic matter of the soil is greatly improved when implementing crop rotations, especially when grasses or legumes are included in the rotation. Legumes have been used in crop rotation practices for many years. Legumes have nodules located on the roots that aid in gathering nitrogen from the air and converting it into a useable form. This natural process reduces the need for commercial fertilizers by providing nitrogen for the next crop. A common example of this type of rotation is using a legume crop of soybeans followed by corn.

Soil nutrients are utilized more effectively with crop rotations. Crops differ in the amount and proportion of nutrients they require and use. One crop may require very few nutrients, while another requires several, neither dependent on the same nutrients. Carefully selecting complementary crops in a rotation leads to better use of soil nutrients.

Fertilizer utilization is also improved through crop rotation. A variety of fertilizers may be used including lime, commercial fertilizers, or biosolids, which allow a producer more options in selecting the best fertilizer for a specific crop. How and when fertilizer is applied, along with the tillage method, determine how much, if any, is available for the next crop. Crop rotation can utilize any carryover fertilizer (fertilizer that remains in the soil after a crop has been harvested) that reduces production costs and waste.

Erosion may be minimized in crop rotation practices by seeding grasses and legumes to protect erodible soils from wind and water. Conservation practices included for specific crops in a rotation will also maintain crop residues and limit erosion.

Summary

Using appropriate soil management methods is vital to crop production, profitability, and erosion prevention. The selected methods must provide a suitable seedbed as well as control crop pests. While accomplishing this, the physical condition of the soil must be maintained to ensure continued fertility and avoid additional soil depletion.

Tillage methods are classified as conventional or conservation tillage and are differentiated by how much crop residue is left on the soil. The conventional tillage method leaves less than 15% crop residue, whereas conservation tillage methods maintain at least 30% crop residue. Reduced or minimum tillage is a component of conservation tillage that leaves between 15 to 30% crop residue. The methods of conservation tillage used in Missouri are no-till, mulch-till, and ridge-till. There are advantages and disadvantages to all tillage methods with selection based on costs, location, soil type, crop, and other site-specific factors.

Planting methods commonly used by Missouri farmers are row, drill, broadcasting, and aerial. Row planting places the seeds in evenly spaced parallel rows. Seed germination rates are high, but population counts are reduced due to spacing requirements. Drilling places seeds in narrow rows at high population rates. Because cultivation is not an option, herbicides are used to control weeds. The broadcasting and aerial methods provide faster coverage and reduced erosion; however, poor germination may occur due to inferior seed to soil contact.

Crop residue, soil compaction, and soil moisture are the primary factors altered by tillage and planting effects on soil structure. Crop residue has good and bad effects on soil structure such as reduced erosion but makes soil cooler and wetter. Soil compaction is more common due to the trend toward continuous row cropping. Compaction is directly affected by field machine weight, tire size, and tire inflation pressure. Soil moisture levels are affected by crop residue, soil compaction, and drying from tillage.

Crop rotation helps maintain the fertility of the soil and productivity of a crop. Crop rotation aids in limiting competition from weeds for nutrients. Organic matter resulting from crop rotation reduces the need for commercial fertilizers by providing nitrogen for the next crop. Fertilizer carried over in the soil from the previous crop can save the producer additional costs. Crops have to be carefully selected to complement each other and produce the best nutrients. Grasses and legumes are included in the crop rotations to minimize erosion.

Credits

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Lesson 6: Soil Conservation Practices

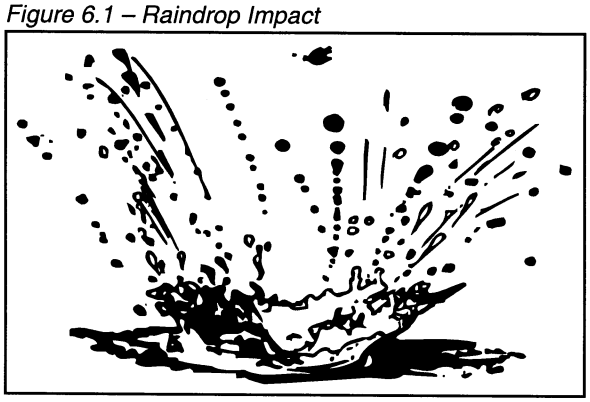
Selecting the proper use of farmland is the first and most important step in conserving soil. The success of all other phases of a farm's conservation program will depend on selecting a land use pattern that is within the land's capability. Soil survey maps, as discussed in Lesson 2 of this unit, contain the informational building blocks for land use planning. It is an ongoing challenge for producers to adjust their practices of tillage, planting, and fertilizing to protect our natural resources and our wildlife.

Soil Erosion

A producer's biggest challenge in soil conservation is the reduction and prevention of soil erosion. Soil erosion is the wearing away of the land surface by water, wind, ice, and other geologic agents such as earthquakes, floods, and the natural wearing away of rock. Crop producers have no control over ice or geological soil erosion. Wind erosion occurs in areas of high prevailing wind speeds and low annual rainfall.

Water is the single most destructive force to Missouri's soil, especially raindrop splash and flowing water. Soil erosion by water occurs in two steps: (1) the detachment of the soil particles and (2) the transporting of those particles. The first step is caused by a raindrop splash or impact. As indicated in Figure 6.1, a drop of rain is a high-energy force falling as fast as 20 mph that can splash more than 2 feet high and 5 feet to the side. In the second step, soil particles are carried off by flowing water on the soil surface. The goal of soil conservation practices is to interrupt one or both of these steps.

Figure 6.1 – Raindrop Impact



Water erosion falls into three main categories: sheet, rill, and gully. Sheet erosion is defined as the uniform removal of soil from an area by raindrop splash or water runoff. Water moves across the field surface at a very shallow depth and the soil is removed in thin layers or sheets. When sheet erosion occurs, the soil is removed in such thin layers that it is often unnoticed.

Rill erosion occurs primarily in recently tilled fields where runoff water forms into small, well-defined channels. The channels are typically less than 12 inches deep and can be easily filled in by tillage.

Gully erosion occurs where trenches are cut to a depth greater than 12 inches. In general, ditches that are too deep to cross with farm machinery are considered gullies. These gullies can range from a depth of 1 to 100 feet. They develop where steep, erodible land has been farmed. Gullies also develop when water concentrates in areas where the vegetative cover has been disturbed, such as livestock trails, field roads, or plow furrows.

Wind erosion, unlike water, cannot be divided into distinct types. Occurring mostly in flat, dry areas and moist, sandy soils along bodies of water, wind erosion removes soil and natural vegetation. It causes dryness and deterioration of soil structure. All mucks, sands, and loamy sands can easily be detached and blown away by the wind. Regular loams, silt loams, clay loams, and clay are not damaged by the wind, but on wide, level plains, there may be a loss of fine silts, clays, and some organic matter.

Factors Contributing to Soil Loss

Reducing soil erosion is important to maintaining healthy soil. Healthy topsoil is the foundation in which plants' roots take hold. Topsoil also contains nutrient-rich organic matter that serves as plant food. The topsoil that is carried away by erosion can cause other environmental problems by impairing air and water quality. When soil washes off a field, it may flow into a lake or stream and impose economic and health risks by lowering the quality of a community's water system. Topsoil loss on cropland in Missouri averages about 5.5 tons per acre per year. This is a significant decrease from the 1987 figures of 10 tons per acre per year. This decrease is a result of government conservation programs and adoption of residue management systems.

Six factors generally contribute to soil loss from water erosion: rainfall, soil erodibility, slope length, slope degree, cropping practice, and conservation practices. The Universal Soil Loss Equation (USLE), developed by the U.S. Department of Agriculture (USDA), is used to calculate these factors that contribute to sheet and rill erosion. The equation is A=RKLSCP with A being the computed soil loss per unit area.

The rainfall factor (R) is a measure of rainfall energy rather than just rainfall. A short, intense 4-inch rainstorm will cause much more erosion than a slow, steady 4-inch rain. Southern portions of Missouri are more prone to having heavy thunderstorms that create more rainfall energy and hence erosion problems.

The soil erodibility factor (K) is a measure of the soil's relative resistance to erosion. Sandy soil particles are easily detached by rain drop impact but are not easily transported due to their large size. In addition, water infiltration is high, which increases runoff from the site. Therefore, soil erodibility for sandy soil is low. Clay soils are held together with chemical bonds that are not easily broken by the erosion process; any free particle is small enough to be subject to erosion when broken free of the bonding. This makes clay soils moderately erodible. Silt soil particles are not chemically bonded so detachment and transportation by water erosion is quite easy. Therefore, silty soils are highly erodible.

Slope is the inclination of the land surface from each 100 feet of horizontal distance. The slope length (L) and slope degree (S) factors influence the amount of runoff and the rate of water infiltration. Table 6.1 indicates the classification categories for determining slope. Erosion increases sharply when either slope length or steepness increases. In steep areas, runoff is rapid and very little water passes through the soil, leaving it less fertile. In areas with a more gentle slope, runoff is slow, erosion is minimal, and most of the water passes through the soil. Slope length and gradient need to be considered together. For example, a steep slope may not be a concern if the length is only 5 feet. However, a gentle slope of 3% may be a concern if the slope length exceeds 200 feet. Additionally, the shape of a slope, whether concave, continuous, or convex, will affect the soil erosion that occurs. Sheet and rill erosion will more likely occur on a convex slope than on a concave or continuous slope. Slope percentage is determined by dividing the slope's vertical distance by the horizontal distance, then multiplying by 100.

$$\text{Slope percentage} = \frac{\text{Vertical distance}}{\text{Horizontal distance}} \times 100$$

Table 6.1 - Slope Classification

Classes	Description	% of Slope
Nearly level	Flat or nearly flat	Less than 2%
Gently sloping	Slopes very gently and usually has no abrupt changes	2 – 5%
Moderately sloping	Considerable slope and usually some irregularity	5 – 9%
Strongly sloping	Has considerable irregularity	9 – 14%
Moderately steep	Breaks sharply	14 – 25%
Very steep	Slopes very abruptly	More than 25%

The crop practice factor (C) determines if there will be soil cover from prior crops. Any crop that covers the soil during at least part of the year will reduce the erosion occurring on that soil. Crop practice factors include tillage practices, vegetative cover, crop rotation, fertility level, crop residue management, and any other factors that will have an effect on erosion.

The conservation practice factor (P) is a management tool that changes the flow pattern of water runoff on the soil and further reduces the effects of erosion, such as terracing, contouring, strip-cropping, and minimum tillage.

A factor not given in the USLE is the soil loss tolerance factor (T). This factor indicates the amount of soil that can be lost each year without seriously reducing productive capability. For the numerical equivalents of these USLE factors, NRCS personnel use special charts and information such as shown in Table 6.1. With this information, the actual soil loss of a specific site can be determined. Although soil erosion can never be stopped, good management practices, along with soil replenishment through natural regeneration, can control erosion to a tolerable productivity level.

Management Practices

The appropriate erosion control management practice for a specific field or farm can be determined by an on-site inspection. The NRCS provides technical assistance to guide producers in the installation of conservation management practices. Individual conservation plans are based on recommendations from soil maps that have been interpreted according to the information in soil survey reports.

The basic goal of conservation practices is to give the soil more protective cover or to shorten a slope to reduce the speed of the flowing water. Soil loss from a field with good grass or legume cover is very minimal. When sod or legumes are tilled under, the residue helps improve water absorption and retention capacity of the soil, thus reducing its erodibility. Figure 6.2 illustrates and defines conservation practices approved and recommended by the NRCS.

Residue management leaves the past year's crop residues on the soil surface to reduce erosion. It is most effective when high residue-producing crops are used in the crop rotation and tillage passes are kept to a minimum. Chisels and disks should be set to a shallow work level to keep the residue at tillage depth. No-till planting is recommended because it disturbs only residue in the row.

Contour farming is preparing the soil, planting, and cultivating crops around a slope, rather than up and down the slope. The row pattern of the contours is dependent on the lay of the land (the shape and steepness of the slopes). It is most effective on slopes of 2% to 8%. Contour farming reduces erosion, controls runoff water, and increases moisture infiltration. If rainfall amounts exceed the ability of the contours to remove the runoff, erosion can increase. Therefore, it is important to use this practice in conjunction with other conservation practices.

Cross slope farming is to farm across the slope. It allows deviation from the contour line and provides an option for slopes that are very difficult to farm. However, it is not as effective at saving soil as contour farming.

Contour strip cropping is a system of growing crops on the contour in approximately even-width strips or bands. Crops are arranged so that a strip of row crop is alternated with a strip of meadow or close-growing crop. To be most effective, no more than half a field should be planted in a row crop in any 1 year.

Contour buffer strips alternate contoured perennial vegetation strips, which are at least 15 feet wide, with wider cultivated bands. The vegetation will slow runoff and trap sediment. Buffer strips are the most effective when used with conservation tillage and crop rotation.

Field borders planted with grass or legumes stop erosion on end rows. The field border should be at least 16 feet wide. The border is useful as a turn row and often qualifies as set-aside acres.

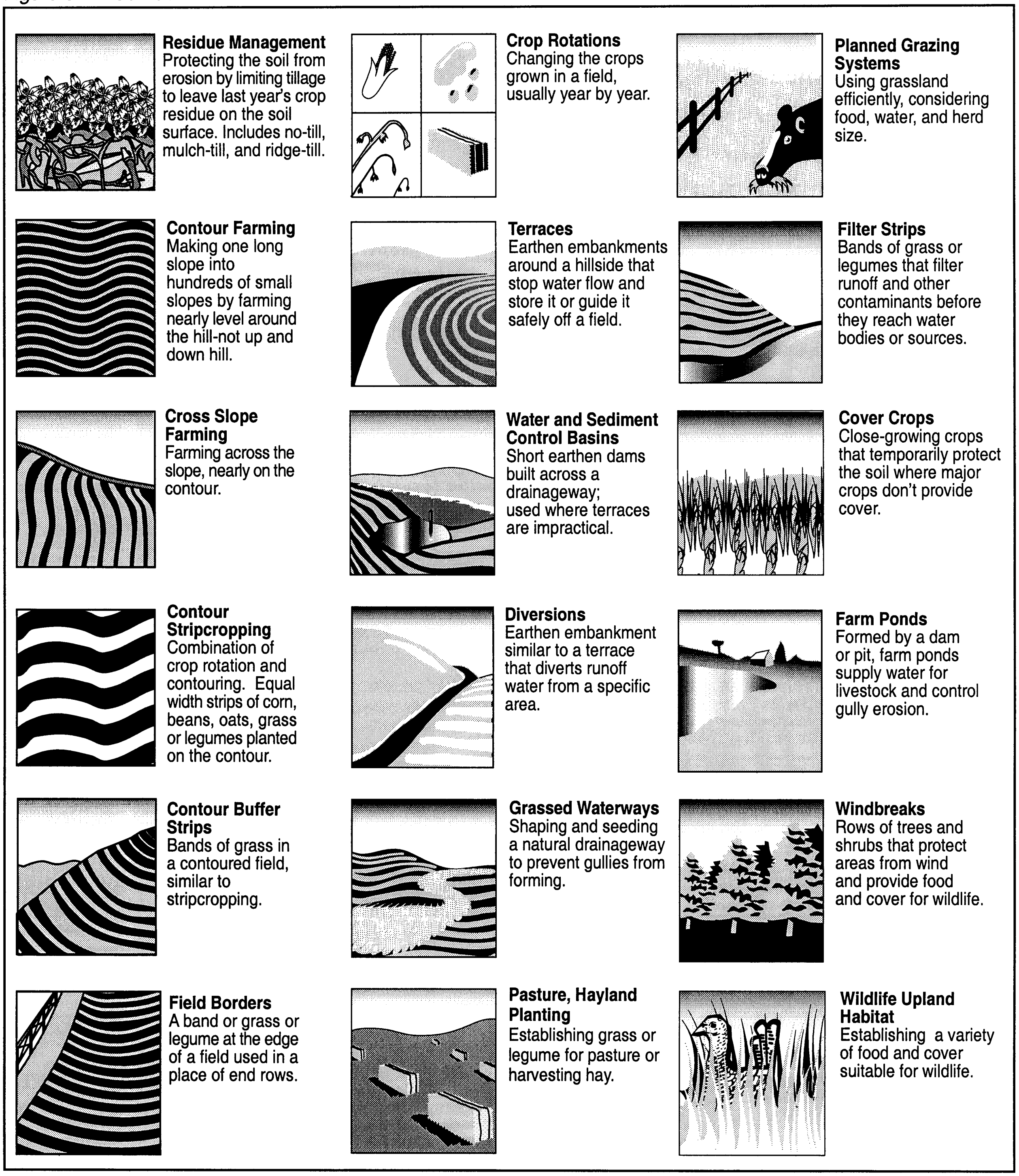
Crop rotation involves growing crops on the same land in an orderly sequence, including row crops, grasses, and legumes. Crop rotation provides soil cover to help reduce erosion and improve soil fertility. The effect on soil erosion will depend on the land capability, the crops used, how they are grown, and how the residue is managed.

Terraces are earthen embankments designed to slow down and catch runoff on moderate to steep slopes. Terraces allow soil particles to settle without forming erosion channels. They should fit the contour of the land with spacing determined by the soil type, slope, and tillage practices used. Types of terraces include the storage terrace and the gradient terrace. Storage terraces collect and store water until it can penetrate into the ground or release through underground outlets. Gradient terraces slow runoff water and channel it to a grassed waterway.

Water and sediment control basins are used in areas not suited to terrace systems. Short earthen dams are built across the slope and minor drainage ways. The basins trap sediment, reduce gully erosion, and reform the land surface. Basins should be used in combination with conservation tillage, crop rotations, field borders, and cross slope farming.

A diversion is a channel or ridge similar to a terrace that diverts excess runoff from an area. The runoff is directed for use or safe deposit in another area. Diversions are useful to divert water from cropland, farm buildings, feedlots, or active gullies.

Figure 6.2 – Soil Conservation Practices



<u>Grassed waterways</u> are grassy areas where flowing water gathers and is slowed as it is guided off the field. The waterway should begin slightly above the point where the gully begins and end where it spreads out into the field. End rows should not be planted along the waterway.

<u>Pasture and hayland planting</u> build topsoil and organic matter, making the soil better for crop growth. Disease, insect, and weed cycles that occur with continuous row crops are disrupted, reducing the need for pesticides.

A planned grazing system allows a resting time between two or more grazing areas in a planned sequence. Grazing affects both the plants and the soil in pastures. Continuous grazing reduces plant growth and results in pasture deterioration. Rotational grazing lets the soil rest, and the plants are allowed to grow and multiply. Improved grass reduces soil erosion, increases livestock production, and improves water quality.

Filter strips are strips of vegetation that can be used on cropland lying next to streams, ponds, and lakes. The strips remove sediment, organic matter, and other pollutants from runoff before reaching the waterways. The vegetation strips should be a minimum of 15 to 25 feet wide.

Cover crops can be planted to control soil erosion during periods when the major crops do not furnish enough ground cover. They are often seeded in the fall to protect the soil until the next spring's planting. They may also add organic matter to the soil and trap excess plant nutrients. Close-growing grasses, legumes, or small grains are examples of cover crops.

Farm ponds control gully erosion and provide water for livestock. Ponds are also considered a conservation practice that enhances wildlife habitat by providing a water source for birds and animals. Ponds can be developed by building a dam or digging a pit. A pond should be located in an area that has a dependable source of noncontaminated water, is protected from silt deposits, has a proper outlet, and has appropriate capacity and storage.

Windbreaks are a row of trees and shrubs planted to protect the soil, conserve energy, control snowdrifts, give shelter to livestock, and provide food and shelter for wildlife. Windbreaks should be planted on the north and west sides of the area to be protected. Space should be left downwind of plantings for air circulation. A variety of tree and shrub species will lessen the chance of total loss from drought, insects, or diseases.

Enhancing Wildlife Habitats

Conservation practices that reduce soil erosion can also be an effective means of enhancing wildlife habitats. Although the specific needs of each type of wildlife vary, the three basic components needed to sustain wildlife are water, food, and cover.

Cropland that uses conservation tillage methods produces crop residue that feeds and protects wildlife. Waste grain and weed seeds left after harvesting are staple foods for wildlife in winter. Crop rotation practices provide plant diversity, nesting cover, and food for wildlife. Planned rotations should include residue producing crops, small grains, or a grass/legume meadow. A wildlife food plot established within an existing crop field can help wildlife through the winter when food supplies are short. It may be as simple as leaving four rows of corn standing after harvest to provide food over the winter.

Grassland areas created for soil erosion control provide food, water, and cover areas for wildlife. Contour strip cropping, contour buffer strips, field borders, terraces, water and sediment control basins, diversions, grassed waterways, pasture and hayland planting, planned grazing systems, filter strips, and cover crops all include grassland areas that can be seeded to a grass/legume mixture that is beneficial to wildlife. These grassland areas provide nesting and roosting cover and, if possible, should not be mowed until mid-July.

Idle lands such as field borders, fence rows, turn-rows, and areas around farm ponds can be planted to warm-season grasses and other grasses such as redtop and timothy. These areas can serve as valuable nesting, brood rearing, and concealment cover for wildlife. These grasses may be cut in July when the adjoining crops provide cover. These areas should be protected from livestock grazing.

The NRCS provides recommendations to landowners for implementing conservation practices that support wildlife as well as crops and livestock. In many cases, federal or state cost-share funds are available for installing conservation practices.

Summary

Erosion removes vital topsoil and lowers the basic productivity of the land. When evaluating soil loss for a specific area of land, the factors to consider are rainfall, soil erodibility, slope length and degree, crop practice, and conservation practice. All of these factors must be considered when determining the appropriate soil conservation methods that are most suited for the soil. The Natural Resources Conservation Service assists

landowners to determine the most appropriate conservation practices to reduce soil erosion and maintain the fertile topsoil necessary to produce crops. Conservation practices that reduce soil erosion can also be an effective means of enhancing wildlife habitats.

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