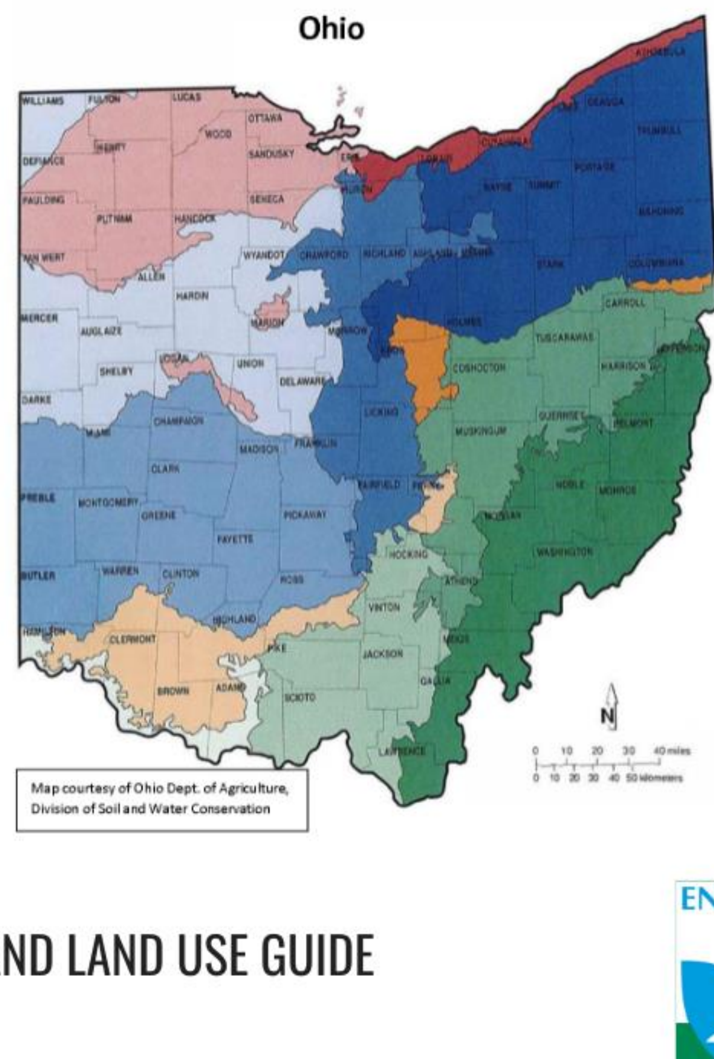
2022
NCF-ENVIROTHON
OHIO



Map courtesy of Ohio Dept. of Agriculture, Division of Soil and Water Conservation

SOILS AND LAND USE GUIDE

ENVIROTHON
OHIO 2022

2022 NCF-Envirothon Ohio

Soils and Land Use Study Resources

Key Topic 1: Physical Properties of Soil and Soil Formation

1. Name the five soil forming factors, and describe how they influence soil properties.
2. Explain the defining characteristics of a soil and describe how the basic soil forming processes influence these characteristics in different types of soil.
3. Identify different types of parent material, their origins, and how they impact the soil that develops from them.
4. Identify and describe soil characteristics (horizon, texture, structure, color).
5. Identify and understand physical features of soil profiles and apply this information to determine soil properties and limitations in the field.
6. Explain how geologic history has played a key role in the soil formations and land use of Ohio.

Study Resources

Resource Title	Source	Located on
Chapter 2 and Glossary from Urban Soil Primer	*USDA NRCS, Scheyer, J.M., and K.W. Hipple. 2005*	Pages 3-16
Excerpt (pages 51-53) from Ohio Future Farmers of America Land Judging Contest Agricultural Soils Manual	*Ohio FFA, ODA, 2018 Edition*	Pages 17-19
Soil Regions of Ohio	*Ohio Department of Agriculture, Division of Soil and Water Conservation, Revised 2018*	Pages 20-25
GeoFacts No. 23, A Brief Summary of the Geologic History of Ohio	*Ohio Department of Natural Resources, Division of Geological Survey, Revised June 2014*	Pages 26-27
GeoFacts No. 33, Ice Age in Ohio: Evidence Below Our Feet	*Ohio Department of Natural Resources, Division of Geological Survey, Compiled by Tyler Norris, October 2019*	Pages 28-29
Shaded Drift-Thickness Map of Ohio	*Ohio Department of Natural Resources, Division of Geological Survey, 2004*	Pages 30-31

Study Resources begin on the next page ➡

Chapter 2: Basic Soil Properties

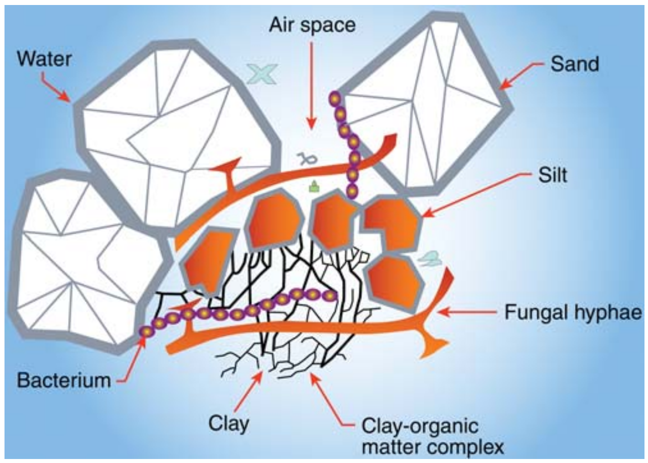


Figure 2.1

Soils in an urban area may share some properties with soils in forests, pastures, cotton fields, or even other urban areas. There are large differences in soils as they naturally occur in forests, farmed fields, and grazing land areas, and these differences are changed when an area is converted to an urban area. Soil scientists have developed conventions and language to communicate among themselves. It is important that we share scientific information with everyone, not just other scientists and professionals. Soil properties, such as soil texture and structure, particle-size distribution, soil reaction, and bulk density, help us to understand and predict how soils react and respond to different uses. Construction activities, compaction, and surface sealing dramatically change soil properties and can sometimes result in a reduced ability to perform the critical functions or activities of natural soil.

Topics in this chapter:

- **Soil variation**
- **Soil components**
- **Soil-forming processes**
- **Soil horizons**
- **Measuring and monitoring soil properties**

Soil Variation

What is soil and why is soil important to each of us? Traditionally, soil is defined as a dynamic natural body that is made up solids, liquids, and gases, occurs on the earth's surface, contains living matter, and supports or is capable of supporting plants. Bockheim (1974) defines urban soil as "soil material having a non-agricultural, man-made surface layer more than 50 cm (20 inches) thick that has been produced by mixing, filling, or by contamination of land surface in urban and suburban areas." In some important ways, soils of urban areas differ from soils of other areas.

Differences in urban soils have been observed and recorded by scientists, engineers, equipment operators, and construction workers for a long time. Even within urban areas, there is a multiplicity of soil conditions, ranging from "natural" soils that are relatively undisturbed to soils in which the natural materials have been mixed or truncated, to soils that formed in added materials, or fill, of varying thickness. Each of these areas, in turn, can be subject to different types of use and management, which can further affect their soil properties. Soils in urban areas can be divided into two general types: *natural* soils, which formed in material naturally deposited by water, wind, or ice or in material weathered from the underlying bedrock, and *anthropogenic* soils, which formed in human-deposited material, or fill (table 2.1). Anthropogenic soils are almost anywhere in the urban environment. The purpose of adding fill to an area may be to alleviate undesirable soil properties or to modify the urban landscape for specific activities.

Table 2.1: Examples of Fill Material in Urban Soils

- Natural soil materials that have been moved around by humans
- Construction debris
- Materials dredged from waterways
- Coal ash
- Municipal solid waste
- A combination of any or all of the above

Characteristics of soil in any urban area depend on many things. They depend on how deep the site has been excavated during construction and if new materials were brought in and mixed with the original soil materials. They depend on the properties of the original natural soil and the past uses of the site. Many times topsoil is removed from the site prior to construction and may or may not be returned to the site. After excavation, subsoil may be placed as fill over topsoil. Changing the order of the soil layers or mixing the topsoil and subsoil can alter soil properties. These variables make predicting soil behavior difficult in urban areas.

Soil Components

All soil is made up of air, water, numerous kinds of living and/or dead organisms (organic matter), and mineral matter (sand, silt, and clay). In the urban arena, it includes many manmade materials. The amount of each of these soil components varies from one place to another in the world or from one kind of soil to another. Soil components can vary dramatically within distances of only a few feet on the same landscape.

Soil composition can be dramatically changed by pedestrian or vehicular traffic, especially when the soil is wet. The soil components most easily changed are the amounts of soil air and water. Imagine the change in soil composition at construction sites after large trucks and heavy construction equipment drive over a soil and compact it. Imagine people walking and playing on wet soils in city parks and recreation areas or yards. Note the differences in percent of soil air and soil water in figures 2.2 and 2.3. Figure 2.2 illustrates the general composition of a natural soil. Figure 2.3 illustrates the general composition of a soil that has been compacted by heavy traffic. As soil particles are squeezed together, pores for air and water are reduced in size and number (figure 2.4). The reduced pore space changes the way a soil handles water intake and water movement throughout its layers, or horizons.

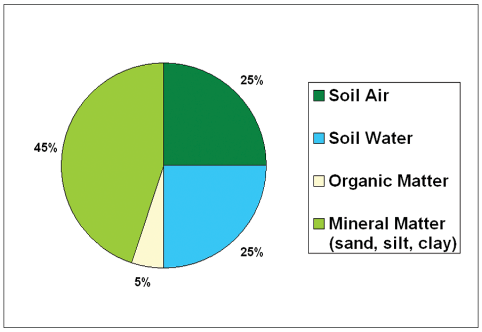


Figure 2.2: Composition of a natural soil, by weight.

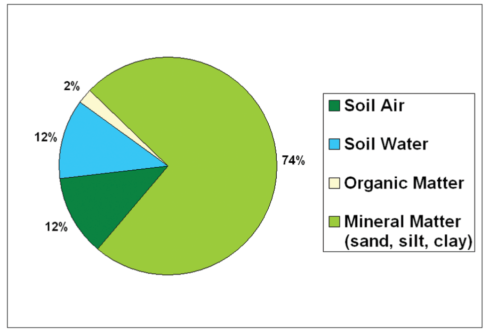


Figure 2.3: Composition of a compacted soil, by weight.

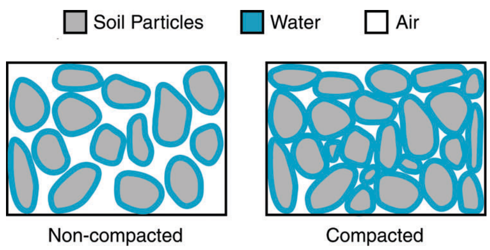


Figure 2.4: Soil pore space.

Soil-Forming Processes

Soils form through a group of processes no matter where they are located or what they are used for. All soils form because of four processes operating along with five basic soil-forming factors. The four processes that operate on soil material are additions, transformations, translocations, and losses (figure 2.5). We are able to map, classify, and interpret soil because a given set of environmental factors produces a predictable kind of soil.

The soil-forming factors are parent material, climate, living and dead organisms, time, and landscape position. When all soil-forming factors are similar, a similar soil is produced. If we change one or more of the soil-forming factors significantly, then a different soil is produced.

Additions to soil generally include organic matter, fertilizer, pollutants, and deposits of soil material. All of the additions change a soil and how it functions. In urban areas new soil material is sometimes added on top of an existing soil. If thick enough, the new layer or layers can change the way the soil develops. When a layer of concrete or asphalt is added to the top of a soil in areas where streets, parking lots, or driveways are built, additions to the soil are suddenly altered, restricted, or even stopped.

Transformations are changes that take place within a soil. In figure 2.5, transformations are illustrated by the letters x and y and the arrows that connect them. During transformation processes, material does not leave the soil but is simply changed from one form to another or from one compound to another. Micro-organisms and earthworms play an important role in soil transformations. Earthworms eat soil and plant materials and transform them into organic material that provides food for plants and other organisms. Chemical weathering changes parent material, such as rocks and sand grains, and creates new minerals and/or smaller particles. Rocks are transformed into sand grains, and sand grains are transformed into silt and clay particles over time. As iron particles change form, they change soil colors from gray to brown or to red and yellow. Applying too much fertilizer of certain kinds can transform a soil into one that is too acidic for plants to grow.

Translocations are movements of soil components from one place to another in the soil. Translocations can move materials from one soil layer to another and can even move the materials completely out of a soil. Water moves through a soil profile and carries clay particles, soluble salts, organic matter, and chemical compounds downward into the soil. Translocations can also be upward or horizontal. As soil dries and water evaporates from the soil surface, minerals and salts may move back toward the soil surface. In dry areas translocations are restricted because there is less water to carry compounds and materials deep into the soil. Compounds and minerals can move only as deep as water moves into a soil. Concentrations of soluble material generally are closer to the surface in dry areas than in other areas. Windthrow and the activity of animals (i.e., ants, termites, groundhogs, and worms) also can move soil components upward.

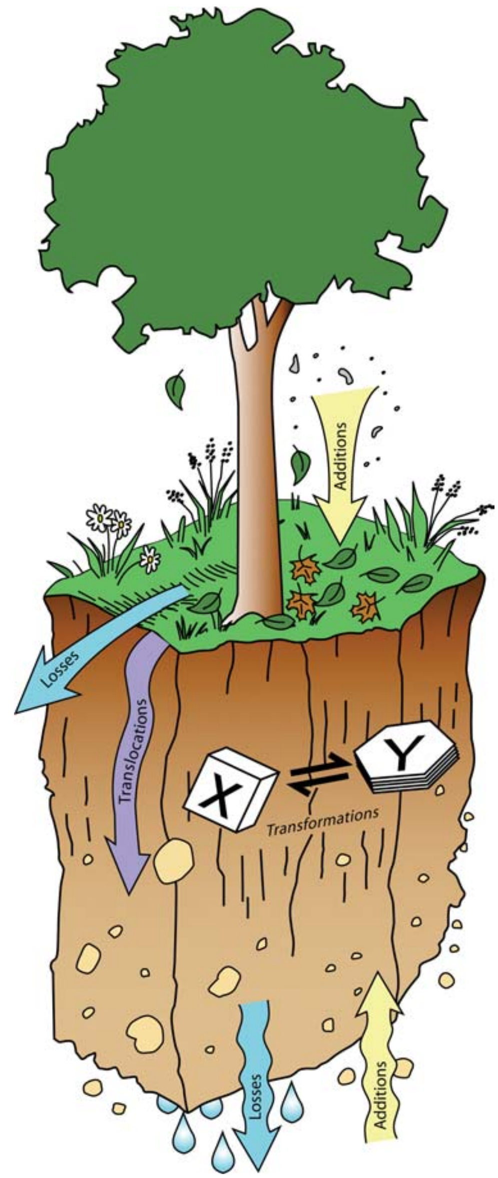


Figure 2.5: Soil-forming processes.

Losses occur when water moves material through and out of a soil profile. If enough water is available, soluble materials, such as sodium and calcium, are removed early in the process of soil formation. Lawn and garden fertilizers are relatively soluble and may be removed from a soil when too much water is applied. Ground-water pollution can occur if too much water is added to a soil that contains contaminates. Erosion by wind or water removes the soil particles and compounds needed for plant growth. Topsoil removed through water erosion in a given area can improve the soil in the area where the sediments are deposited.

Soil Horizons

Soils are made up of soil horizons, or layers, that form as the result of five soil-forming factors. The six major kinds of soil horizons are designated as O, A, E, B, C, and R (figure 2.6). All six of these horizons are not always evident in every soil profile.

For example, most agricultural soils do not have an O horizon because organic horizons are usually mixed with A horizons during tillage. Also, a soil has an R horizon only if bedrock is close to the surface.

O horizons are generally the uppermost layers and form on top of mineral horizons where they occur. They are formed by the accumulation of fresh and decaying plant parts, such as leaves, grass, needles, and twigs. O horizons are dark colored (mainly black or brown) because decomposing plant and animal materials produce humus. They are generally in forested or wet areas.

A horizons are below O horizons and are made up mostly of mineral material. They are characterized by the loss of iron, clay, and aluminum and the addition of organic matter by soil organisms. Hence, they are dark colored in most areas, except for extremely dry areas. A horizons are commonly referred to as topsoil.

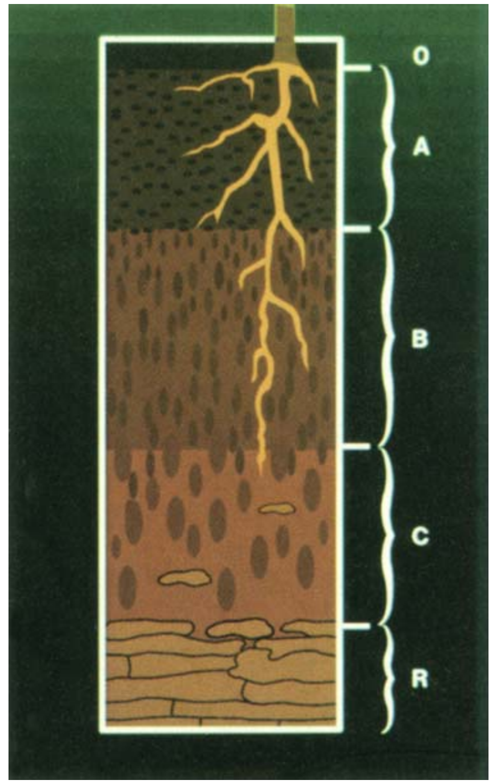


Figure 2.6:Natural soil profile with major horizons.

E horizon*s* are commonly in forested areas. The “E” stands for eluvial, which means that clay, iron, organic matter, and other minerals have been removed from this horizon. E horizons commonly appear white or lighter in color than the horizons above and below them.

B horizons are below A or E horizons and are characterized by the accumulation of iron, clay, aluminum, and other compounds. B horizons are commonly referred to as subsoil.

C horizons are below B horizons and are commonly referred to as the substratum. They are made up mainly of partially weathered or disintegrated parent material, but soft bedrock can also occur. Because C horizons are deeper in the profile, the effects of the soil-forming factors are less pronounced than the effects in the overlying A and B horizons.

R horizons are made up of bedrock. The bedrock can be far below or just a few inches below the surface.

Horizons in urban soils may not be fully related to the natural soil-forming factors but instead may be manmade layers formed by the deposition of dredge, fill, and/or mixed materials. Human artifacts, such as bricks, bottles, pieces of concrete, plastics, glass, pesticides, petroleum products, pollutants, garbage, and disposable diapers, are often components of urban soils. Manmade materials may be added to raise a landscape to a higher level, backfill ditches or foundation walls, or construct berms. In urban areas, human activity is often the predominant activity in making soil instead of the action of the natural agents of wind, water, ice, gravity, and heat.

Urban soils differ from natural soils because they have been altered to some degree. They have been excavated, compacted, disturbed, and mixed and may no longer possess their natural soil properties and features. Many highly disturbed soils in urban areas or on construction sites have not been in place long enough for soil-forming factors to significantly change them and to form soil horizons. In areas where

Figure 2.7: Urban soil profile.

fill materials have been in place for a considerable time (e.g., 50 years or so), the formation of A horizons and sometimes weakly expressed B horizons has been documented. Figures 2.7 and 2.8 show soil horizons in urban and natural soil profiles.

Measuring and Monitoring Soil Properties

Soil properties are measured at specific sites or sampled for laboratory analysis. The properties that can be described in the field include horizonation and layering, color, texture, structure, consistence, depth to bedrock, and drainage class. The properties that generally are measured in the laboratory include content of organic matter, particle-size distribution, clay mineralogy, reaction, exchangeable cations, and concentrations of contaminants. The soil characteristics that are estimated or calculated from the measured properties include engineering classification and erodibility.

Physical Soil Properties

Soil is a mixture of mineral matter, organic material, air, and water. The texture of a mineral soil is based on the amounts of sand, silt, and clay in the soil. Sand, silt, and clay are defined on the basis of the size of each individual soil particle. These size

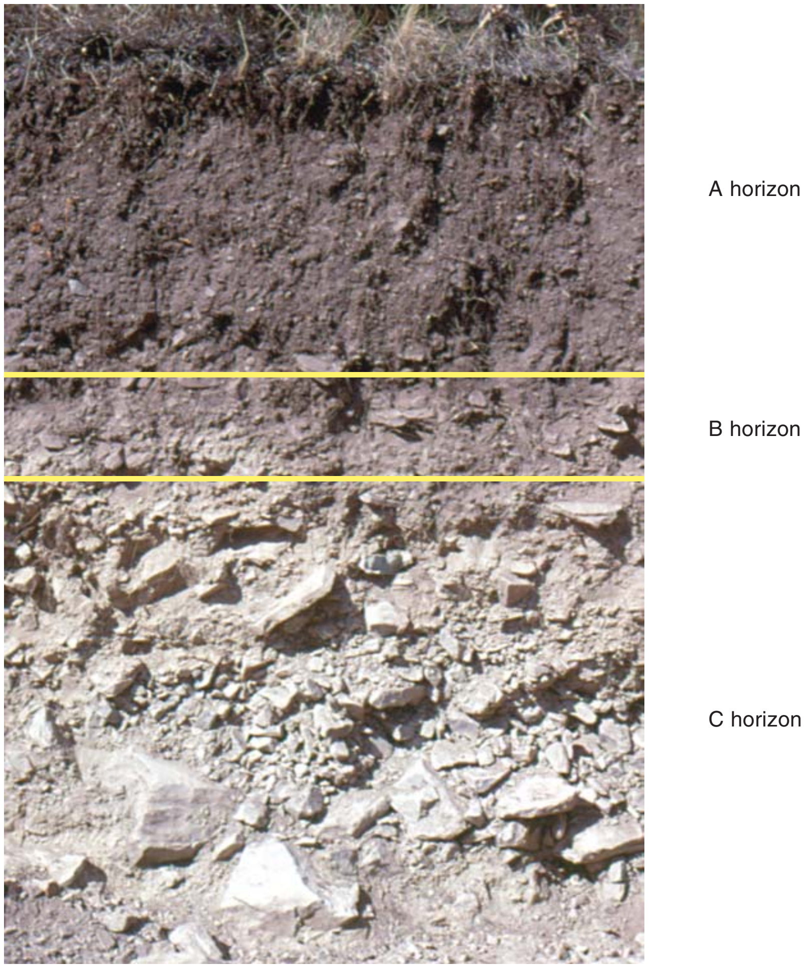


Figure 2.8: Natural soil profile.

relationships can be demonstrated by imagining that a sand particle is the size of a basketball, a silt particle is the size of a baseball, and a clay is the size of an aspirin tablet (figure 2.9).

Soil texture and other soil properties vary significantly within short distances on urban or natural landscapes. This variation is caused by the movement and mixing of soil materials during construction activities or changes in any of the soil-forming

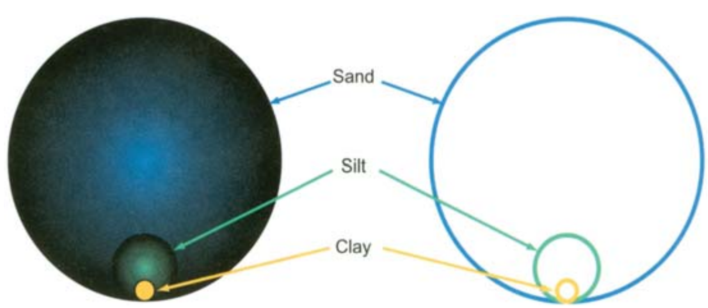


Figure 2.9: Relative sizes of sand, silt, and clay particles.

factors. The combinations of different textures may improve or limit the soil for a specific use.

Soil texture affects water and air movement through the soil as particles of different sizes pack together and thus determine the size and spacing of pores and channels. Sand particles have the largest pore spaces and allow water to drain through the pores most freely. Silt particles have smaller pore spaces, so water moves through them more slowly. Clay particles have very small pores, and so they tend to adsorb and hold more water. The mixture of particle sizes affects water, nutrient, and contaminant absorption. The specific type of mineral influences engineering properties, such as shrink-swell potential and excavation difficulty, especially in expanding clays (smectite), which behave like plastics.

The soil textural triangle (figure 2.10) can be used to determine soil texture from the relative amounts of particles of any two sizes. For example, a clay percentage of 15 with a silt percentage of 70 gives a soil texture of silt loam.

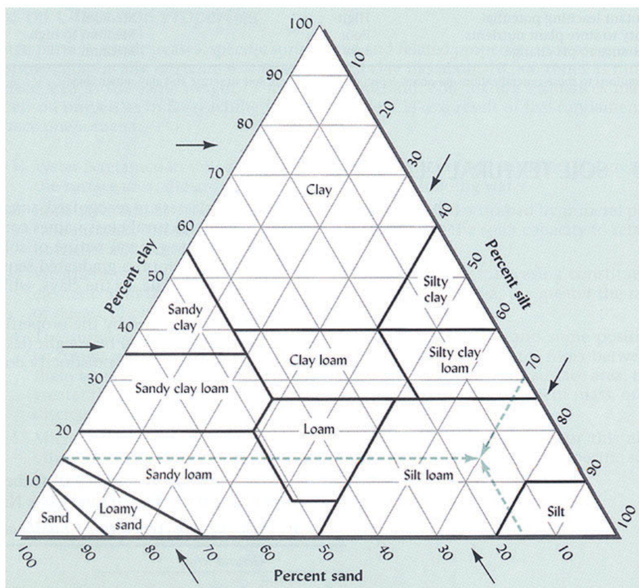


Figure 2.10: Soil textural triangle.

Measures of Water Movement

Water movement in urban soils is described in three ways (figure 2.11):

- infiltration into the soil surface, especially from rainfall
- percolation within the soil drain lines from septic systems, which is especially important in the soil below the drain line and above a restrictive layer
- permeability within the soil from the surface to a restrictive layer

Key terms in understanding water movement in soils are “restrictive layer” and “water table.” Restrictive layers have high density (high weight in a given volume of soil) and low porosity (limited space between particles), so that water cannot flow into or through them. Restrictive layers at the surface can cause surface sealing and limit

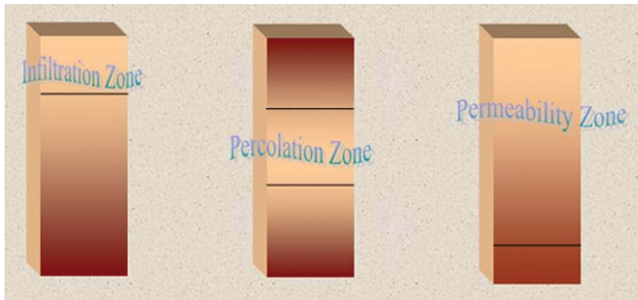


Figure 2.11: Comparison of descriptive terms for water movement in soils.

infiltration of water into the soil. Restrictive layers within the percolation zone reduce the drainage rate of fluids in septic drain lines and can cause septic systems to back up and fail. Compaction of soil materials can occur if heavy weight is on the surface when the soil is wet, resulting in dense restrictive layers below the surface.

A "perched" water table occurs when a restrictive layer anywhere in the soil limits waterflow deeper into the soil. Water drains down from the soil surface and builds up, or "perches," above the restrictive layer and above the expected water table depth. An "apparent" water table is fed from below by ground water, streamflow, or subsurface lateral flow as water moves across a restrictive layer below the soil surface.

Soil Color

Soil color differences in a profile reflect soil-forming processes and can be an indicator of soil wetness. These differences help to distinguish fill from natural soil. Important coloring agents in soil include parent (geologic) material, soil wetness, extent of leaching, content of organic matter, and the chemical form and content of iron.

Organic matter darkens the soil to a degree, depending on the content and the extent of decomposition. *Iron* gives soil a brown, yellow, or red color. Shades of blue or green may also appear, depending on iron amount, oxidation state, and hydration state. When soil is saturated, iron can become soluble and can be removed, leaving the soil with "mottled" brown and gray colors or completely gray colors, depending on the extent of the wetness.

Soil Structure

Soil structure is the combination or arrangement of primary soil particles into secondary units or aggregates. Organic materials and clay are important binding agents. Wetting and drying cycles are important in creating structure. Soil structure influences pore space and water movement in soils.

The principal forms of soil structure are—*granular* (roughly spherical)*; platy* (laminated); *angular or subangular blocky* (roughly cube shaped, with more-or-less flat surfaces); *prismatic* (vertical axis of aggregates longer than horizontal); and *columnar* (prisms with rounded tops). See figures 2.12 to 2.15.

Structureless soils are either *single grained* (each grain by itself, as in dune sand) or *massive* (the particles adhering without any regular cleavage, as in many hardpans).

Figure 2.12: Granular structure.

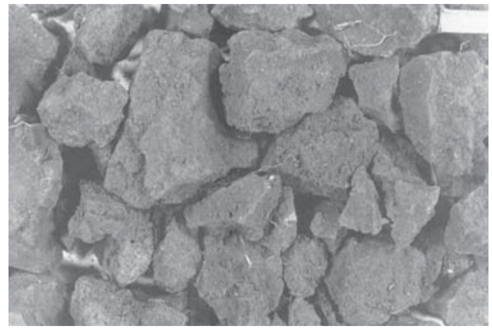


Figure 2.13: Blocky structure.

Figure 2.14: Prismatic structure.

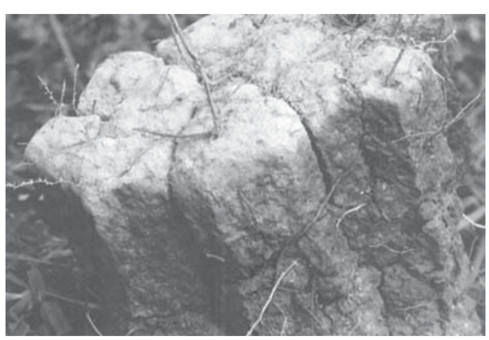


Figure 2.15: Columnar structure.

Glossary

Aggregate, soil. Many fine particles held in a single mass or cluster. Natural soil aggregates, such as granules, blocks, or prisms, are called peds. Clods are aggregates produced by tillage or logging.

Bedrock. The solid rock that underlies the soil and other unconsolidated material or that is exposed at the surface.

Catena. A sequence, or "chain," of soils on a landscape that formed in similar kinds of parent material but have different characteristics as a result of differences in relief and drainage.

Cation. An ion carrying a positive charge of electricity. The common soil cations are calcium, potassium, magnesium, sodium, and hydrogen.

Cation-exchange capacity. The total amount of exchangeable cations that can be held by the soil, expressed in terms of milliequivalents per 100 grams of soil at neutrality (pH 7.0) or at some other stated pH value.

Clay. As a soil separate, the mineral soil particles less than 0.002 millimeter in diameter. As a soil textural class, soil material that is 40 percent or more clay, less than 45 percent sand, and less than 40 percent silt.

Compaction. Creation of dense soil layers when the soil is subject to the heavy weight of machinery or foot traffic, especially during wet periods.

Composting. Managing the decomposition of organic materials, such as leaves, grass, and garden waste.

Container gardens. Gardens planted in pots, concrete boxes, brick or stone basins, or other isolated rooting areas within paved areas.

Contaminated soil. A soil that has high concentrations of trace metals or organic waste that is toxic or a high risk to people or animals.

Drainage class (natural). Refers to the frequency and duration of wet periods under conditions similar to those under which the soil formed. Alterations of the water regime by human activities are not a consideration unless they have significantly changed the morphology of the soil. Seven classes of natural soil drainage are recognized—*excessively drained, somewhat excessively drained, well drained, moderately well drained, somewhat poorly drained, poorly drained,* and *very poorly drained*.

Drainage, surface. Runoff, or surface flow of water, from an area.

Erosion. The wearing away of the land surface by water, wind, ice, or other geologic agents and by such processes as gravitational creep.

Erosion (geologic). Erosion caused by geologic processes acting over long geologic periods and resulting in the wearing away of mountains and the building up of such landscape features as flood plains and coastal plains. Synonym: natural erosion.

Erosion (accelerated). Erosion much more rapid than geologic erosion, mainly as a result of human or animal activities or of a catastrophe in nature, such as a fire, that exposes the surface.

Fertility, soil. The quality that enables a soil to provide plant nutrients, in adequate amounts and in proper balance, for the growth of specified plants when light, moisture, temperature, tilth, and other growth factors are favorable.

Gravel. Rounded or angular fragments of rock as much as 3 inches (2 millimeters to 7.6 centimeters) in diameter. An individual piece is a pebble.

Hard bedrock. Bedrock that cannot be excavated except by blasting or by the use of special equipment that is not commonly used in construction.

Heat islands. Small areas of artificially drained urban soils surrounded by tall buildings that change soil temperature and moisture patterns. May also refer to an entire city with an artificial microclimate.

Horizon, soil. A layer of soil, approximately parallel to the surface, having distinct characteristics produced by soil-forming processes. In the identification of soil horizons, an uppercase letter represents the major horizons. Numbers or lowercase letters that follow represent subdivisions of the major horizons. The major horizons of mineral soil are as follows:

O horizon.—An organic layer of fresh and decaying plant residue.

A horizon.—The mineral horizon at or near the surface in which an accumulation of humified organic matter is mixed with the mineral material. Also, a plowed surface horizon, most of which was originally part of a B horizon.

E horizon.—The mineral horizon in which the main feature is loss of silicate clay, iron, aluminum, or some combination of these.

B horizon.—The mineral horizon below an A horizon. The B horizon is in part a layer of transition from the overlying A to the underlying C horizon. The B horizon also has distinctive characteristics, such as (1) accumulation of clay, sesquioxides, humus, or a combination of these; (2) prismatic or blocky structure; (3) redder or browner colors than those in the A horizon; or (4) a combination of these.

C horizon.—The mineral horizon or layer, excluding indurated bedrock, that is little affected by soil-forming processes and does not have the properties typical of the overlying soil material. The material of a C horizon may be either like or unlike that in which the solum formed. If the material is known to differ from that in the solum, an Arabic numeral, commonly a 2, precedes the letter C.

Cr horizon.—Soft, consolidated bedrock beneath the soil.

R layer.—Consolidated bedrock beneath the soil. The bedrock commonly underlies a C horizon, but it can be directly below an A or a B horizon.

Humus. The well decomposed, more or less stable part of the organic matter in mineral soils.

Hydrologic soil groups. Refers to soils grouped according to their runoff potential. The soil properties that influence this potential are those that affect the minimum rate of water infiltration on a bare soil during periods after prolonged wetting when the soil is not frozen. These properties are depth to a seasonal high water table, the infiltration rate and permeability after prolonged wetting, and depth to a very slowly permeable layer. The slope and the kind of plant cover are not considered but are separate factors in predicting runoff.

Hydrologic unit or watershed. In urban areas, a catchment area with an outlet in or affecting a densely populated area.

Impervious soil. A soil through which water, air, or roots penetrate slowly or not at all. No soil is absolutely impervious to air and water all the time.

Infiltration. The downward entry of water into the immediate surface of soil or other material, as contrasted with percolation, which is movement of water through soil layers or material.

Landslide. The rapid downhill movement of a mass of soil and loose rock, generally when wet or saturated. The speed and distance of movement, as well as the amount of soil and rock material, vary greatly.

Leaching. The removal of soluble material from soil or other material by percolating water.

Loam. Soil material that is 7 to 27 percent clay particles, 28 to 50 percent silt particles, and less than 52 percent sand particles.

Low strength. The soil is not strong enough to support loads.

Nutrient, plant. Any element taken in by a plant essential to its growth. Plant nutrients are mainly nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, iron, manganese, copper, boron, and zinc obtained from the soil and carbon, hydrogen, and oxygen obtained from the air and water.

Organic matter. Plant and animal residue in the soil in various stages of decomposition.

Parent material. The unconsolidated organic and mineral material in which soil forms.

Percolation. The movement of water through the soil.

Permeability. The quality of the soil that enables water or air to move downward through the profile. The rate at which a saturated soil transmits water is accepted as a measure of this quality. In soil physics, the rate is referred to as "saturated hydraulic conductivity."

pH value. A numerical designation of acidity and alkalinity in soil. (See Reaction, soil.)

Pocket park. A relatively small area reserved for recreation or gardening and surrounded by streets or buildings.

Profile, soil. A vertical section of the soil extending through all its horizons and into the parent material.

Raised bed gardens. Gardens that are planted in boxes made of wood or other materials and have the rooting area above the ground surface. The boxes may be filled with composted materials mixed with uncontaminated soil.

Reaction, soil. A measure of acidity or alkalinity of a soil, expressed in pH values. A soil that tests to pH 7.0 is described as precisely neutral in reaction because it is neither acid nor alkaline.

Relief. The elevations or inequalities of a land surface, considered collectively.

Restrictive layer. A compact, dense layer in a soil that impedes the movement of water and the growth of roots.

Runoff. The precipitation discharged into stream channels from an area. The water that flows off the surface of the land without sinking into the soil is called surface runoff. Water that enters the soil before reaching surface streams is called ground-water runoff or seepage flow from ground water.

Sand. As a soil separate, individual rock or mineral fragments from 0.05 millimeter to 2.0 millimeters in diameter. Most sand grains consist of quartz. As a soil textural class, a soil that is 85 percent or more sand and not more than 10 percent clay.

Sealed soil. Soil that is covered with buildings, pavement, asphalt, or other material. Water and air do not enter the soil from the surface.

Series, soil. A group of soils that have profiles that are almost alike, except for differences in texture of the surface layer. All the soils of a series have horizons that are similar in composition, thickness, and arrangement.

Shale. Sedimentary rock formed by the hardening of a clay deposit.

Shrink-swell potential. The potential for volume change in a soil with a loss or gain in moisture. Volume change occurs mainly because of the interaction of clay minerals with water and varies with the amount and type of clay minerals in the soil. The size of the load on the soil and the magnitude of the change in soil moisture content influence the amount of swelling of soils in place. Shrinking and swelling can damage roads, dams, building foundations, and other structures. It can also damage plant roots.

Silt. As a soil separate, individual mineral particles that range in diameter from the upper limit of clay (0.002 millimeter) to the lower limit of very fine sand (0.05 millimeter). As a soil textural class, soil that is 80 percent or more silt and less than 12 percent clay.

Sinkhole. A depression in the landscape where limestone has been dissolved or lava tubes have collapsed.

Slope. The inclination of the land surface from the horizontal. Percentage of slope is the vertical distance divided by horizontal distance, then multiplied by 100. Thus, a slope of 20 percent is a drop of 20 feet in 100 feet of horizontal distance.

Soft bedrock. Bedrock that can be excavated with trenching machines, backhoes, small rippers, and other equipment commonly used in construction.

Soil-forming factors. Five factors responsible for the formation of the soil from the unconsolidated parent material. The factors are time, climate, parent material, living organisms (including humans), and relief.

Structure, soil. The arrangement of primary soil particles into compound particles or aggregates. The principal forms of soil structure are platy, prismatic, columnar, blocky, and granular. Structureless soils are either single grained or massive.

Texture, soil. The relative proportions of sand, silt, and clay particles in a mass of soil. The basic textural classes, in order of increasing proportion of fine particles, are *sand, loamy sand, sandy loam, loam, silt loam, silt, sandy clay loam, clay loam, silty clay loam, sandy clay, silty clay,* and *clay*. The sand, loamy sand, and sandy loam classes may be further divided by specifying “coarse,” “fine,” or “very fine.”

Topographic maps (USGS). Maps that show terrain, ridges, waterways, contours, elevations, and geographic locations. Also may show roads and buildings.

Trace elements. Chemical elements, for example, zinc, cobalt, manganese, copper, and iron, in soils in extremely small amounts. They are essential to plant growth.

Soil Forming Factors

Soil properties are developed through five principle soil forming factors. The five soil forming factors are Parent Material, Climate, Relief, Living Organisms, and Time. These five factors determine the unique characteristics and overall development of the soil that we see and evaluate today.

Parent Material

To understand soils first we must understand where they came from. Parent material is the unconsolidated organic and mineral material from which the soil is formed. The soil inherits characteristics and properties from the parent material. Parent material experiences a chemical and physical alteration called weathering. Weathering is the process of breaking down materials in place so that soil can form. Soils are basically earth materials that have been transformed into a medium yielding different types of soils. Soils can contain multiple parent materials, (ie. loess over glacial till). The following are descriptions of the parent materials found in the Ohio landscape.

Residuum

Residuum is unconsolidated weathered, or partly weathered mineral material that accumulated as consolidated rock and disintegrated in place. Bedrock is very abundant on the Earth. In soil developed from bedrock, the natural conditions of the atmosphere break the large massive rocks into smaller and smaller pieces until the material was small enough for living organisms to establish residence and develop soil. We call weathered bedrock residuum and it is the predominant parent material in Southeast Ohio. Some bedrock types are more prone to weathering than others which explain the relatively dynamic hills and valleys associated with the unglaciated portions of the Southeast Ohio landscape.

Colluvium

Soil material, rock fragments or both moved by creep, slide, or local wash and deposited at the base of steeper slopes is called colluvium. Colluvium parent material is typically found in areas with steep slopes and contrasting elevations. Unlike residuum the parent material colluvium, will be located on the lower lying footslopes while the residuum can be located at the backslopes and the peaks of the hills. Since the soil was a product of different materials rolling down the hill, the assortment of rocks fragments will have a disorganized appearance. Rock placement will not have any reasonable pattern but rather appear jumbled and randomly placed. Confirmation must be made by looking at the soil profile.

Alluvium

Alluvium is the material (sand, silt, or clay) that is deposited on land by flowing streams. Soils formed in alluvium can be found anywhere there is a flowing water system. These soils are typically very young because new materials are constantly being laid down. Alluvium is characterized by the lack of horizons formed from developmental processes. Sediments are often stratified, or arranged in layers as a result of the different flooding events.

Glacial Till

Glacial till is the unsorted, non-stratified, glacial drift consisting of clay, silt, sand and boulders that was transported and deposited by glacial ice. Glacial Till is the dominant and most abundant parent material in the glaciated landscape of Ohio. The glaciers flowed across the land like a bulldozer, destroying the original hills and topography while picking up debris ranging in size from clay particles to large boulders. The glaciers did not simply push all the materials but rather a majority of the particles were picked up and incorporated into the ice sheet becoming a part of the glacier itself. Once the glaciers retreated, the debris (glacial till) was left behind.

Loess

Loess is fine grained (silt material) carried by the wind and deposited in another location. This parent material was originally in a form of a solid rock but was ground down into a powder form called rock flour. After the glaciers melted, the fine materials washed down slope into the floodplains of the Missouri and Mississippi River valley creating huge mud flats. The mud flats dried out and were exposed to the conditions of the atmosphere. Wind picked up the fine silt grains creating huge dust storms spreading across the Midwest similar to the Dust Bowl in Oklahoma during the 1930s. The states like Iowa and Illinois received a large portion of Loess while Ohio, being farther away from the Missouri and Mississippi River received the tail end of the wind-blown silts. Most of the silts covered the Till material after the glaciers retreated. The region in Ohio with the deepest loess is located in South West Ohio where up to five feet of Loess covered the glacial till. The parent material in this region is said to be Loess over Glacial till. The northwest to north central part of Ohio were exposed to just a thin layer of loess over the glacial till material.

Outwash

Outwash is the stratified sand and gravel produced by the glaciers that was carried, sorted, and deposited by the glacial melt water. During the period of glacial melt, major river systems were created and the channels cut by these rivers were much larger than the present day streams. The floodplains of these rivers were much wider than the current flood plains, which resulted in the present day stream terraces. Stream terraces are essentially the old floodplains from the melting of glaciers. Stream terraces are composed mainly of outwash material.

Lacustrine Sediments

Lacustrine sediments is the parent material where fine silt and clay particles where settled out by still bodies of water. Lacustrine sediment is a parent material that occurs mostly in the glaciated landscape and the exact distinction of these old lake beds are hard to pick out on the landscape but can be accomplished when examining the soil profile. After the glaciers melted not all the water flowed through a river system but rather some of the water was trapped. These trapped bodies of water formed glacial lakes and the still nature of a lake provides time for very fine particles such as clay and silt to settle out. Over time these fine sediments settled and accumulated at the bottom of the lake bed. The lakes eventually disappeared and left behind Lacustrine Sediment.

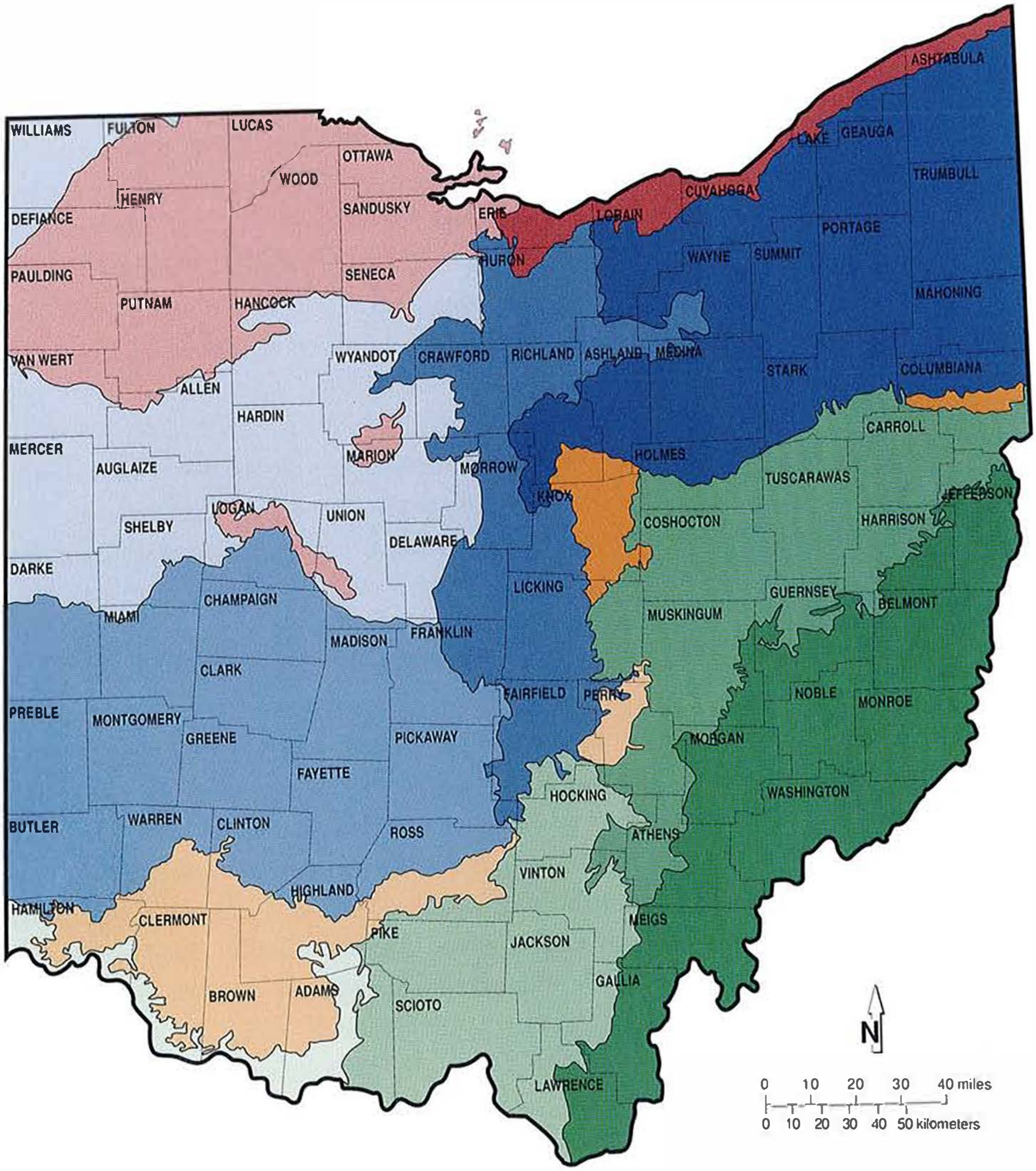
Beach Deposits

Beach deposits consist of sandy and other coarse material formed though wave action. These deposits are found in beach ridges, a low, essentially continuous mound of coarse grained material heaped up through the action of waves and currents on the backshore of a beach. These beach ridges define the boundaries of the old glacial lakes, and were left behind when the lakes disappeared.

Organic Deposit

The soils that were once recognized as swamp land (or wetlands) have an abundance of organic material. These wetlands had a shallow water depth enough to allow for some water loving plants to grow. As these plants and animals died, they settle to the bottom of the wetland. Since there is little to no oxygen the breakdown of the plant residue was little to none. Overtime a buildup of this organic material accumulated. Soils from organic deposits are very rare but can be found in Northwest Ohio They developed in the glaciated portions of the Ohio landscape.

Soil Regions of Ohio



LEGEND*

1 Hoytville-Nappanee-Paulding-Toledo

2 Conotton-Conneaut-Allis

3 Blount-Pewamo-Glynwood

4 Miamian-Kokomo-Eldean

5 Bennington-Cardington-Centerburg

6 Mahoning-Canfield-Rittman-Chili

7 Clermont-Rossmoyne-Avonburg-Cincinnati

8 Westmoreland-Homewood-Loudonville

9 Eden-Bratton-Brushcreek

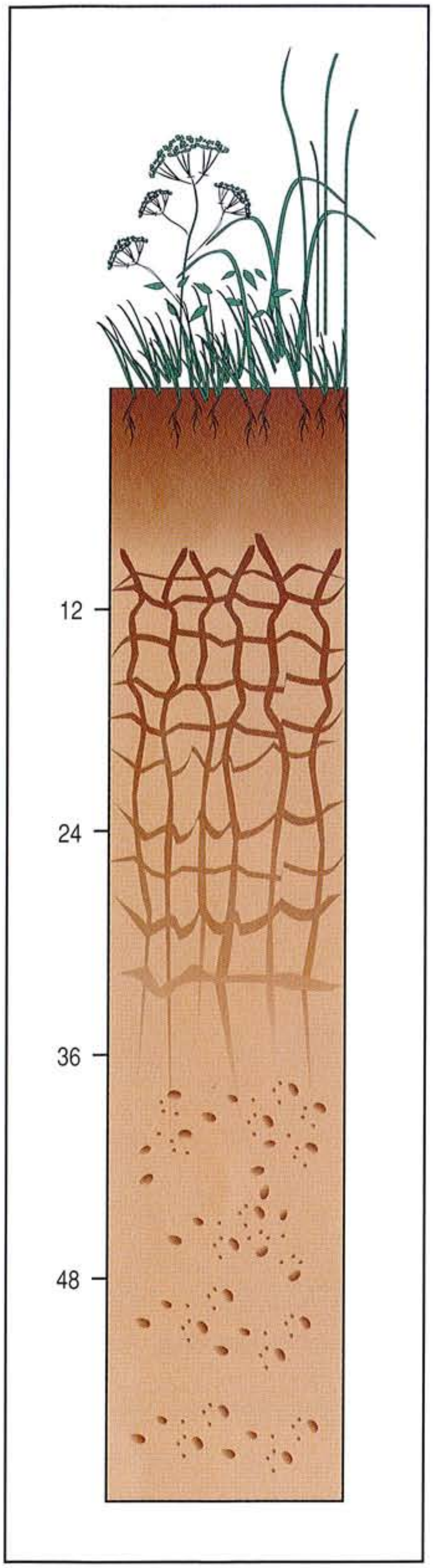
10 Shelocta-Brownsville-Latham-Steinsburg

11 Coshocton-Westmoreland-Berks

12 Gilpin-Upshur-Lowell-Guernsey

*Soil Regions are identified by the names of the soil series that are most common in each region

The Soil Regions of Ohio Map and Legend



What are soil series?

Scientists have classified the world's soils according to a six- level system, much as plants and animals are classified. The system follows a "most general to most specific" arrangement; order-suborder-great group-subgroup-family-series. Soil "series" are at the most specific level in the system. A soil series corresponds to the "species" level in the classification system for plants and animals. Soil series are commonly named for cities or towns near where the soils were first studied. Soils classified in the same series have horizons (or layers) that are similar in composition, thickness, and arrangement.

Soils in the Miamian series, for example, are well drained. They typically have a very dark grayish brown to brown silt loam or loam topsoil layer ("A horizon") 5 to 10 inches thick. They commonly have a brown or yellowish brown subsoil layer ("B horizon"), 8 to 35 inches thick, with a higher clay content than the A horizon. Below the subsoil, soils in the Miamian series have a brown to light olive brown substratum ("C horizon") that is slightly or moderately alkaline and has a lower clay content than the B horizon.

How were the soils identified?

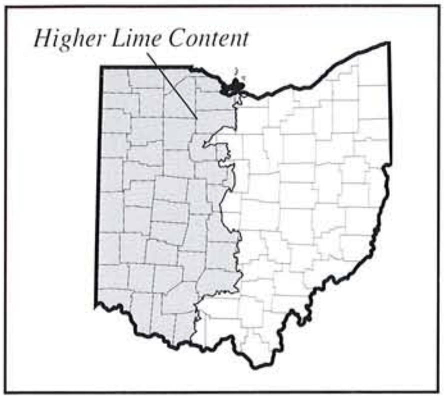
Soil surveys in Ohio have been conducted on a county by county basis by soil scientists with shovels, augers and other tools since 1899. The Soil Survey of Montgomery County, Ohio, published in 1900, recognized only one soil series (Miami). A statewide soil survey was conducted in 1912, and 24 different soil series were recognized.

By 1992, soil surveys had been completed in every county in the state. Modern soil surveys must be much more detailed than the early surveys in order to provide the information needed to manage Ohio's soil resources. Today, soil maps for Montgomery County show 38 different soil series, delineated in areas as small as five acres. More than one hundred soil series are recognized on detailed soil maps in the area identified as Miami in the 1912 survey. (The most common soil series in this part of the state, corresponding to Soil Regions 3 and 4, are Miamian and Blount.)

How was this map prepared?

In the late 1980s, information on thousands of detailed Ohio soil maps was analyzed for the Natural Resources Conservation Service to develop a statewide geographic soil data base known as STATSGO. This data base identified 166 different groupings, or "associations," of soil series that are common in areas that could be mapped at a scale of 1:250,000. The Soil Regions of Ohio map was prepared by combining these associations into twelve regions at a scale of 1:2,500,000, with the assistance of ODNR's Division of Real Estate and Land Management's geographic information system (GIS).

Geology and Soil Regions



Soil Regions 1 through 8 represent the portion of Ohio that was covered by glacial ice during one or more glaciations. The most common soils in these regions formed in glacial deposits. The older glacial deposits are in Regions 7 and 8. Most of the soils in the glaciated part of the state are very deep to bedrock.

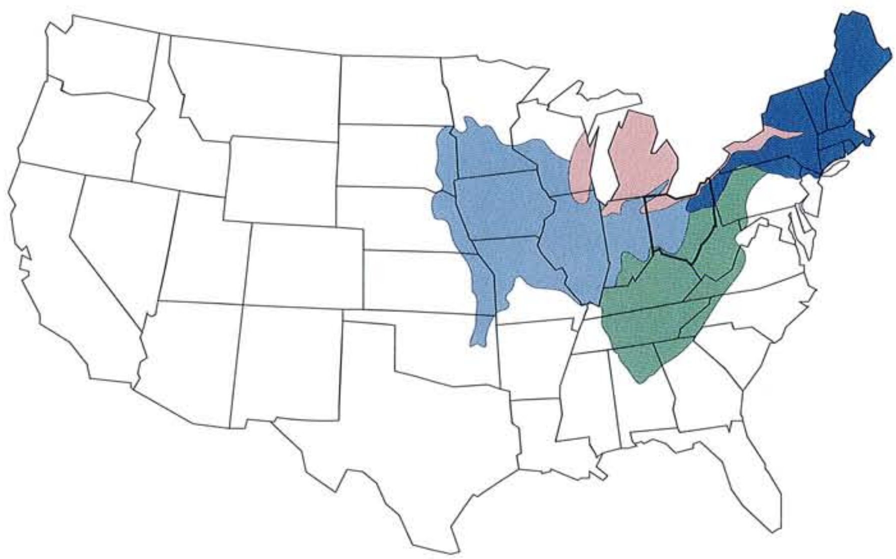
The most common soils in Regions 9 through 12 formed in materials weathered from sedimentary rocks. Because soil forms more slowly from bedrock than from unconsolidated glacial material, soils in Regions 9 through 12 tend to be more shallow to bedrock than soils in Regions 1 through 8.

Soil Regions 1, 3, 4, 7 and 9 occur in the part of Ohio where limestone, dolomite and limy shales are the most common bedrocks, and so the soils in these regions tend to have a relatively high lime content in the substratum. The glacial deposits in Regions 2, 5, 6, and 8 have a lower lime content. In most of Regions 10, 11 and 12 the soils formed in materials weathered from acid sedimentary rocks, mainly sandstone, siltstone and shale.

Soils naturally become more acid over time under Ohio's weather conditions, but soils with lime in the substratum are neutral or only slightly acid in part of the subsoil. Since most plant nutrients are chemically active under neutral or slightly acid conditions, soils with more lime in the substratum are generally more fertile for crop production. Ohio farmers commonly increase crop yields by spreading lime to neutralize the acidity of the topsoil and the upper part of the subsoil.

Soil Regions and Land Resource Regions

Because soil affects and is affected by other elements in the environment, it is not surprising that boundaries between the twelve soil regions correspond to boundaries between other natural and cultural regions. USDA Agriculture Handbook 296 recognizes 24 distinct Land Resource Regions in the country based on the following elements: land use, elevation and topography, climate, water, soils, and potential natural vegetation.



Ohio is part of four Land Resource Regions that extend from Maine to northern Alabama and as far west as eastern Nebraska.

Ohio is part of four Land Resource Regions that extend from Maine to northern Alabama and as far west as eastern Nebraska. The name of each Land Resource Region reflects the types of agricultural activities that affect the economy and ecology of that region. A brief summary of characteristics of Ohio's soil regions, by Land Resource Regions and by subregions called Major Land Resource Areas (MLRA), follows:

LAND RESOURCE REGIONS IN OHIO

Lake States Fruit, Truck, and Dairy Region: The most common soils in Ohio Soil Regions 1 and 2 formed in lake and beach sediments and in glacial till associated with glacial lakes. Region 1 is part of the Erie-Huron Lake Plain (MLRA 99), and Region 2 is part of the Erie Fruit and Truck Area (MLRA 100). Region 1 is characterized by nearly level crop fields with drainage ditches and subsurface drains. Coarser-textured and sloping or steep soils are more common in Region 2, which is also more urbanized.

Central Feed Grains and Livestock Region: Ohio Soil Regions 3, 4, 5 are part of the Indiana and Ohio Till Plain (MLRA 111). The glacial deposits in Region 4 are coarser-textured than those of Regions 3 and 5, and well drained soils such as the Miamian soil are more common in this region than elsewhere in MLRA 111 in Ohio. Region 7 is associated with the Southern Illinois and Indiana Thin Loess and Till Plain (MLRA 114). Because the soils in this region formed in older glacial deposits than the soils in MLRA 111, they are more weathered and less fertile for crop production.

East and Central Farming and Forest Region: Ohio Soil Region 9 is on the fringe of the Kentucky Bluegrass (MLRA 121), Regions 10 and 11 make up nearly all of the Western Allegheny Plateau (MLRA 124), and Region 12 is in the Central Allegheny Plateau (MLRA 126). These soil regions are heavily wooded and include many scenic areas. Soil Regions 10, 11 and 12 include areas where coal has been surface-mined. Many of the less sloping areas in Region 10 are associated with the remnants of an ancient stream system. Relatively wide ridgetops and valleys are associated with Region 11. Soils with a clayey, red or yellowish brown subsoil are common in Region 12.

Northeastern Forage and Forest Region: Ohio Soil Regions 6 and 8 are in the Eastern Ohio Till Plain (MLRA 139). The glacial deposits in Region 6 range from coarse-textured to fine-textured, but coarser-textured and better drained soils are more common in the southern portion of the region. Dairy farms are still common, but many areas that were once farmed are now in urban or wooded areas. Many areas in Region 8 have soils similar to those in Region 11 (note Westmoreland). Glacial deposits are relatively thin in Region 8, and have eroded from many of the steeper areas.

Soil Characteristics by Region

Percentage of Soils in Regions with Selected Characteristics												
	REGION NUMBER											
CHARACTERISTICS	1	2	3	4	5	6	7	8	9	10	11	12
More than 8 percent slope	1	7	6	19	12	17	38	65	83	79	68	88
More than 3 percent organic matter in the upper 10 inches	63	8	32	20	14	2	<1	<1	5	<1	2	<1
More than 27 percent clay in the topsoil	61	11	32	22	11	2	2	<1	38	1	3	40
Seasonal high water table less than 1 foot below the surface	63	24	31	17	17	15	20	2	<1	1	3	<1
Bedrock less than 40 inches below the surface	<1	11	1	2	<1	3	7	26	49	25	14	19

Significance of Selected Characteristics

Slope: Slope, expressed as a percent, measures the change in elevation over a distance of 100 feet. For example, an 8 percent slope has a change in elevation of 8 feet over a horizontal distance of 100 feet. Soils on slopes of more than 8 percent generally do not meet the criteria for "prime farmland," because of the hazard of erosion on cropland. Soils on slopes steeper than 8 percent commonly have at least moderate limitations for urban uses.

Organic Matter Content in the Upper 10 Inches: As plants and animals live and die on and in soil, they contribute organic matter that is then decomposed by micro organisms in the soil. Organic matter contributes to the fertility and stability of the topsoil. The soils in Ohio that have more than 3 percent organic matter in the upper 10 inches are most commonly associated with areas that were in prairie grasslands and elm-ash swamp forests at the time of settlement. The higher organic matter content in these soils make them appear darker in color at the soil surface than the more common soils in Ohio.

Clay Content in the Topsoil: Clay particles are very small (less than .002 millimeters in diameter), but they have a big effect on soil texture, and determine how "sticky" the soil becomes when it is wet. Topsoil with a silt loam texture has less than 27 percent clay, and such topsoil is dominant in all but one soil region in the state. Topsoil with a silty clay loam, clay loam, silty clay or clay texture is generally more difficult to till or excavate, especially when it is wet.

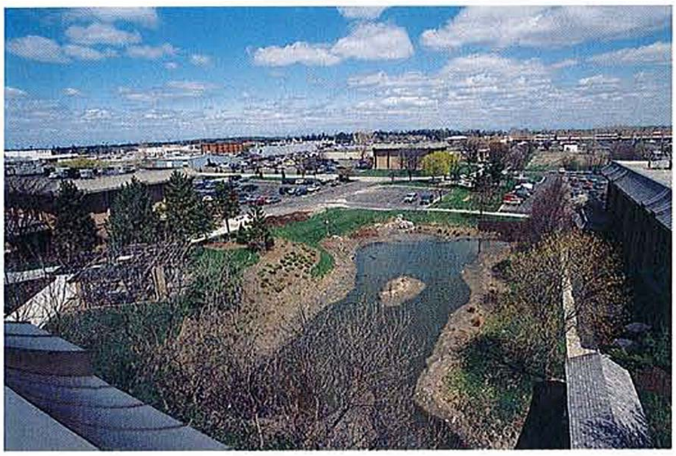
Depth to Seasonal High Water Table: Water accumulates in soils that receive rainfall or runoff from adjacent slopes faster than it can move through the soil. Soils that are not saturated for more than a few days in the typical year are generally the easiest to manage for a wide variety of uses. Wetlands are common in soils that are saturated in the upper 12 inches for a month or more during a typical year.

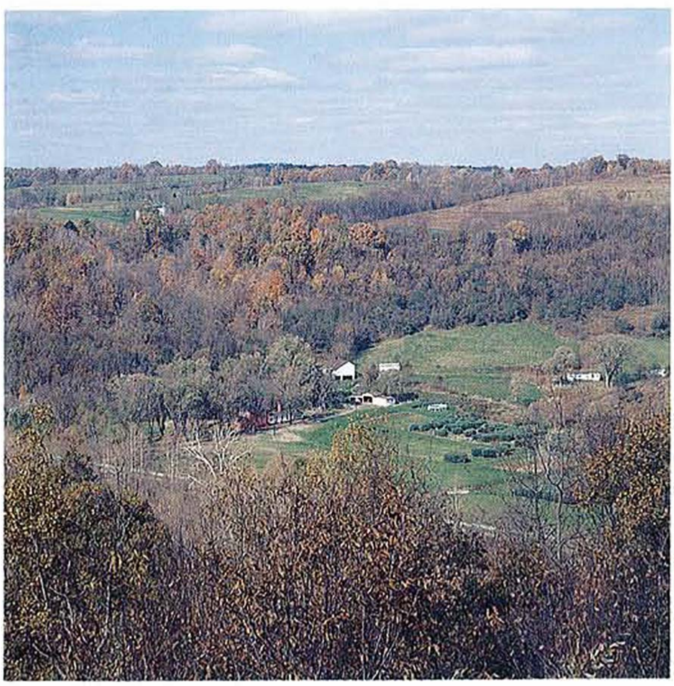
Depth to Bedrock: Glacial material, hundreds of feet thick in places, covers the bedrock in much of the western and north-eastern parts of the state. Bedrock is encountered in construction projects more commonly in the other areas of the state. Crop growth on soils with bedrock less than 40 inches below the surface is restricted during part of many growing seasons because of insufficient moisture available to the root system.

Soil surveys in the state are conducted under the guidance of the Ohio Soil Inventory Board, whose membership includes representatives from the Ohio Department of Agriculture, Division of Soil and Water Conservation; United States Depart-ment of Agriculture, Natural Resources Conservation Service; and Ohio Agricultural Research and Development Center.

Soil is one of our most basic natural resources, but we rarely see more than its surface - and even that is usually hidden by pavement, crops or trees. To most people, the soils of Ohio all look and feel pretty much the same. However, farmers and builders know that soils differ within most fields and city blocks. Soils are also different from region to region across the state.

The vast majority of soils are composed mostly of mineral material - small bits of decomposed rock. But soil is more





than a collection of mineral particles. Pore spaces between these particlescontain air and water required by the plants and animals living in the soil. Most soils also contain organic matter (from plants and animals), which darkens the uppermost layer of soil and affects the way in which soil particles hold together. While many people think of soil as "dead", soil literally teems with life, from roots, insects and worms to molds, fungi and bacteria that number in the billions.

Soils form slowly over time as the mineral particles from geologic or "parent" materials are changed by the effects of weather, plants and animals in a landscape setting. Soils vary between regions largely because there are so many different types of parent material across the state.

This publication describes how, over the past century, soil scientists have identified more than 400 different kinds of soils, called series, in Ohio. It also describes how the soil regions are related to geologic regions and to four nationally recognized agricultural regions. Finally, this publication provides information about five basic soil characteristics in each of the soil regions.

Ohio Department of Agriculture

Division of
Soil and Water Conservation
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OHIO GEOLOGY

GEOFACTS No. 23

OHIO DEPARTMENT OF NATURAL RESOURCES • DIVISION OF GEOLOGICAL SURVEY

A BRIEF SUMMARY OF THE GEOLOGIC HISTORY OF OHIO

GEOLOGIC PERIOD[1] (million years ago)	SETTING	LIFE FORMS	ROCK TYPES	ECONOMIC PRODUCTS
Quaternary 2.6 mya–Present	Two-thirds of Ohio was covered by mile-thick ice during glacial periods.	• many large mammals such as mastodons, mammoths, giant beavers, and ground sloths, as well as modern plants and animals, including humans	• glacial till, clay, silt, sand, gravel • form the surface sediments in northern and western Ohio	• common clay products (clay) • material for road construction and cement (sand, gravel) • Sand and gravel are also important aquifers
Mesozoic & Tertiary 251–2.6 mya	Ohio was above sea level, and weathering erosion and nondeposition prevailed.	• no known record, but dinosaurs probably roamed Ohio during the Mesozoic		
Permian 299–251 mya	During early Permian time, southeastern Ohio was a coastal-plain swamp. Ohio lay about 5° north of the Equator. The swamp eventually was filled by influx of deltaic sand and mud. Later Permian time was characterized by uplift and erosion.	• sparse freshwater fossils such as snails, clams, fishes • marine fossils rare • sparse land fossils include plants, amphibians, reptiles	• sandstone, shale, freshwater limestone, coal • form the surface rocks in southeasternmost Ohio	• crushed stone (limestone) • electric power (coal)
Pennsylvanian 318–299 mya	Ohio in Pennsylvanian time was a relatively flat coastal-plain swamp in equatorial latitudes. Fluctuations in sea level resulted in alternating terrestrial, freshwater, and marine deposits.	• land plants abundant • terrestrial and freshwater life included amphibians, reptiles, freshwater clams • marine life included crinoids, snails, cephalopods, brachiopods, fishes • trilobites rare	• sandstone, conglomerate, shale, clay, limestone, coal, flint, ironstone • form the surface rocks in eastern Ohio	• building stone, crushed stone for construction and industrial uses such as glass manufacturing, oil and gas (sandstone) • crushed stone for construction and cement (limestone) • pottery and common clay products (shale, clay) • electric power (coal) • during the 1800s Ohio was a major iron-producing state
Mississippian 359–318 mya	During latest Devonian and early Mississippian time, dark organic muds gave way to fluvial and deltaic silts and sands. Ohio lay in equatorial latitudes. During late Mississippian time, a shallow sea deposited limy sediments. During latest Mississippian time the seas retreated, leaving a sparse rock record.	• brachiopods, clams, crinoids, fishes • land plants increasingly abundant	• sandstone, siltstone, conglomerate, shale, limestone • form the surface rocks in northwestern and east-central Ohio	• building stone, crushed stone for construction and industrial uses, oil and gas (sandstone) • crushed stone for construction and cement (limestone) • common clay products (shale) • Ohio has been a major producer of building stone from the Mississippian Berea Sandstone for over 150 years
Devonian 416–359 mya	Most of Ohio was dry land during early Devonian time, although the sea still covered eastern Ohio. Ohio was in equatorial latitudes. During Middle Devonian time, warm, shallow seas deposited limy sediments. Layers of muddy sediments and some volcanic ash during late Middle Devonian time signaled renewed volcanic activity and mountain building east of Ohio. During late Devonian time, the Ohio sea became stagnant; circulation was poor, and the water was generally anoxic (lacking oxygen). Thick layers of black, organic-rich, uranium-bearing mud were deposited in these "stinking seas."	• coral reefs, bryozoans, brachiopods, trilobites, cephalopods, clams, crinoids, ostracodes • first major appearance of sharks and bony fishes during Middle Devonian • true land plants appear	• limestone, dolomite, shale, sandstone • form the surface rocks in northwestern Ohio, through central Ohio, and along the Lake Erie shore	• crushed stone for construction and cement, aglime (limestone & dolomite) • synfuels and natural gas (shale, sandstone, limestone)

continued

GEOLOGIC PERIOD[1] (million years ago)	SETTING	LIFE FORMS	ROCK TYPES	ECONOMIC PRODUCTS
Silurian 443–416 mya	At the beginning of Silurian time, Ohio was dry land subject to erosion. Then warm, shallow seas returned. Ohio lay 20° south of the Equator. Middle Silurian seas were deeper and covered Ohio; reef environments were common. Late Silurian seas were shallower and formed evaporite (salt-bearing) basins in northern Ohio.	• coral reefs abundant, also echinoderms, clams, brachiopods, cephalopods	• limestone, dolomite, shale, gypsum • form the surface rocks in western Ohio • salt and sandstone (eastern Ohio) present in the subsurface	• crushed stone for construction and cement, aglime, oil and gas (limestone, dolomite, sandstone) • road salt (salt) • wallboard (gypsum)
Ordovician 488–443 mya	A warm, shallow sea (deeper in eastern Ohio) similar to the Bahamas covered Ohio, which lay 20° south of the Equator. The western part of Ohio, at times, emerged as low muddy islands. Limy sediments were dominant. Volcanic activity and mountain building to the east of Ohio produced periodic layers of ash over the entire state and muddy deltaic sediments in eastern Ohio. The sea deepened during later Ordovician time, covering all of the state. At the close of Ordovician time, continental glaciation in the southern hemisphere lowered sea level and the seas retreated.	• bryozoans abundant, also brachiopods, cephalopods, trilobites, horn corals, snails, clams, echinoderms, graptolites • Ohio is world famous for its fossiliferous Ordovician rocks in the Cincinnati area	• limestone, shale • form the surface rocks in southwestern Ohio • dolomite in subsurface	• crushed stone (limestone) • oil and gas (limestone, shale) • in 1884 the first giant U.S. oil field was discovered in Ordovician rocks in northwestern Ohio • limestone in the Cincinnati area formerly was a source of building stone
Cambrian 542–488 mya	Marine seas gradually flooded the Precambrian land surface and covered Ohio by late Cambrian time, initially depositing sands, then silts, muds, and limy muds. Ohio lay 10° south of the Equator. Toward the end of Cambrian time, limy sediments accumulated in a shallow marine sea in an arid climate.	• marine life abundant, but few fossils known from Ohio because knowledge is limited to core samples • trilobites reached their peak diversity during the late Cambrian	• sandstone, shale, dolomite • present in subsurface only	• oil and gas (sandstone, dolomite)
Precambrian 4.6 billion–542 mya	Between 1.4 and 990 million years ago, volcanic activity, crustal rifting, and filling of basins formed by rifting took place. Between 990 and 880 million years ago, a mountain range formed in eastern Ohio. Between 880 and 544 million years ago, these mountains were eroded, reducing the landscape to a gently rolling surface.	• none known from Ohio • algae and lower invertebrates found in areas other than Ohio	• igneous, metamorphic, and metasedimentary rocks • present only at great depths—2,500 to 13,000 feet beneath the surface	• no current production

[1]Time assignments are based on U.S. Geological Survey Fact Sheet 2010-3059, *Division of Geologic Time—Major Chronostratigraphic and Geochronologic Units*, 2010, available at <http://pubs.usgs.gov/fs/2010/3059/>.

DIVISION OF GEOLOGICAL SURVEY
OHIO DEPARTMENT OF NATURAL RESOURCES
STATE OF OHIO

• This GeoFacts compiled by staff of Division of Geological Survey • Revised June 2014 •

OHIO GEOLOGY

GEOFACTS No. 33

OHIO DEPARTMENT OF NATURAL RESOURCES • DIVISION OF GEOLOGICAL SURVEY

ICE AGE IN OHIO: EVIDENCE BELOW OUR FEET

Imagining ice thousands of feet thick trudging over much of Ohio's landscape during the most recent ice age is overwhelming, especially because these ice sheets are completely absent from Ohio today. However, the debris left behind by glaciers informs us of not only the former presence of ice, but how the mass moved across the land. A simple way to visualize when and where ice advanced, retreated, or stagnated across the state is to study the distribution of glacial landforms in Ohio. Glaciers are not strictly composed of ice; rather, they contain significant amounts of rocks, wood, and other debris from the surrounding landscape. This mass of material is transported and eventually deposited directly by the ice (known as *till*) or can possibly be carried far away by discharging meltwater as outwash. Moraines are the most notable glacial feature created directly by ice movement and are composed of a mixture of till and debris. From flat till plains to morainal hills, much of the material we see on Ohio's surface today is a result of processes that occurred during several events in the Pleistocene, an epoch lasting from about 2.6 million until 11,700 years ago. Only materials deposited during the most recent Wisconsinan Glaciation (24,000–13,000 years ago) remain relatively well preserved compared to earlier events, such as the Illinoian Glaciation that began about 300,000 years ago.

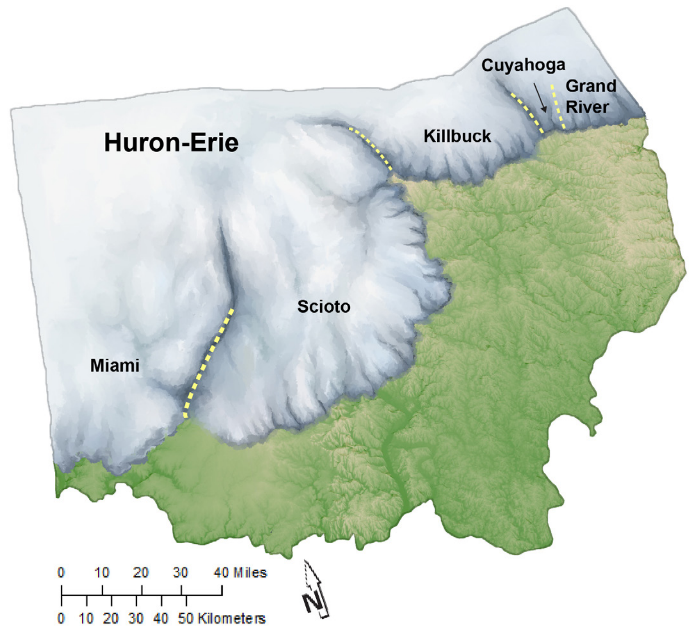

Figure 1. A generalized depiction of the Laurentide Ice Sheet over Ohio during the Late Wisconsinan (last glacial maximum position, approximately 21,000–18,000 years ago) with the associated sublobes of the Huron-Erie Lobe (yellow dashed lines) labelled. The Appalachian Plateau covers most of the unglaciated region in eastern Ohio. Illustration by Madison Perry.

ICE LOBES OF OHIO

Southward glacial expansion from northern Canada began more than two million years ago (mya), during the early Pleistocene, and resulted in the formation of a continental ice mass known as the Laurentide Ice Sheet, which extended into the northern United States and eventually covered approximately two-thirds of Ohio. The ice sheet grew and advanced as the accumulation rates of ice mass exceeded ablation (ice removal or melting) rates. Physical ice movement was attributed to three factors: solid ice flowing internally because of the gravitational pull of glacial material downslope; ice sliding at its base caused by lubricating meltwater beneath the glacier; and underlying soils being deformed as ice progressed across the landscape. Climatic changes caused the ice sheet to advance southward and retreat northward in cycles. During ice advance and retreat, pronounced zones within the ice would move more rapidly than others. Thus, the Laurentide Ice Sheet did not move as a massive, singular block, but rather as separate ice lobes. The last ice lobe to move through Ohio was the Huron-Erie Lobe (or Erie Lobe). The ice was about one mile thick towards present day Lake Erie and thinned to about 1,000 feet towards its southern margin. The speed at which lobes traversed the landscape varied significantly throughout the Pleistocene because of climatic factors. Advance rates of tens to hundreds of feet per year during the Late Wisconsinan are estimated from age dating organic material found in glacial sediment.

The Huron-Erie Lobe was further separated into the Miami, Scioto, Killbuck, Cuyahoga, and Grand River sublobes (fig. 1) as a response to varying conditions beneath the ice, such as bedrock geology and surface topography. These sublobes are named after modern water bodies located within the path of each ice sublobe. Each sublobe had unique thickness, flow direction, and movement. In eastern Ohio, sublobe positions were predominantly controlled by the resilient Pennsylvanian-aged (323–299 million years ago) sandstones and shales of the Appalachian Plateau. To the north of this barrier, ice near present day Lake Erie flowed south and split into the Killbuck, Cuyahoga, and Grand River sublobes. These three northeastern sublobes are less defined because of a lack of clear moraine boundaries, but their paths are often identified by examining differences in soils and subsurface materials. To the west of the Appalachian Plateau, the Late Wisconsinan ice encountered less resistance from the carbonate rocks of lower elevations resulting from earlier glaciations that had travelled through these areas.

The most notable obstacle affecting ice lobe movement west of the Appalachian Plateau was the Bellefontaine outlier, located mostly in Logan and Champaign Counties. The Bellefontaine Outlier, the highest elevation in Ohio, is a glacial-sediment-covered series of uplands composed of Devonian-aged (419–359 mya) shales and limestones surrounded by older Silurian-aged (444–419 mya) carbonate rocks. The Bellefontaine outlier may be an erosional remnant, or it may have formed as a result of deep, structural faulting. As seen by the mapping of moraine distributions, the Bellefontaine outlier effectively separated the Miami Sublobe to the west from Scioto Sublobe to the east (fig. 2). During retreat, the ice became deeply lobed around this

continued

obstacle and created a complex terrain of deposits down ice of the Bellefontaine outlier between the Miami and Scioto sublobes. This complex deposit of till and other glacial material creates an area known as the *interlobate region* or *zone*. These sublobes moved almost independently of one another, which is evidenced by the intermingling of moraines and the results of radiocarbon age-dating methods.

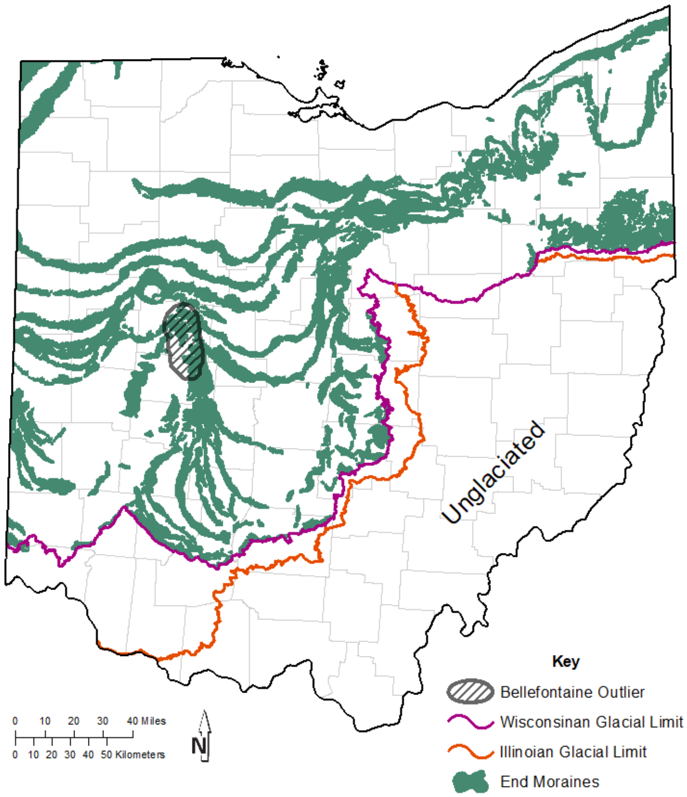

Figure 2. End moraines of Ohio with the last glacial limit (Wisconsinan) and an older glacial limit (Illinoian) denoted. Also marked is the location of the Bellefontaine outlier uplands.

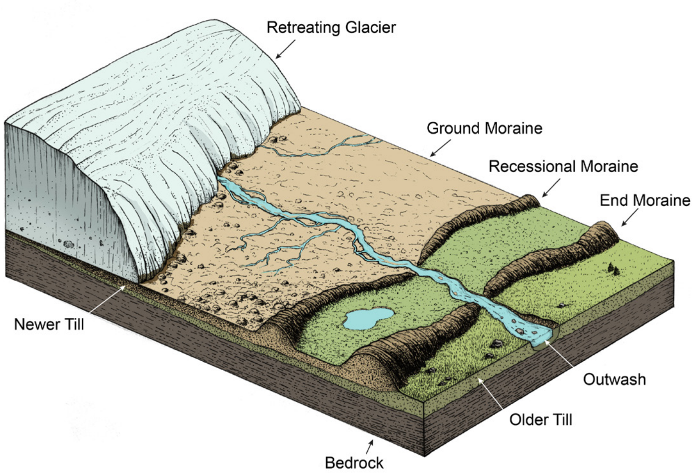

Figure 3. Conceptualized diagram of an ice sheet retreating across a land surface. Illustration by Madison Perry.

MORAINES OF OHIO

Several types of moraines cover over half of the surface of Ohio and are composed of varying amounts of boulders, gravels, sand, silt, and clay (fig. 3). End (or terminal) moraines are ridges of mostly till that form at the edge of the ice's maximum advance. Recessional moraines are similar to end moraines but were formed later, behind the end moraine as the ice lobe retreated and stagnated. In contrast, many flatter areas of till between end or recessional moraines are often ground moraines, which were deposited directly by ice sheet as a widespread blanket of mixed material. Ground moraines are generally formed when the ice was rapidly retreating; till would otherwise be deposited as an end or recessional moraine if the ice was stagnating or was slowly retreating. Moraines may take decades to form depending upon ice activity and debris supply. The assemblage of these moraines serve as geologic snapshots, indicating lobe positions at a specific point in time.

The presence of these moraine features is important when determining glacial chronology, soil characteristics, engineering properties, and aquifer potential. Moraines are often productive agricultural lands when they weather into mixed textured soils. However, compacted clay-rich tills also can have a detrimental effect on plant growth as they can act as an impermeable layer and restrict water flow. These impermeable clay layers also protect deeper water sources from pollution. Abundant clay material from till is sometimes utilized as a resource and is used in pottery, bricks, and construction purposes. Till is usually dense below the surface and is suitable for foundations or building material. Moraines may also contain lenses of stratified sand and gravel, which are typically not mineable sources for aggregates but constitute notable local groundwater aquifers.

The deposits left behind by ice ages leave a lasting impression on Ohio's scenic landscape and influence the lives of many people. Understanding glacial deposits allows us to properly utilize and protect our natural resources. Anyone can appreciate the geologic power of Ohio's ancient ice by studying detailed maps or by simply, and inquisitively, looking beneath our feet.

FURTHER READING

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• This GeoFacts compiled by Tyler A. Norris • October 2019 •
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STATE OF OHIO
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF GEOLOGICAL SURVEY

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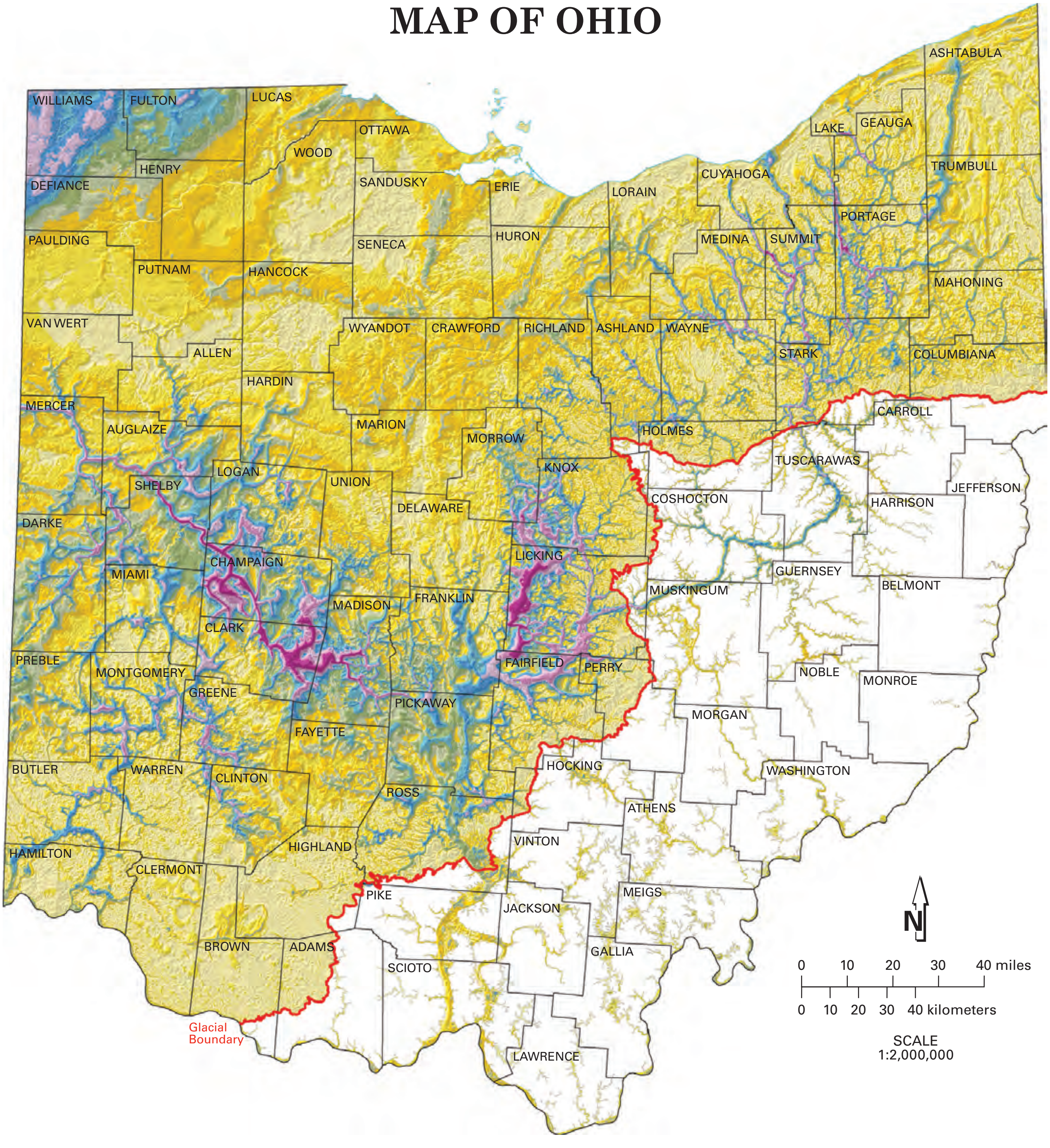
SHADED DRIFT-THICKNESS MAP OF OHIO



EXPLANATION

Thickness (in feet) of drift in glaciated areas and of outwash and glaciolacustrine deposits in sediment-filled valleys beyond the glacial boundary.

0–20	51–80	121–160	211–260	331–440
21–50	81–120	161–210	261–330	441–726

Recommended citation: Ohio Division of Geological Survey, 2004, Shaded drift-thickness map of Ohio: Ohio Department of Natural Resources, Division of Geological Survey Map SG-3, generalized page-size version with text, scale 1:2,000,000.

DRIFT THICKNESS OF OHIO

The Drift-Thickness Map of Ohio depicts the thickness and distribution of glacially derived sediments (called *drift*) and post-glacial stream sediments overlying the buried bedrock surface. This map was produced by subtracting bedrock-surface elevations from land-surface elevations to produce a residual map of drift thickness (see fig. 1). Colors portray thickness intervals of glacial and modern sediments, which range up to several hundred feet.

Prior to the onset of continental glaciation about 1.8 million years ago, the Ohio landscape was dominated by rolling hills and deeply incised, mature rivers and streams. Erosion and deposition by Ice Age glaciers advancing into northern and western Ohio produced a low-relief land surface compared to the unglaciated, high-relief land surface of southeastern Ohio.

Drift thicknesses in western and northern Ohio are highly variable, a consequence of numerous geologic factors. In some areas, drift has been deposited on a relatively flat bedrock surface and changes in drift thickness primarily are the result of variations in the amount of glacial material deposited. In other areas, drift has infilled deeply incised bedrock valleys, and changes in drift thickness primarily are the result of variations in bedrock-surface elevation. In still other areas, the drift surface parallels the underlying bedrock surface to produce areas of relatively uniform drift thickness (fig. 1).

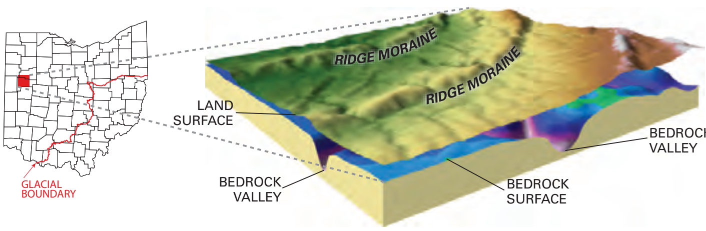


FIGURE 1.—Schematic cross section of glacial drift overlying the bedrock surface. Note areas where drift thickness is controlled by thickening of glacial sediment over a relatively flat bedrock surface, by drift infilling bedrock valleys, or by fluctuations in both the land surface and the bedrock surface. Also note areas where buried-bedrock vallys are not evident on the surface.

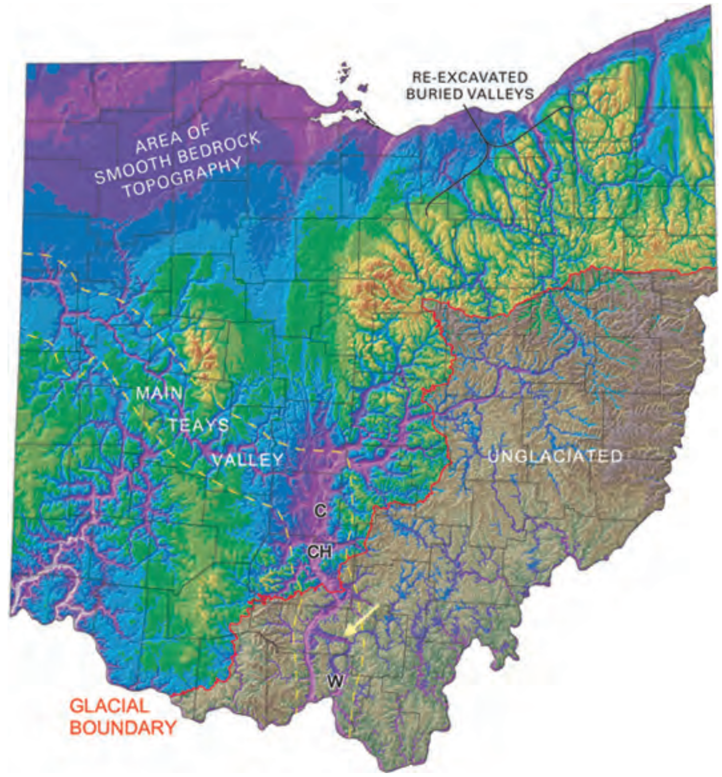


FIGURE 2.—Shaded Bedrock-Topography Map of Ohio showing the sculpted bedrock surface that lies beneath glacial drift in northern and western Ohio and the land surface in unglaciated southeastern Ohio. Note the surface expression of the Teays Valley System south of the glacial boundary (arrow), the location of the main Teays Valley (between yellow dashed lines), the area of smooth bedrock topography, and the area of re-excavated preglacial bedrock valleys in northeastern Ohio. **C** = Circleville, **CH** = Chillicothe, **W** = Wheelersburg (modified from Ohio Geological Survey, 2003).

Distinct, narrow linear patterns of thick drift in western and central Ohio are the result of deep incisions in the underlying limestone and dolomite bedrock by a large, northwest-flowing drainage system—the Teays Valley—which existed prior to and during early glaciations (fig. 2). The main Teays Valley entered Ohio at what is now Wheelersburg (Scioto County), where remnants of the Teays Valley still are evident on the land surface. At Chillicothe (Ross County), the valley disappears under glacial sediments that cover western Ohio. However, the valley continues north, below the surface, to Circleville (Pickaway County) and then northwest to Mercer County where the valley exits the state into Indiana. Early southward-advancing glaciers blocked the north-flowing river system of the Teays and created immense lakes in southeastern Ohio (Hansen, 1995).

In northeastern Ohio, narrow areas of thick drift located south of Lake Erie also were preglacial bedrock valleys. These valleys were partially filled with thick deposits of till and glaciolacustrine (glacial lake) sediment and then re-excavated later by northward-flowing rivers, such as the Cuyahoga River and the East Branch of Rocky River.

In northwestern Ohio, repeated scouring of the relatively soft bedrock surface by glacial ice flowing southwestward from the Lake Erie Basin destroyed most pre-existing drainage systems. In this part of Ohio, the bedrock surface is smooth and the upper surface of the drift has been planed off by both wave action and deposition by a post-glacial, high-level ancestral Lake Erie. In the extreme northwest corner of Ohio, in Williams County and portions of Defiance County, drift thickens considerably because of numerous moraines that formed along the northwestern edge of the Erie Lobe.

In western Ohio, draping linear features of thick drift, called *ridge moraines* (fig. 1), formed along the temporarily stationary ice front as glacial sediment was released from the ice. These ribbons of thick drift define the lateral dimensions of glacial ice lobes. Many ridge moraines in western and northeastern Ohio have a draped appearance because southward-flowing ice, impeded by bedrock highlands, moved more easily along major lowlands. The numerous resistant bedrock highlands in northeastern Ohio caused ridge moraines to be especially curved and closely stacked.

Southeastern Ohio is unglaciated and devoid of ice-deposited sediment (glacial till). However, many valleys in this area carried huge volumes of glacial meltwater away from the ice front and toward the Ohio River. In the process, many of these valleys at times were made deeper by the erosive force of fast-flowing meltwater streams. At other times, these valleys were partially filled with sediment. Some valleys in unglaciated Ohio contain thick deposits of clay and silt which accumulated on the bottoms of lakes that formed when glacial ice blocked the flow of rivers or when rapidly accumulating meltwater sediments blocked the mouths of smaller tributaries.

This map is a reduced version of Map SG-3: *Shaded Drift-Thickness Map of Ohio* (Powers and Swinford, 2004). For more information or to order a copy of Map SG-3, visit the Geologic Records Center, 2045 Morse Rd., Bldg. C, Columbus, OH 43229; or call (614) 265-6576; or visit the Division of Geological Survey website: **OhioGeology.com**.

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Ohio Geological Survey, 2003, Shaded bedrock topography of Ohio: Ohio Department of Natural Resources, Division of Geological Survey Map BG-3, scale 1:500,000.

Powers, D.M., and Swinford, E.M., 2004, Shaded drift-thickness map of Ohio: Ohio Department of Natural Resources, Division of Geological Survey Map SG-3, scale 1:500,000.

2022 NCF-Envirothon Ohio

Soils and Land Use Study Resources

Key Topic 2: Soil Ecosystems and Soil Fertility

7. Describe the cycles of essential elements (such as nitrogen, phosphorus, and carbon) as they relate to soil, nutrient availability, and plant growth.
8. Explain how plants take in nutrients and water, and what soil conditions and characteristics influence this uptake.
9. Describe the ecosystem services provided by soil, such as water filtration, carbon sequestration, nutrient cycling, et cetera.
10. Explain how soils impact the biodiversity of an ecosystem, and how biodiversity in an ecosystem may impact the soil.
11. Describe the procedures for taking soil samples and conducting nutrient analyses and apply them to field scenarios.
12. Describe the composting process and explain how compost can improve soil structure and health
13. Explain the process of using plants to remove contamination and apply it to field scenarios.

Study Resources

Resource Title	Source	Located on
Chapter 4 of the Urban Soil Primer	*USDA NRCS, Scheyer, J.M., and K.W. Hipple. 2005*	Pages 33-39
Soil Testing for Ohio Lawns, Landscapes, Fruit Crops, and Vegetable Gardens – HYG-1132	*Joe Boggs, Cindy Meyer, Gary Gao, and Jim Chatfield, The Ohio State University, January 2017*	Pages 40-47
Tri-State Fertilizer Recommendations for Corn, Soybean, Wheat, and Alfalfa, Bulletin 974	*Culman, S., Fulford, A., Camberato, J., & Steinke, K., The Ohio State University, Updated 2020*	Pages 48-58
Composting Tip Sheet	*USDA NRCS, 2017*	Pages 59-62
A Citizen's Guide to Phytoremediation, EPA 542-F-12-016	*USEPA Office of Solid Waste and Emergency Response, September 2012*	Pages 63-64
5 Best Plants for Phytoremediation	*Land 8 Landscape Architects Network, Boi, Jay. November 30, 2015*	Pages 65-70

Study Resources begin on the next page ➡

Chapter 4: Soils Sustain Plant and Animal Diversity and Productivity

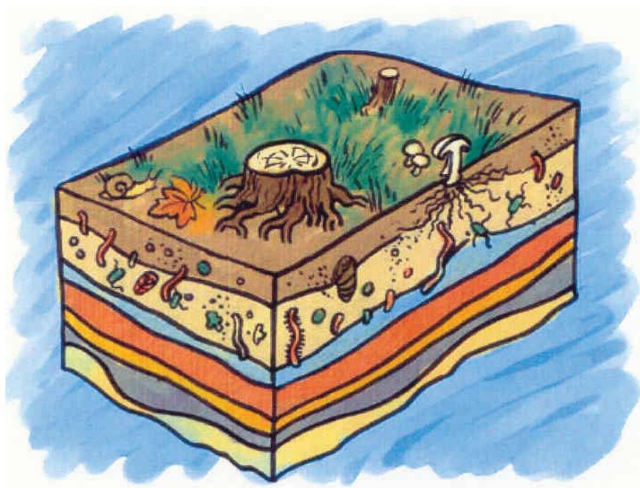

Figure 4.1

Whether they are in urban or natural areas, soils provide living space and supply air, water, and nutrients for micro-organisms, plants, animals, and humans. In most areas, soil properties determine which plants and animals can live in and on the soil. Urban soils that have been disturbed and mixed may no longer possess the natural characteristics needed to support life. Soil amendments may be required to reestablish plants. In many urban areas, the remaining soil materials must be modified before they can support plant and animal life.

Topics in this chapter:

- **Soil fertility and plant nutrition**
- **Soil acidity**
- **Soil organisms and biochemistry**
- **Soil as a filter and buffer for waste**
- **Identifying problem sites from historical records**
- **Identifying problem sites by visual clues**
- **Precautions for community gardens, playgrounds, and parks**
- **Historical tidbits on waste management**

Soil Fertility and Plant Nutrition

Management of urban soils for productive gardens requires a basic understanding of physical and chemical soil properties. Local sampling and testing can help gardeners to determine the suitability of urban soils for certain plants and the need for fertilizer, or plant food (table 4.1).

Table 4.1: Examples of the Factors That May Affect the Productivity of Urban Soil

- Little or no addition of organic matter
- Artifacts that disrupt water movement
- Elevated salt content
- Interrupted nutrient cycling and modified activity of micro-organisms
- High soil temperatures that increase the rate of chemical reactions
- Generally higher pH values resulting from additions of cement, plaster, and road salts
- Lateral (sideways) subsurface waterflow resulting from compacted layers

Meeting the nutritional needs of urban plants requires consideration of soil moisture and temperature as well as the chemicals and biological organisms needed to convert fertilizers into useful nutrients. Plant selection may vary according to the grower's nutritional needs, cultural traditions, soil conditions, and the space available. Plants common in different diets can be successfully grown in urban areas (figures 4.2 and 4.3). Attention must be paid to different plant tolerances for metals and to drainage, the growing season, and weed control.

Figure 4.2: Produce from a home garden.

Figure 4.3: Intensive home garden in an urban area

Plant growth and nutrition are closely linked to soil properties. The ability of soil particles to hold and release nutrients for plants and micro-organisms to use is called the cation-exchange capacity (CEC). This capacity determines which nutrients stay in solution and are available for uptake by plant roots and which nutrients are moved through the soil and thus are not available for plant and microbe use. Cations in the soil are positively charged nutrients, such as nitrogen, sodium, calcium, and potassium. Different plants and microbes require different kinds and amounts of nutrients. Trace metals also are nutrients in the soil. They generally are used in very small amounts. Such trace metals as iron and manganese are necessary for plant growth. Also, they help plants to fight diseases. Metal mobility and potential toxicity in soil occur at the lower pH levels and depend on metal binding through cation exchange.

Various kinds of clay in the soil attract and hold cations onto negatively charged parts of their surfaces. Certain clays internally bind some chemicals very tightly. As a result, it is difficult for plants to obtain the necessary nutrients from the soil solution. In areas of these highly active clays, we often add lime (calcium carbonate) to reduce the acidity of the soils and facilitate release of the nutrients from the clays into soil solution.

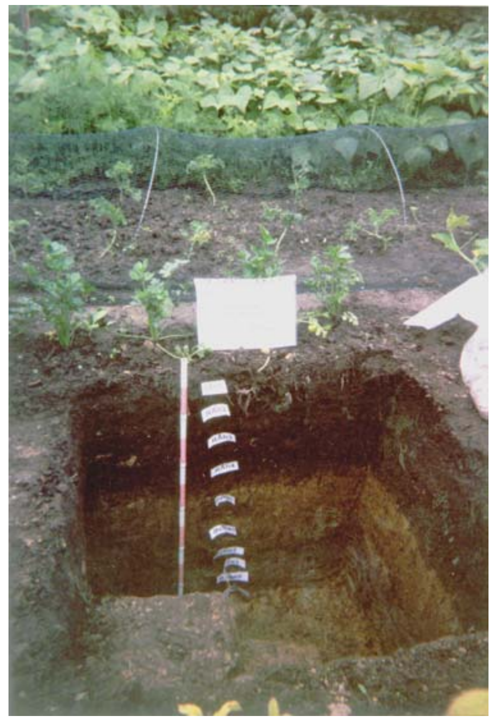

Figure 4.4 Soil profile in a long-term garden.

Organic matter has many active sites that bind chemicals in a manner similar to the way clay particles bind the chemicals in the soil. Organic matter is often visible in a thick, dark surface layer, in which plants begin to grow and take up nutrients. Clays and other soil materials are mixed with the organic matter in each soil layer to form a chemical system. Intensive vegetable gardening over many years during which unused plant materials and organic waste are returned to the soil can produce a thick, dark surface layer of organic matter. The color of the resulting dark surface layer may contrast with the color of the underlying soil, as is shown in figure 4.4, which pictures a 100-year-old continuous vegetable garden.

Soil Acidity

An acid is a substance that has a positive charge and usually yields hydrogen ions when dissolved in water. Hydrogen ions are positively charged. The stronger the acid, the better it dissolves in water. The pH scale (1-14) is a common measure of soil reaction. The lower the number, the greater the acidity. The midpoint of the pH scale is neutral (7.0), a good level for the growth of most plants.

Changes in soil reaction, as measured by pH, have significant effects on metals in soil. Metal toxicity to plants and animals increases in strongly acid soils with a low pH (3.5). Metals in these soils are released from negative sites back into soil solution. At a higher pH (8.5), the metals often are sequestered in the soil. The term "sequestered" indicates that the positively charged metal ions are bound tightly to negatively charged sites in the soil. These sites may be on clays, mineral compounds, or organic matter, including the surfaces of some micro-organisms. These strong, tight bonds restrict the availability of metals for plant uptake and reduce the risk of animal consumption or human skin contact.

Soil Organisms and Biochemistry

Soil is made up of mineral particles and organic matter, the decomposed remains of living things. Bacteria, fungi, and other micro-organisms are largely responsible for breaking down dead plants and animals in the soil. Small organisms (microbes) have negatively charged sites where soil nutrients and metals can bind to form soil aggregates and compounds. Earthworms and larger animals eat and digest organic materials and minerals, transform them into soil aggregates, and deposit them as waste. Soil aggregates are loose groupings of many different soil components in a structure allowing water and air movement as well as biochemical reactions for energy production and nutrient cycling (figure 4.5).

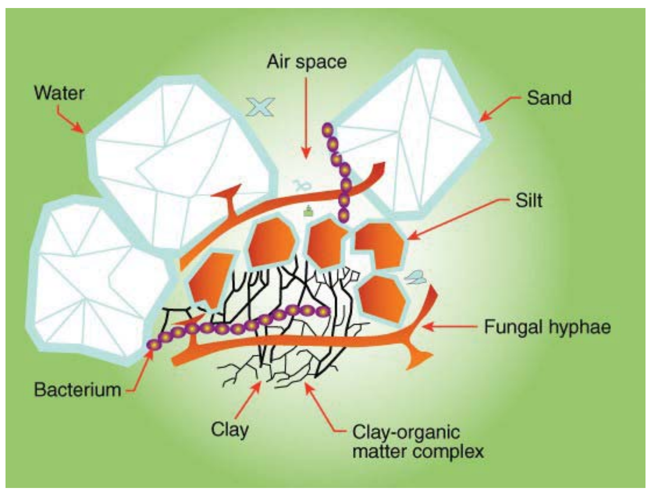

Figure 4.5 : Soil components at a microbial scale.

Soil as a Filter and Buffer for Waste

Managing compost and organic waste is important for plant nutrition and for the biological degradation and conversion of contaminants into inactive forms in the soil. Two key ways to manage waste are filtering and buffering. Waste is filtered when it flows through the soil and is slowly trapped and bound to soil particles. Soil buffering traps waste particles and transforms them into inactive forms.

Composting and using septic systems are examples of waste management in urban soils. Organic materials are needed to hold water and nutrients in the soil for plant growth. In urban parks and community gardens, as well as suburban home gardens and yards, composting can recycle most of the leaves and grass clippings (figure 4.6). This management alternative provides inexpensive soil conditioner that increases porosity and improves the rooting environment for plants.

The major considerations in applying yard and garden waste after composting are plant nutritional needs and the potential of the compost to contain weed seeds or contaminants. Existing resources from the Cooperative Extension Service provide guidelines for managing compost in a manner that maximizes the nutrient content and minimizes the transfer of diseases or contaminants. The same practices work for

Figure 4.6: Composting barrels or traditional fenced piles fit different management intensities in home gardens.

organic waste whether from urban or agricultural sources, and the economic benefits of recycling apply to both.

Understanding the role of soils in septic systems helps residents of small towns or remote housing developments to manage the return of some nutrients to the soil. The liquid septic effluent can provide nitrogen and phosphorus for use by the roots of lawn grasses. Lawn areas receiving liquid drainage from poorly designed or failing septic systems may appear darker green and have thicker grass than surrounding lawn areas. Lakes surrounded by intensive development using septic systems may have water-quality problems, such as algae blooms or high phosphorus levels, if the systems become overloaded.

Conversion of summer cottages to year-round homes may lead to septic system failure or excessive drainage of nutrient-rich septic effluent to lakes or streams. Upgrades, cleanouts, and enlargements of septic systems are needed to accommodate the amount of human waste produced and to make sure that the waste does not pollute surface water or the ground-water supply for wells. Soil properties affecting septic system design and installation include slope, depth to bedrock, permeability, depth to the water table, plasticity of the soil (possible expansion when the soil is wetted and then dried), soil texture and structure, and potential for corrosion of steel or concrete pipe.

Identifying Problem Sites From Historical Records

Metals in soils come from various sources. They may have been present in the geologic rock, or they may occur as atmospheric additions of copper, mercury, lead, and zinc. Metals also may have been deposited by past industrial activities, such as battery production, brass and steel manufacturing, mining, and many different processes involving nickel, cadmium, copper, and lead. Lead is especially evident near roadways because of automobile emissions before the availability of unleaded gasoline, and automobile demolition areas may contain a variety of metals that were commonly used in older cars. As lead paints and some window blinds and soldered pipes used in houses before 1978 wear out and deteriorate, they add lead to nearby soils.

Other ongoing sources of metals and organic waste material are landfills and dump areas that are poorly maintained or unregulated. Landfill materials eventually decompose and form a highly variable type of urban soil. The volunteer vegetation may be dominated by phragmites, as is shown in figure 4.7. These sites can be reclaimed for limited recreational or industrial use.

Figure 4.7: An older landfill with phragmites.

Areas affected by city fires may have concentrated metals buried in the soils. These concentrations are discovered only by referring to historical records or by digging into the soils (figure 4.8). Major fires may leave surface residue high in contaminants. A variety of plants may still grow well, but careful evaluation of each site is needed to determine the risk to human health.

Marine sediments may be dredged and used as fill in low-lying urban areas. Contaminants in the dredged material may be moved onto a site. Other problems with water movement and root resistance may result from compaction of a subsurface layer of very fine sand.

Figure 4.8: Soil profile with a buried layer of ash and refuse. This site was burned by a city fire.

Identifying Problem Sites by Visual Clues

Metal contamination on a site may be evidenced by plant growth, animal behavior, or paint flecks containing lead from older buildings. Many plants simply cannot grow where the level of certain metals is high. Other plants grow well in contaminated soil but fail to set seed or do not grow as well as expected. Absence of any plant growth is a warning sign that a site may be severely contaminated. Caution during sampling is needed.

Metals may be present at a site but not be a high risk for gardening or recreation, depending on the soil properties, drainage, and vegetation at the site. A human health risk from mosquitoes can occur not only in areas of standing water but also in any areas near homes or on city streets with stagnant water. Compaction is often the main problem causing water to pool on the surface without infiltrating into the soil. Mixing the soil when it is just a little moist can increase the porosity (air space between particles) and allow water to soak in. Other options are to divert the water away from low spots and to create channels for storm water to flow around the site or in specific streams or ditches across the site.

Soil Testing for Ohio Lawns, Landscapes, Fruit Crops, and Vegetable Gardens

HYG-1132
Date: 01/12/2017

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Soil tests provide more helpful information on soils than any other resource. It is an inexpensive way to maintain good plant health in lawns and landscapes, and to maximize productivity of vegetable gardens and fruit crops. Soil test results pinpoint plant nutrient needs and soil test lab recommendations guide fertilizer applications so just the right amount is used. Test results also provide information for making plant selection decisions based on “the right plant in the right place” and a soil test can help diagnose what went wrong if good plants go bad.

Soil samples are sent to a soil testing lab (see table at end of the fact sheet). Results will be sent back to you along with recommendations for taking corrective actions if needed. This includes the amount of fertilizers and other additives needed to support healthy plants. Reliable fertilizer recommendations can help horticulture professionals and gardening enthusiasts make decisions that support good plant health and save money!

A standard soil test will provide information on soil pH, cation exchange capacity (CEC), lime requirement index and base saturation. The soil test will also provide the status of phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg).

For additional fees, soil testing labs will provide information on iron (Fe), manganese (Mn), zinc (Zn) and copper (Cu) as well as a few other elements depending on the soil testing lab. Soil testing labs can also provide information on soluble salts, nitrates, soil texture and the organic matter content of the soil. The extra fees for these analyses may be justified if you are trying to solve a diagnostic problem by gaining information not provided through a standard soil test.

WHY DO I NEED TO SOIL TEST?

The guidance provided by soil tests to horticulture professionals and gardening enthusiasts is sometimes compared to the guidance that blood tests provide to physicians. In this vein, a soil test is like a blood test for the soil. Soil tests can be used for four purposes: maintaining proper soil fertility; guiding plant selection; performing plant problem diagnostics; and for conforming to industry approved standard practices.

1. **Maintaining Proper Soil Fertility.** Healthy plants need certain levels of soil nutrients to thrive. Soil nutrients and fertility may fluctuate during the growing season. This is influenced by the quantity and availability of plant nutrients that are altered by the addition of fertilizers, manure, compost, mulch, and lime or sulfur, in addition to nutrient loss through leaching. Furthermore, large quantities of plant nutrients are removed from soils as a result of plant growth and development, and the harvesting of crops.

A soil test will determine the current fertility status and provide the necessary information to maintain optimum fertility year after year. Soil tests take the guesswork out of fertilization and are very cost effective; they eliminate wasteful spending on fertilizer products. Test results and recommendations help protect our environment by discouraging the overapplication of plant nutrients. Excess nutrients not used by plants may escape into groundwater, streams and lakes where they can contribute to environmental problems, such as algal blooms.

2. **Guiding Plant Selection.** Some plants will grow in a wide range of soil pH levels, while others require a narrow range of pH. Most turfgrasses, flowers, ornamental shrubs, vegetables and fruits grow best in slightly acid soils which represent a pH of 6.1 to 6.9. Plants such as rhododendron, azalea, pieris, mountain laurel and blueberries require a more acidic soil to grow well.

A soil test will determine whether the soil is acidic or alkaline. It is the most cost effective way to match the pH requirements of plants that you select with the pH of the soil in which you are planting.

3. **Performing Plant Problem Diagnostics.** Soil tests are an important tool for learning why plants lack vigor or are showing symptoms of other plant health issues. For example, Figures 1, 2 and 3 show a symptom, called chlorosis, that is typical of a nutrient deficiency in the foliage. If trees are exhibiting yellowing (chlorotic) leaves or needles during the growing season, a soil test may reveal whether the symptom is caused by a lack of an essential nutrient, a problem with the soil pH or both!

Figure 1: Colorado blue spruce showing a nutrient deficiency symptom. *Photo by Joe Boggs, Ohio State University Extension.*

4. **Conforming to Industry Approved Standard Practices.** The American National Standards Institute (ANSI) is a private, non-profit organization that oversees the development process and approval of voluntary consensus standards for the private sector in the United States. The Tree Care Industry Association (TCIA) is accredited by ANSI to develop the actual standards known as ANSI A300 Tree Care Management standards. They are the generally accepted industry standards for tree care practices.

Following are recommendations from the ANSI standards specific to soil testing:

A300 (PART 2)-2011 SOIL MANAGEMENT

- 14.4.4: *Soil testing should be done prior to designing, plant selection, planting and/or developing management plans for landscapes.*
- 15.2: *Soil and/or foliar nutrient analysis should be used to determine the need, formulation and rate of fertilizer.*
- 15.6.3: *When new plants are specified, they should be tolerant of the native soil pH.*

A300 (PART 6)-2012 PLANTING AND TRANSPLANTING

- 63.3 *Plant and site inspections for transplanting.*
- 63.3.5 *Soil at the installation site should be analyzed and tested for pH, structure, texture, density, nutrients and percolation.*

Figure 2: Oak showing a nutrient deficiency symptom. *Photo by Joe Boggs, Ohio State University Extension.*

Figure 3: Red maple showing a nutrient deficiency symptom. *Photo by Joe Boggs, Ohio State University Extension.*

WHEN DO I SOIL TEST?

A soil test is used as a planning tool and the first step in learning what you need to do, or not do. Soil samples can be taken any time of the year, as long as the soil is workable. However, you should allow plenty of time to receive and evaluate your soil test results, and then take action to improve your soil fertility. Any recommended adjustments, such as a fertilizer application, should be made at the appropriate time of the year. For example, fall is the best time of the year to make a lime application to raise the soil pH, while spring is the most appropriate time of the year for a sulfur application to lower the pH.

HOW FREQUENTLY SHOULD I SOIL TEST?

A soil test every two to three years is usually adequate for maintaining soil fertility. Sample more frequently if you desire a closer monitoring of the fertility levels, or if you grow plants that require more nutrients. Soil tests for diagnostic purposes can be made as needed.

WHAT SOIL SAMPLING TOOLS DO I NEED?

1. **Soil Probe**
   A soil probe is the easiest tool for taking soil samples. Soil probes quickly extract samples to a consistent depth simplifying the job of taking soil samples, especially when taking multiple composite samples. Soil probes are also useful for assessing soil moisture to monitor irrigation needs and for evaluating

other physical properties of the soil such as compaction. Purchasing a soil probe is a good investment for horticulture professionals and serious gardeners.

Figure 4 shows examples of some typical soil probes available for purchase. Others are also available. The T-handle step probe is recommended for more compacted soils or when collecting samples in a large area such as a lawn. The longer length and welded step reduces back and shoulder strain from bending over and applying pressure to insert the probe into the soil. Figure 5 shows how a soil probe is used to collect a soil sample beneath turfgrass.

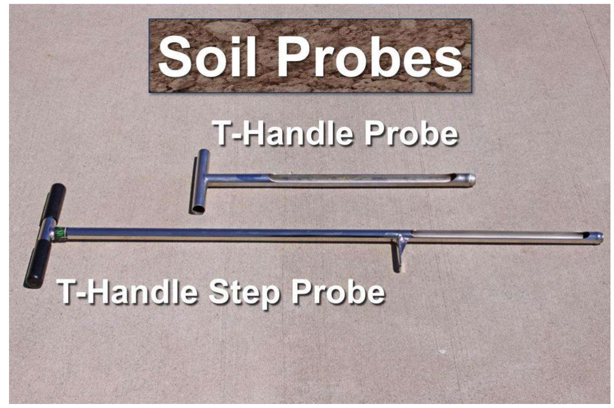


Figure 4: Soil probes provide a simple method for collecting soil samples *Photo by Joe Boggs, Ohio State University Extension.*

2. **Garden Spade, Knife or Hand Trowel**
   A garden spade, heavy gauged knife (e.g., soil knife), or hand trowel as shown in Figure 6 can also be used to take thin slices or sections of soil for gathering soil samples. These tools require more time, effort and skill for taking precise soil samples compared to a soil probe. However, they are simple and effective if you are sampling loose soil, such as in vegetable gardens and flowerbeds. They are also cost effective for lawns and landscapes if you are only performing plant nutrient maintenance tests over small areas every few years.

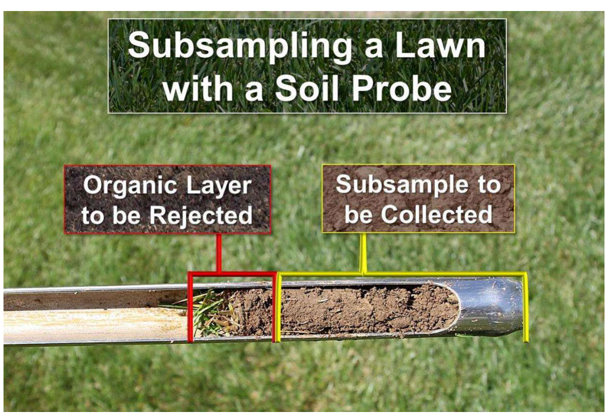


Figure 5: Using a soil probe for soil sampling in turfgrass. *Photo by Joe Boggs, Ohio State University Extension.*

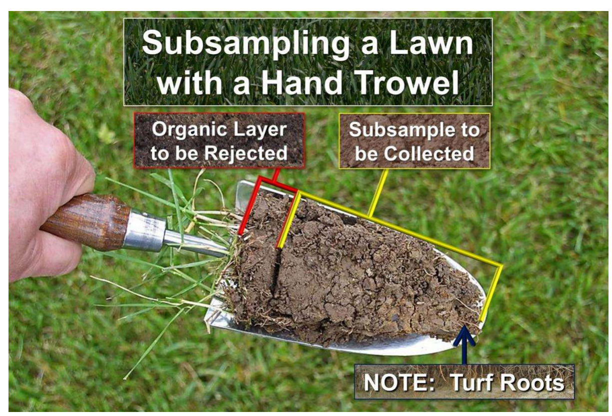


Figure 6: Using a hand trowel for soil sampling. *Photo by Joe Boggs, Ohio State University Extension.*

3. **Plastic Bucket**
   Soil samples should be collected in a clean plastic bucket or box as shown in Figure 7. Metal buckets, such as aluminum or zinc plated buckets, should never be used as the metals may contaminate the samples and influence the test results.

Figure 7: Soil samples should be collected in a clean plastic bucket. *Photo by Joe Boggs, Ohio State University Extension.*

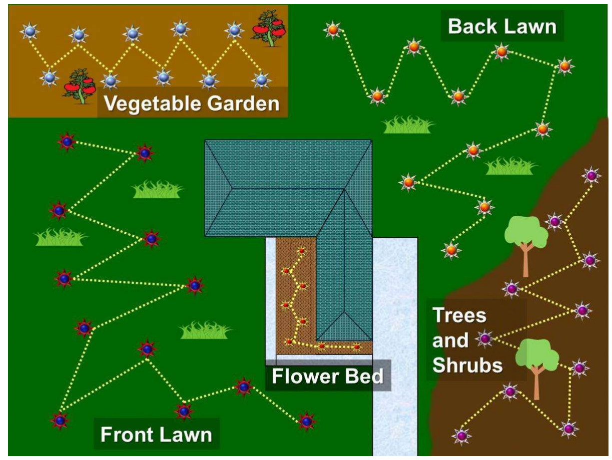


Figure 8: This graphic shows five zones that will be soil tested. The stars in the graphic show where the subsamples should be taken. The subsamples should be taken in a zig-zag pattern, shown by the yellow-dotted lines. *Graphic by Joe Boggs, Ohio State University Extension.*

HOW DO I TAKE SOIL SAMPLES?

The validity of soil test results and recommendations depend on the quality of the samples taken and sent to a testing lab. Soil fertility varies throughout a lawn, landscape, fruit planting or vegetable garden. Because of this, the soil sample sent to the lab must be representative of the entire area. Submitting a *composite sample* reduces the influence of soil fertility variations. A composite sample is a number of individual subsamples randomly collected over the entire test area. The subsamples are mixed together and a small amount of soil, about 1 pint in volume, is sent as a representative sample to the testing lab. Figure 8 shows examples of subsample numbers and patterns to create a composite sample. The number of subsamples depends upon the size of the area being tested. In general, 5 to 10 subsamples are sufficient for small areas such as flowerbeds and 10 to 15 samples are recommended for larger areas such as lawns. Subsamples should be taken at random in a zigzag pattern over the entire area and each subsample should be taken to the same depth and soil volume.

SOIL SAMPLING TIPS:

1. Separate soil tests should be used for:

- Areas that have received different applications for soil fertility programs.
- Soils distinguishable by color (i.e., light vs. dark), drainage or other factors.
- Different types of plant cultivation (i.e., turfgrass, vegetable gardens, trees/shrubs, etc.). Figure 8 shows different zones for soil sampling.

2. Sample when soils are suitable for spading or plowing.
3. Organic matter on top of the soil should not be included in soil test samples. Organic matter can affect the soil test results. This includes plants (e.g., turfgrass plants), the typical 1 inch or less “organic layer” typically found over Ohio soils, mulch, thatch, etc. Coarse organic matter, such as mulch or thatch, should be removed before taking a soil sample.

The organic layer included in soil probe (Figure 5) or hand trowel (Figure 6) samples should be removed prior to dropping the sample into a plastic bucket. Soil should be sampled to root depth, which typically means 5 to 8 inches for trees, shrubs, flowerbeds and vegetable gardens, and 3 to 4 inches for lawns. Of course, root depth may vary based on soil type and other conditions. Sample a vegetable garden between rows to avoid fertilizer bands where applications were made directly to plants.

HOW TO PREPARE SOIL SAMPLES FOR SUBMISSION

1. Contact a soil-testing lab for instructions, soil test kits and appropriate forms. A list of testing labs is at the end of this fact sheet.
2. Break up lumps and air dry the soil on parchment or butcher paper (do not use newspaper or colored paper) at room temperature with no artificial heat.
3. Dry until the lumps can be crushed to the size of wheat grains or smaller.
4. Mix well and remove roots and other large pieces of organic debris as well as small stones or rock pieces.

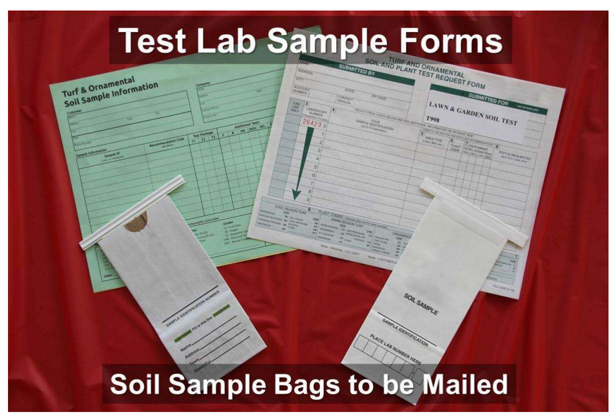


Figure 9: A typical soil test kit you will receive from the soil-testing lab.

5. Take about one pint of the composite sample and place it in the sample bag associated with the kit.

Figures 9 through 13 below illustrate a typical soil test kit that you will obtain from the lab. Make sure the information on the forms is complete so you receive recommendations for your lawn, landscape, fruit or vegetable needs. *Photos by Joe Boggs, Ohio State University Extension.*

Figure 10: Complete all forms required by the testing lab.

Figure 11: Take about one pint of the composite sample to be sent for testing.

Figure 12: The bag is filled and ready to be sent to the testing lab.

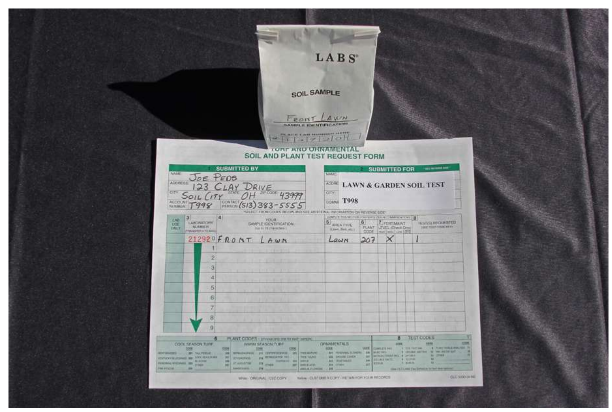


Figure 13: The form is completed and ready to be mailed with the filled bag.

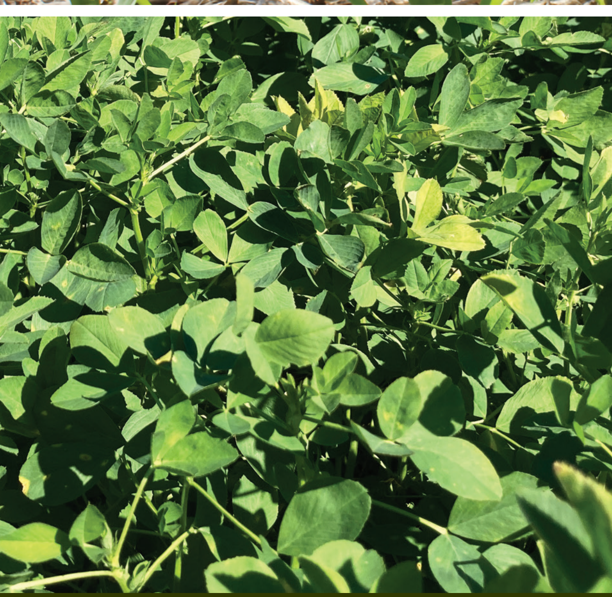
WHERE DO I SEND MY SOIL SAMPLE?

Table 1 at the end of the fact sheet shows a list of soil testing labs in Ohio and neighboring states as well as the types of materials they will test. The labs listed belong to the North American Proficiency Testing (NAPT) program that is operated under the supervision of the Soil Science Society of America (SSSA). For a fee, these labs will provide basic soil testing. Some labs also offer more advanced testing such as an

Bulletin 974

TRI-STATE FERTILIZER RECOMMENDATIONS

for Corn, Soybean, Wheat, and Alfalfa



THE OHIO STATE UNIVERSITY
COLLEGE OF FOOD, AGRICULTURAL, AND ENVIRONMENTAL SCIENCES

MICHIGAN STATE UNIVERSITY | Extension

PURDUE EXTENSION | LOCAL FACES COUNTLESS CONNECTIONS

NITROGEN

KEY CONCEPTS

- Optimizing nitrogen management is challenging and requires careful consideration of many factors.
- Nitrogen rate recommendations for corn are based on an economic model designed to maximize farmer profitability (maximum return to N (MRTN)) available at **cnrc.agron.iastate.edu.**
- Nitrogen recommendations for wheat have been updated and are similar to the original recommendations

The profitability of crop production is highly dependent on proper nitrogen (N) management, as N fertilizer represents a large fraction of the total cost of production. Unfortunately, N is the one of the most challenging nutrients to manage in field crops for a number of reasons: 1) many crops require large amounts of N for growth and development, 2) soil N availability is primarily governed by soil organic matter decomposition dynamics and 3) there are many pathways for N loss to the environment. Nitrogen availability and losses are strongly driven by temperature and rainfall and therefore, weather variability adds a large amount of uncertainty to N management.

A primary challenge for farmers is to provide a sufficient quantity of plant available nitrogen (nitrate and/or ammonium) to crops, while minimizing N loss to the environment. Nitrogen is a very dynamic nutrient and large amounts of available N can be lost to the atmosphere (gaseous losses via denitrification or volatilization) or with water draining out of the soil profile (leaching). Typically, the longer the time that soluble quantities of available N exist in the soil, the larger the risk of loss and reduced return on investment. Farmers have some control of N loss through best management practices of N fertilizer and soil, but uncontrollable factors of rainfall and temperature also drive N loss. Farmers can retain N in soil through best management practices, but uncontrollable factors of rainfall and temperature also drive N loss.

Nitrogen Best Management Practices

Best N fertilizer management strategies have been studied for decades and there is a great deal of valuable information available. Here we attempt to summarize some main points on when to apply (timing), how to apply (placement), what to apply (source), and how much to apply (rate).

Nitrogen Timing

There are inherent tradeoffs and risks with timing of N fertilizer application. Nitrogen should be applied to coincide with crop demand and uptake to the extent possible. Application of N fertilizer before planting simplifies management but poses a greater risk of N loss to the environment. Application of N fertilizer during the growing season minimizes N loss, but adds a new risk of not being able to apply N if soil conditions remain wet for too long. Growers need to balance these tradeoffs and adjust N management based on time, equipment constraints, soil texture, and weather patterns.

Fall applications of N are generally not recommended for corn as potential for N loss is high. If N fertilizer is applied in the fall for corn, the recommendation is to use anhydrous ammonia (AA), and delay application until the soil temperature is below 50 °F and continuing to decline. Addition of a nitrification inhibitor with AA reduces the risk of N loss from fall applications. Fall N application can be beneficial for fall-planted small grains to foster plant establishment and encourage tillering. A low rate (20-30 lb N/acre) at or before planting can be made with a commonly available N fertilizer source or using the ammonium present in phosphorus fertilizers.

Spring applications of N should strive to minimize the time between N application and N uptake. Fertilizers that do not initially contain nitrate, such as anhydrous ammonia, are preferred for earliest applications for corn. Small grains should receive urea ammonium nitrate (UAN) or urea before the first node visible (Feekes Growth Stage 6 or "jointing," typically mid- to late April), as this begins the period of rapid N uptake. Fertilizing N at Feekes Growth Stage 5 "Leaf Sheaths Strongly Erect," typically early to mid-April is recommended. Research has found little benefit to applying N fertilizers in the spring before this stage. Benefits from properly timed N applications are most likely to be realized with warmer temperatures that favor conversion of ammonium to nitrate or with greater rainfall to drive N losses.

For loam and clay soils, yield differences between preplant and side-dress applications to corn can vary depending on the year, soil texture and weather. Side-dress applications on sandy soils are usually more effective at reducing N loss and maintaining yield than preplant treatments containing a nitrification inhibitor. Multiple applications of N fertilizer during the growing season can be an effective method of reducing N losses on sandy soils with high potential for N loss through leaching. Irrigation systems equipped for fertigation are often used to apply N efficiently in irrigated crops.

Nitrogen Placement

The appropriate placement of N fertilizer depends on the type and timing of fertilizer applied. Anhydrous ammonia (AA) must be placed into the soil to capture ammonia. Urea containing fertilizers should be incorporated into the soil when temperatures are warm but can be left on the soil surface when cold. Banding urea-containing fertilizers and AA slows their conversion to nitrate which can reduce N loss. More details related to placement are discussed below for different N sources.

Nitrogen Sources

Nitrogen fertilizer source trials have consistently shown that numerous N fertilizer forms are effective in providing N nutrition to crops. Nitrogen fertilizers commonly used to supply the majority of the crop N requirement are shown in Table 6. The choice of fertilizer source should be based on application timing and placement, cost, availability, equipment considerations, and farmer preference.

Table 6. Common N Fertilizers Found in the Tri-State Region

Source	Advantages	Disadvantages
Anhydrous ammonia (82% N)	Most concentrated and often cheapest form of N, losses to enviroment can be low, preferred source for fall and early-spring applications	Hazardous to handle, needs to be injected properly and in right conditions or volatilization losses can be high
UAN (28 to 32% N)	Safe and easy to handle, can be mixed with other liquid fertilizers or herbicides	Surface applications can result in high volatilization losses, nitrate can be lost to leaching or denitrification
Urea (46% N)	Concentrated N form, safe and easy to handle	Surface applications can result in high volatilization losses

Anhydrous Ammonia. Sealing the application slot is critical to capturing ammonia (NH_3) during application. Sealing may be incomplete in soils that are excessively wet or dry and significant amounts of NH_3 can be lost to the air during application. In excessively dry soil even when the slot is sealed, NH_3 may diffuse through the soil to the air and be lost. In moist soils, NH_3 reacts with water to form ammonium (NH_4^+) which is retained by negative charges on organic matter and clay prior to conversion to nitrate.

Moisture and soil texture influence the size of the initial zone of ammonia retention, commonly referred to as the injection zone. The sandier and drier the soil the larger the injection zone. In the injection zone, AA results initially in an extremely high pH, and high concentrations of NH_3, nitrite, and salt. All these factors often cause a reduction in soil organisms that convert ammonium to nitrate (nitrification). The delay in nitrate formation is why AA is preferred for fall and early spring N applications. Over time, conditions in the injection zone equilibrate and soil organisms recolonize from the periphery and nitrate conversion resumes.

Under some circumstances if AA is placed too close to the seed row, the harsh conditions in the injection zone can inhibit seed germination and damage seedlings. Plant growth may be reduced by AA even if seedlings become established. If the location of the AA band and planted row cannot be controlled then deep placement, delayed planting, and diagonal application of AA are tactics used to avoid damaging the crop. Placement of AA no shallower than 7 inches deep is recommended. Although delay between AA application and planting reduces the risk of damage, even fall AA applications have been known to damage corn planted in the spring. Application of AA diagonal to the planted row avoids planting directly over the AA band so that the number of plants affected are limited to the intersection of the planted row and the AA application. Using real-time kinematic (RTK) positioning to keep AA bands at least 5–7 inches offset from the planted row generally avoids negative effects.

Urea and Urea-Containing Fertilizers. Urea is a 46% nitrogen (N) fertilizer that may be added to soils alone or in combination with other N fertilizers. The most common example is the liquid nitrogen fertilizer urea-ammonium nitrate (UAN) which is approximately half urea and half ammonium nitrate and ranges from 28% to 32% N by weight. Surface-applied urea fertilizers can result in some nitrogen being lost to the air as ammonia. Losses are more likely and greater in magnitude in no-till cropping systems and when temperatures are warm. Incorporate urea fertilizers into the soil whenever possible to reduce nitrogen losses. If surface applications must be made, band rather than broadcast the fertilizer to encourage movement into the soil and reduce ammonia loss. Using a strong urease inhibitor with broadcast applications of urea fertilizers and avoiding early-spring applications are strategies that slow N losses to the environment.

Secondary Nitrogen Sources. The most commonly utilized phosphorus (P) sources monoammonium and diammonium phosphate (MAP and DAP) are primarily used to supply P, but also contain N. MAP and DAP applications providing 100 pounds of P_2O_5 per acre supply approximately 21 and 39 pounds of N per acre, respectively. Ammonium sulfate (AS) is commonly used to supply sulfur (S) to crops, but also contains N. An application rate of 100 pounds of AS per acre provides 21 pounds of N per acre and 24 pounds of S per acre.

The N in MAP, DAP, or AS is utilized efficiently when applied to small grains in the fall. Despite all the N being in the ammonium form in these fertilizers, fall applications of MAP, DAP, and AS likely result in considerable N loss after conversion to nitrate, thus contributing little N to a spring-planted corn crop. When left on the soil surface under most conditions MAP, DAP, and AS do not result in ammonia loss to the air. MAP, DAP, and AS generate approximately twice the acidity as AA or urea-containing fertilizers. Therefore, liming requirements would increase substantially if these sources were used to supply the majority of the crop N requirement.

Ohio Corn N Rates

Ohio corn N rates are based on 281 total trials (228 trials after soybean, 53 after corn). The recommended nitrogen rates can be found in Table 8-9.

Table 8. Ohio Recommended Nitrogen Rates (lb nitrogen/acre) for Corn Following Soybean Based on Price of Corn Grain and Nitrogen Fertilizer

	Price of Nitrogen Fertilizer ($/ lb)				
Price/ bushel corn	$0.30	$0.35	$0.40	$0.45	$0.50
$3.25	185	176	168	162	155
$3.50	187	180	173	166	160
$3.75	191	184	176	170	164
$4.00	195	186	180	174	168
$4.25	199	190	184	177	171
$4.50	200	193	185	180	175

Table 9. Ohio Recommended Nitrogen Rates (lb nitrogen/acre) for Corn Following Corn Based on Price of Corn Grain and Nitrogen Fertilizer

	Price of Nitrogen Fertilizer ($/ lb)				
Price/ bushel corn	$0.30	$0.35	$0.40	$0.45	$0.50
$3.25	193	185	177	170	164
$3.50	197	189	182	175	168
$3.75	201	193	185	179	172
$4.00	205	196	189	182	176
$4.25	208	200	192	186	180
$4.50	211	203	195	189	183

PHOSPHORUS AND POTASSIUM

KEY CONCEPTS

- The framework for P and K fertilizer management remains a build and maintain approach. Minor tweaks to the original framework have been made.
- Soil test levels determine phosphorus and potassium fertilizer application rates and timing.
- Mehlich-3 (M3) is now the default soil extractant, replacing Bray P1 for phosphorus and ammonium acetate for base cations.
- Critical levels are largely consistent with the original recommendations, but now in Mehlich-3.
- Crop removal rates were updated with current grain P and K concentrations.
- A typical corn-soybean rotation yielding 180 bushel per acre corn and 60 bushel per acre soybean removes 100–120 pounds per acre of both P_2O_5 and K_2O. This is equivalent to 210 pounds MAP (11-52-0)/acre, 240 pounds DAP (18-46-0)/acre, 180 pounds potash (0-0-60)/acre.

Build-up and Maintenance Framework

The tri-state fertilizer recommendations for P and K are based on a build-up and maintenance approach. This framework strives to build soil test levels up to and beyond a critical level, then maintain these levels over time. The critical level is a key component to this framework. Soil test levels above the critical level are "optimal," unlikely to be responsive to fertilizer application. Soil test levels below the critical level are "deficient," more likely to have a yield response to fertilizer application. The critical level has been determined empirically from the results of hundreds of field trials across the tri-state region.

The original tri-state recommendations had three distinct recommendations based on soil test values: 1) build-up, 2) maintenance and 3) drawdown (Figure 1). Overall, as soil test levels increase, recommended fertilizer rates decrease. At low soil test levels (below the critical level) the recommendations are in the build-up phase, where fertilizer rates include crop removal plus additional fertilizer to build soil test levels to the critical level within 4 years. When soil test levels are between the critical level and the maintenance limit, recommendations are designed to keep soil test levels in the maintenance range. Here fertilizer rates approximate crop removal, that is, nutrients removed in the harvested grain or forage. As soil test levels extend above the maintenance limit, the recommendations are in the drawdown phase. In the drawdown phase, fertilizer rates are less than crop removal so that soil test levels decrease over time to the maintenance limit. The drawdown phase provided an additional buffer beyond the maintenance range, which is already, as the original tri-state recommendations stated, a "safeguard against sampling or analytical variation." No fertilizer is recommended when soil test levels are above the drawdown phase.

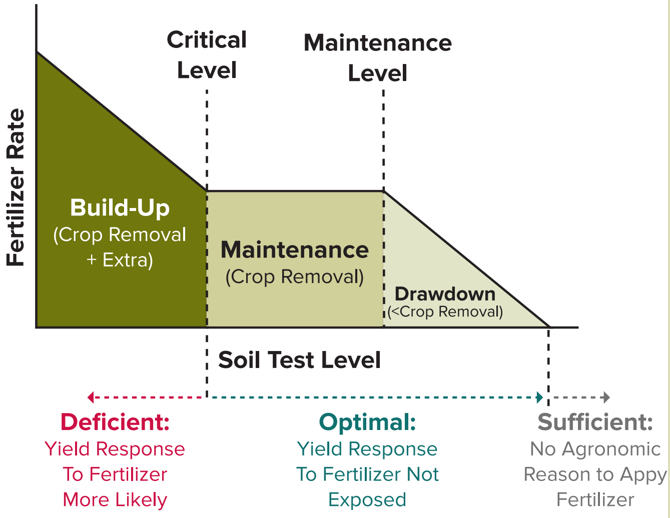


Figure 1. The Original Tri-State Fertilizer Recommendation Framework

The new tri-state fertilizer recommendations use a similar but simplified framework (Figure 2). The major changes to the new framework include 1) providing the option where the build-up phase is recommended but not required and 2) eliminating the drawdown phase. These changes are intended to simplify recommendations and provide farmers with greater flexibility in managing nutrients.

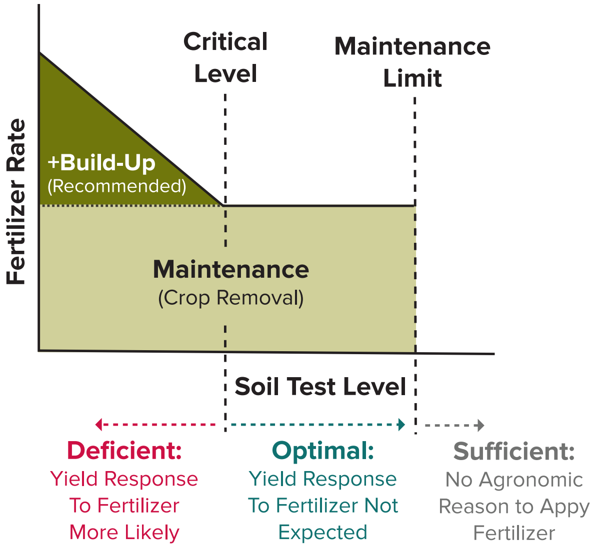


Figure 2. The New Tri-State Fertilizer Recommendation Framework

Making the build-up rate recommended, but not required, acknowledges the fact that the build-up rate may not be the most economical rate for a single season. A significant percentage of cropped acres in the tri-state region is rented under various land contracts often on a year to year basis. The uncertainty of future rental agreements, along with fluctuations in fertilizer and grain prices complicate decisions regarding when and to what degree to invest in building soil fertility. Providing farmers with the option of either investing in building soil test levels or waiting until future years gives them additional tools to run their farming operation as a profitable business.

However, farmers should recognize that as soil test levels decline below the critical level, the likelihood of reduced yield increases, and the amount of fertilizer needed to optimize profit also increases. A recent soybean trial in Indiana demonstrates how simply applying crop removal at low soil test K levels is insufficient to optimize profit. Fertilizing K_2O at removal rates in this field with very low soil test K levels (20-25 ppm, cation exchange capacity (CEC) <6 meq/100g) resulted in a 15 bushel/acre reduction in yield and a $100/acre decrease in profit, relative to following the tri-state build-up equation.

In low testing soils, P and K fixation can increase dramatically, necessitating a higher rate of fertilizer to increase soil test levels. For example, Thom and Dollaride (2002) fertilized 16 soils in Kentucky with different initial soil test P levels. They found that soils with lower STP levels required much more P_2O_5 fertilizer to raise STP levels, compared to high STP soils which took little fertilizer to raise STP levels (Figure 3). This demonstrates that P fixation rates can be high in low testing soils and therefore fertilizer application rates that only match crop removal and do not attempt to build soil test levels, pose an additional risk of yield loss.

Rates of P and K fixation vary by soil texture, environment, and management history, so farmers should recognize the potential tradeoffs of not attempting to build up soil test levels. Note that this modification should also not be misconstrued as a greenlight to neglect soil fertility levels in rented fields, failing to apply sufficient fertilizer and allowing soil test levels to drop to extremely low levels. Building-up and maintaining soil test levels in the long-term remains an unchanged recommendation in this update.

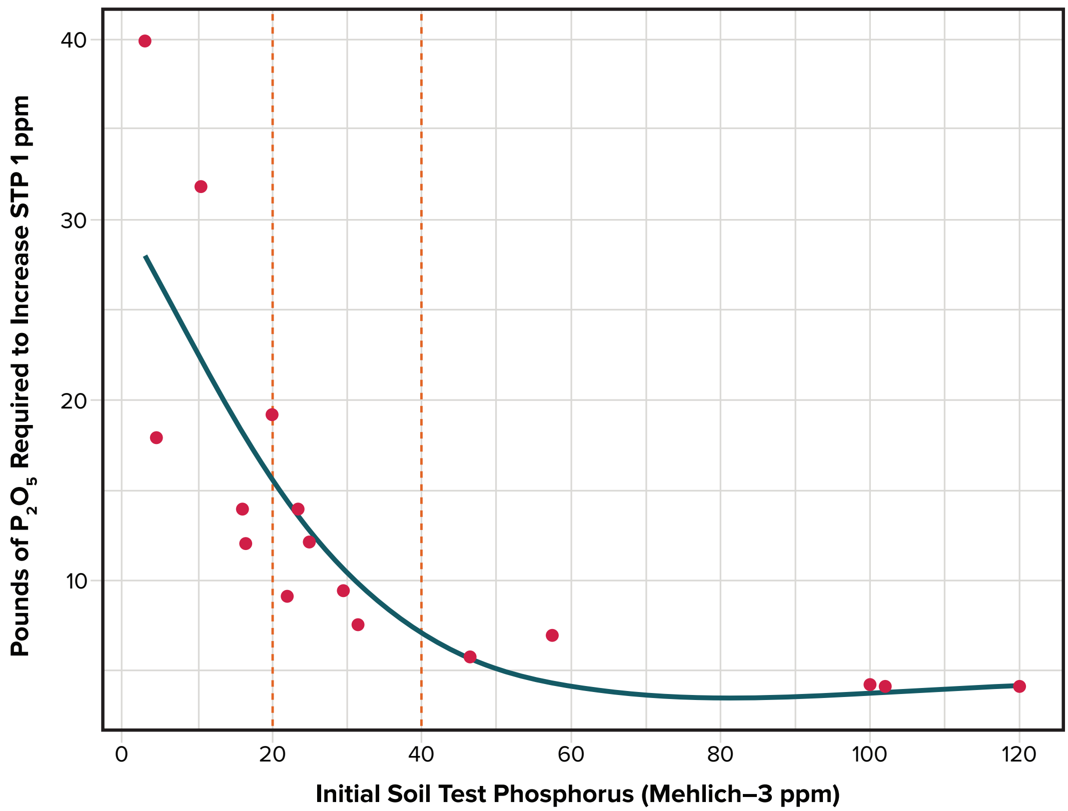


Figure 3. Pounds of P_2O_5 fertilizer required to increase soil test phosphorus levels by 1 part per million in 16 Kentucky soils (Adapted from Thom and Dollarhide, 2002). Red vertical, dashed lines indicate the tri-state maintenance range for corn and soybean.

The second change to the framework is to eliminate the drawdown phase. The uncertainty of soil test levels has generally decreased over the past several decades because 1) more fields are being tested on a regular basis than ever before, 2) soil sampling densities within fields have increased over time as more farmers move to grid and zone sampling and variable rate technologies, 3) commercial soil testing laboratories in the region generally do an outstanding job of generating precise and accurate soil test numbers, and 4) most farmers are applying fertilizer more frequently than every 4 years. The original 1995 drawdown phase has often been misinterpreted to mean that some fertilizer (lower than crop removal) is needed if soil test levels are anywhere above the maintenance limit. Eliminating the drawdown phase for the 2020 update simplifies the recommendations and provides greater clarity, while still maintaining the safeguard against yield reductions from insufficient crop nutrition.

New fertilizer rate and timing specifics are summarized in Table 11.

Table 11. Overview of Build-up and Maintenance Phases and Associated Fertilizer Recommendations

Assessment	Phase	Rate to Apply	When to Apply
Deficient	Build-Up (below critical level)	Crop removal + additional fertilizer to build soil test levels	Immediately, before next crop
Optimal	Maintenance (above critical level, below maintenance limit)	Approximate crop removal	Sometime within the rotation
Sufficient	Above maintenance	Do not fertilize	Do not fertilize

Under the new framework, the default recommendation remains as build-up (crop removal plus additional fertilizer to build soil test levels) **if soils test below the critical level or are "deficient**." The recommendations are designed to supply additional nutrients and to raise the soil test to the critical level over a four-year period. For deficient soils, recommended rates of fertilizer should be applied annually. Placement and timing techniques to enhance nutrient availability, such as sub-surface banding, or spring application may also be beneficial on nutrient-deficient soils. Applying 25 to 50 percent of the recommended fertilizer in a band to enhance early growth should be considered.

When soils are in the maintenance range (above the critical level, less than the maintenance limit) they are "optimal," that is, capable of supplying nutrients required by the crop. No response to fertilizer is expected. Fertilizer should be applied at some point within the rotation to replace the nutrients removed in the harvested crop each year. Fertilizer applications can be made annually or every other year. In some cases, fertilizer may be applied every 3 or 4 years. Soil testing should be used to assess soil test levels and fertilizer requirements no less than every 4 years. **Soils above the maintenance limit are "sufficient."** There is no agronomic reason to apply fertilizer when soil tests are in this range.

Phosphorus and Potassium Fertilizer Recommendation Overview

P and K Critical Levels

One of the most important components of P and K management is knowing when a crop will need P or K fertilizer. The critical soil test level provides this information. Over the past 6 years, more than 200 on-farm P and K trials have been conducted in corn, soybean and wheat in the tri-state region. These trials were all randomized and replicated and were typically in large strips. In addition, several long-term P and K trials have been conducted on university farms. Soil test levels were measured and related to crop yields to answer the basic question of "Did P or K fertilizer increase grain yield at this given soil test level?" **Collectively, our results demonstrate that when soil test levels are above the critical level and therefore in the maintenance range or above, the chance of a yield response to P or K fertilizer is highly unlikely.**

Our results provide no evidence the original tri-state fertilizer recommendations critical levels are too low or need to be modified. This work confirms that despite new genetics, tillage regimes, plant populations, and other advancements in agronomy, the stated critical levels still serve as a guideline for productive and profitable field crop production in this region. Critical levels for soil test P and K are provided in Table 12.

New critical levels are now reported using Mehlich-3 as the default extractant for soil test P and K (see below for more information).

Table 12. Recommended Mehlich-3 Soil Test Phosphorus and Potassium Levels (Critical Level and Maintenance Limit) for Field Crops in the Tri-State Region

Crop	Mehlich-3 Phosphorus Maintenance Range	Mehlich-3 Potassium Maintenance Range	
		Sandy soils (CEC <5 meq/ 100g)	Loam and clay soils (CEC >5 meq/ 100g)
Corn (grain or forage), Soybean	20–40 ppm	100–130 ppm	120–170 ppm
Wheat, Alfalfa	30–50 ppm	100–130 ppm	120–170 ppm

The critical levels for soil test phosphorus have been modified to use Mehlich-3P but are largely consistent with the original tri-state recommendations. Note that wheat and alfalfa have historically had higher soil testing levels than corn and soybean. Recent evaluations have confirmed the need for higher STP levels with wheat. (Alfalfa was not evaluated but is assumed to be consistent with wheat.) For fields with corn and soybean only (continuously or in rotation), the recommended critical level is 20 ppm Mehlich-3 P. For fields that include a small grain and/or alfalfa in the rotation with corn and soybean, the recommendation is to either 1) increase the critical level to 30 ppm Mehlich-3 P, or 2) to keep the critical level at 20 ppm and apply an annual maintenance rate of P_2O_5 when the soil test level is below 30 ppm Mehlich-3 P. In other words, apply P fertilizer in the fall before planting a small grain, or apply P fertilizer annually with alfalfa if soil test levels are below 30 ppm Mehlich-3 P.

Potassium critical levels have been modified more substantially, primarily simplified. The original tri-state potassium recommendations were based on cation exchange capacity (CEC) levels of the soil. As CEC increased, so did the recommended critical level and the K fertilizer rate in build-up range. Tables in the original recommendations identified four CEC levels (5, 10, 20, 30 meq/ 100 g) and potassium recommendations increased with each level. The results of both our on-farm and on-station trials provide no evidence to justify a successive increase in potassium critical level based on CEC to this level of detail. Furthermore, no other states in the Corn Belt have potassium recommendations scaled continuously by CEC. It is well-established, however, that low CEC sandy soils (<5 meq/100 g) are not capable of supporting the same Mehlich-3 K levels as a silt loam or clay soil. As a result, and consistent with the original tri-state recommendations, the maintenance range (critical level and maintenance limit) is lower for sandy soils than loam and clay soils (Table 12). The new recommendations classify all loam and clay soils together (CEC >5 meq/100 g) into a consistent and simplified recommendation.

Simply stated, the fertilizer recommendations are designed to keep soils in the maintenance range (above the critical level, but below the maintenance limit). When soil test levels are in the maintenance range, farmers can use the fertilizer rates in Tables 13 and 14. More details on equations are provided in Table 17.

Table 13. Recommended Fertilizer Rate Based on Expected Grain Yields When Soil Test P and K Are in the Maintenance Range

Potassium recommendations differ by state.

Crop	Yield (bushel/acre)	Recommended Fertilizer Rate		
		IN, MI, OH	IN & OH	MI
		lb P_2O_5/ acre	lb K_2O/ acre	lb K_2O/ acre
Corn	150	55	50	30
	200	70	60	40
	250	90	70	50
	300	105	80	60
Soybean	30	25	55	35
	50	40	80	60
	70	55	100	80
	90	70	125	105
Wheat	60	30	35	15
	90	45	45	25
	120	60	50	30
	150	75	60	40

Table 14. Recommended Fertilizer Rate Based on Expected Forage Biomass Yields When Soil Test P and K Are in the Maintenance Range

Crop	Yield (tons/acre)	Recommended Fertilizer Rate	
		lb P_2O_5/ acre	lb K_2O/ acre
Corn Silage	20	60	165
	24	75	195
	28	85	225
	32	100	255
Alfalfa	2	25	120
	4	50	215
	6	70	300
	8	95	300

Composting

Backyard Conservation Tip sheet

Composting

Composting turns household wastes into valuable fertilizer and soil organic matter.

In your backyard

All organic matter eventually decomposes. Composting speeds the process by providing an ideal environment for bacteria and other decomposing microorganisms. The final product, humus or compost, looks and feels like fertile garden soil. This dark, crumbly, earthy-smelling stuff works wonders on all kinds of soil and provides vital nutrients to help plants grow and look better.

Decomposing organisms consist of bacteria, fungi, and larger organisms such as worms, sow bugs, nematodes, and numerous others. Decomposing organisms need four key elements to thrive: nitrogen, carbon, moisture, and oxygen. For best results, mix materials high in nitrogen (such as clover, fresh grass clippings, and livestock manure) and those high in carbon (such as dried leaves and twigs). If there is not a good supply of nitrogen-rich material, a handful of general lawn fertilizer will help the nitrogen-carbon ratio. Moisture is provided by rain, but you may need to water or cover the pile to keep it damp. Be careful not to saturate the pile. Turning or mixing the pile provides oxygen. Frequent turning yields faster decomposition.

Getting started

Many materials can be added to a compost pile, including leaves, grass clippings, straw, woody brush, vegetable and fruit scraps, coffee grounds, livestock manure, sawdust, and shredded paper. Do not use diseased plants, meat scraps that may attract animals, or dog or cat manure which can carry disease. Composting can be as simple or as involved as you would like, and depends on how much yard waste you have, how fast you want results, and the effort you are willing to invest.

Cold or slow composting

With cold or slow composting, you can just pile grass clippings and dry leaves on the ground or in a bin. This method requires no maintenance, but it will take several months to a year or more for the pile to decompose. Cold composting works well if you don’t have time to tend the compost pile at least every other day, have little yard waste, or are not in a hurry to use the compost. Keep weeds and diseased plants out of the mix since the temperatures reached with cold composting may not be high enough to kill the weed seeds or disease-causing organisms. Add yard waste as it accumulates. Shredding or chopping speeds up the process. To easily shred material, run your lawn mower over small piles of weeds and trimmings. Cold composting has been shown to be better at suppressing soil-borne diseases than hot composting. Cold composting also leaves more undecomposed bits of material, which can be screened out if desired.

Hot composting

Hot composting requires more work, but with a few minutes a day and the right ingredients you can have finished compost in a few weeks depending on weather conditions. The composting season coincides with the growing season. When conditions are favorable for plant growth, those same conditions work well for biological activity in the compost pile. However, since compost generates heat, the process may continue later into the fall or winter.

Hot piles do best when high-carbon material and high-nitrogen material are mixed in a 1 to 1 ratio. A pile with the minimum dimensions of 3' x 3' x 3' is needed for efficient heating. For best heating, make a heap that is 4 or 5 feet in each dimension. As decomposition occurs, the pile will shrink. If you don't have this amount at one time, simply stockpile your materials until a sufficient quantity is available for proper mixing.

Hot piles reach 110 to 160 degrees Fahrenheit, killing most weed seeds and plant diseases. Studies have shown that compost produced at these temperatures has less ability to suppress diseases in the soil since these temperatures may kill some of the beneficial bacteria necessary to suppress disease.

Steps for hot composting:

1. Choose a level, well-drained site, preferably near your garden.

2. There are numerous styles of compost bins available depending on your needs. These may be as simple as a moveable bin formed by wire mesh or a more substantial structure consisting of several compartments. There are many commercially available bins. While a bin will help contain the pile, it is not absolutely necessary. You can build your pile directly on the ground. To help with aeration, you may want to place some woody material on the ground where you will build your pile.

3. To build your pile, either use alternating layers of high-carbon and high-nitrogen material or mix the two together and then heap into a pile. If you alternate layers, make each layer 2 to 4 inches thick. Some composters find that mixing the two together is more effective than layering. Use approximately equal amounts of each. If you are low on high-nitrogen material, you can add a small amount of commercial fertilizer containing nitrogen. Apply at a rate of 1 2⁄ cup of fertilizer for each 10-inch layer of material. Adding a few shovels of soil will also help get the pile off to a good start; soil adds commonly found decomposing organisms.

4. Water periodically. The pile should be moist but not saturated. If conditions are too wet, anaerobic microorganisms (those that can live without oxygen) will continue the process. These are not as effective or as desirable as the aerobic organisms. Bad odors are also more likely if the pile is saturated.

5. Punch holes in the sides of the pile for aeration.

6. The pile will heat up and then begin to cool. Start turning when the pile's internal temperature peaks at about 130 to 140 degrees Fahrenheit. You can track this with a compost thermometer, or reach into the pile to determine if it is uncomfortably hot to the touch.

7. During the composting season, check your bin regularly to assure optimum moisture and aeration are present in the material being composted.

8. Move materials from the center to the outside and vice versa. Turn every day or two and you should get compost in less than 4 weeks. Turning every other week will make compost in 1 to 3 months. Finished compost will smell sweet and be cool and crumbly to the touch.

Common problems

Composting is not an exact science. Experience will tell you what works best for you. If you notice that nothing is happening, you may need to add more nitrogen, water, or air. If things are too hot, you probably have too much nitrogen. Add some more carbon materials to reduce the heating. A bad smell may also indicate too much nitrogen.

Cold composting often proceeds faster in warmer climates than in cooler areas. Cold piles may take a year or more to decompose depending on the materials in the pile and the conditions.

Adding kitchen wastes to compost may attract flies and insects. To prevent this problem, make a hole in the center of your pile and bury the waste. Do not compost meat scraps, dead animals, pet manure, diseased plant material, or noxious weeds.

Check on any local or state regulations for composting in urban areas– some communities may require rodent-proof bins.

Vermicomposting

Vermicomposting uses worms to compost. This takes up very little space and can be done year-round in a basement or garage. It is an excellent way to dispose of kitchen wastes.

Steps for vermicomposting:

1. You need a plastic storage bin. One 1' x 2' x 3.5' will be enough to meet needs of a family of 6.

2. Drill 8 to 10 holes, approximately 1/4" in diameter, in the bottom of the bin for drainage.

3. Line the bottom of the bin with fine nylon mesh to keep the worms from escaping.

4. Put a tray underneath to catch the drainage.

5. Shredded newspaper works well as bedding. Rip into pieces and water well so that it is thoroughly moist. Place on one side of your bin. Do not let it dry out.

6. Add worms to your bin. Redworms are recommended for best composting, but other species can be used. Redworms are the common small worms found in most gardens and lawns. You can collect them from under a pile of mulch or order them from a garden catalog.

7. Provide worms with food wastes such as vegetable peelings. Do not add fat or meat products. Limit feed– too much at once may cause the material to rot.

8. Keep the bin in a dark location away from extreme temperatures.

9. In about 3 months the worms should have changed the bedding and food wastes into compost. At this time add fresh bedding and more food to the other side of the bin.The worms should migrate to the new food supply.

10.After a couple of weeks, open your bin in a bright light.The worms will burrow into the bedding. Scoop out the finished compost and apply to your plants or save for use in the spring.

Using compost

Compost can be used for all your planting needs. Compost is an excellent source of organic matter to add to your garden or potted plants. It helps improve soil structure which contributes to good aeration and moisture-holding capacity. Compost is a source of plant nutrients. Compost can also be used as a mulch material. Studies have shown that compost used as a mulch, or mixed with the top one-inch layer of soil, can help prevent some plant diseases, including some of those that cause damping of seedlings.

On the farm

On the farm, potential waste is turned into a resource that saves money and helps the environment. Producers use livestock manure to fertilize crops. When manure is properly handled, it can be safely applied to the land without the risk of polluting water. Composting is also practiced in some poultry operations. The compost is used as fertilizer on the farms and for lawns and gardens.

More about Backyard conservation

The Natural Resources Conservation Service, National Association of Conservation Districts, and Wildlife Habitat Council encourage you to sign up in the Backyard Conservation program. To participate, use some of the conservation practices in your backyard that are showcased in this series of tip sheets –tree planting, wildlife habitat, backyard pond, backyard wetland, composting, mulching, nutrient management, terracing, water conservation, and pest management. Then, simply fill in the Backyard Conservation customer response card, send a Backyard e-mail request to landcare@usda.gov, or call 1-888-LANDCARE.

A Citizen's Guide to Phytoremediation

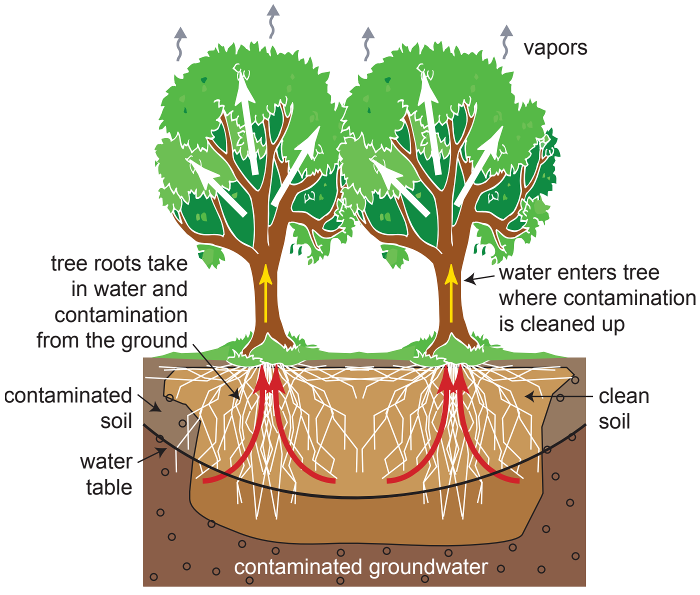
What Is Phytoremediation?

Phytoremediation uses plants to clean up contaminated environments. Plants can help clean up many types of contaminants including metals, pesticides, explosives, and oil. However, they work best where contaminant levels are low because high concentrations may limit plant growth and take too long to clean up. Plants also help prevent wind, rain, and groundwater flow from carrying contaminants away from the site to surrounding areas or deeper underground.

How Does It Work?

Certain plants are able to remove or break down harmful chemicals from the ground when their roots take in water and nutrients from the contaminated soil, sediment, or groundwater. Plants can help clean up contaminants as deep as their roots can reach using natural processes to:

- Store the contaminants in the roots, stems, or leaves.
- Convert them to less harmful chemicals within the plant or, more commonly, the root zone.
- Convert them to vapors, which are released into the air.
- Sorb (stick) contaminants onto their roots where very small organisms called "microbes" (such as bacteria) that live in the soil break down the sorbed contaminants to less harmful chemicals. (See *A Citizen's Guide to Bioremediation* [EPA 542-F-12-003].)



Phytoremediation often is used to slow the movement of contaminated groundwater. Trees act like a pump, drawing the groundwater up through their roots to keep it from moving. This method of phytoremediation is called "hydraulic control." It reduces the movement of contaminated groundwater toward clean areas offsite.

Constructed wetlands are another form of phytoremediation. A wetland may be created at a site to treat acid mine drainage that flows through it or as a final treatment step for water discharged from other treatment systems. Water treated with constructed wetlands generally has very low concentrations of contaminants that need to be removed before it may be discharged into a lake or stream. The construction of wetlands may involve some excavation or regrading of soil at the site in order for water to flow through it without pumping. The area is planted with grasses and other vegetation typical of naturally occurring wetlands in the area.

Certain plants are better at removing contaminants than others. Plants used for phytoremediation must be able to tolerate the types and concentrations of contaminants present. They also must be able to grow and survive in the local climate. Depth of contamination is another factor. Small plants like ferns and grasses have been used where contamination is shallow. Because tree roots grow deeper, trees such as poplars and willows are used for hydraulic control or to clean up deeper soil contamination and contaminated groundwater.

How Long Will It Take?

Phytoremediation may take several years to clean up a site. The cleanup time will depend on several factors. For example, phytoremediation will take longer where:

- Contaminant concentrations are high.
- The contaminated area is large or deep.
- Plants that have a long growing time are used.
- The growing season is short.

These factors vary from site to site. Plants may have to be replaced if they are damaged by extreme weather, pests, or animals. This also will add time to the cleanup.

Is Phytoremediation Safe?

Phytoremediation is a low-risk and attractive cleanup method. Fences and other barriers are constructed to keep wildlife from feeding on contaminated plants. In certain instances, plants may release chemical vapors into the air in a process called “phytovolatilization.” When this occurs, workers sample the air to make sure the plants are not releasing harmful amounts of vapors.

How Might It Affect Me?

Phytoremediation cleanups cause little disruption to the site or surrounding community. Initial work may involve grading or tilling of the soil with earth-moving equipment, and backhoes may be needed to plant trees and large shrubs. Residents and businesses near the site may hear equipment noise or detect an odor if fertilizer is added to the soil. Any airborne dust can be minimized by watering down the soil.

Plants used for phytoremediation can make a site more attractive. The use of native plants is encouraged since they are better adapted to the area’s conditions and less likely to attract nuisance animals or pests.

Why Use Phytoremediation?

EPA uses phytoremediation for many reasons. It takes advantage of natural plant processes and requires less equipment and labor than other methods since plants do most of the work. Also, the site can be cleaned up without digging up and hauling soil or pumping groundwater, which saves energy. Trees and smaller plants used in phytoremediation help control soil erosion, make a site more attractive, reduce noise, and improve surrounding air quality.

Phytoremediation has been successfully used at many sites, including at least 10 Superfund sites across the country.

Poplar trees at a phytoremediation site.

Example

Phytoremediation is being used to clean up contaminated groundwater near a former disposal area at the Aberdeen Proving Ground in Maryland. This area was used for disposal and burning of industrial and warfare chemicals from 1940 through the 1970s. Chemicals used as industrial degreasers and solvents were found to be a particular problem in the groundwater.

In the spring of 1996, 183 poplar trees were planted in a one-acre area. The trees draw in contaminated groundwater and break down contaminants in the root zone. The groundwater levels near the trees show that they are keeping the plume of contaminants from moving to clean areas. EPA estimates that within 30 years of the start of cleanup, the contaminants in groundwater at the site may be reduced by up to 85 percent.

For More Information

For more information about this and other technologies in the Citizen’s Guide Series, visit:

www.cluin.org/remediation
www.cluin.org/products/citguide
www.cluin.org/phyto

United States Environmental Protection Agency

Office of Solid Waste and Emergency Response (5102G)

EPA 542-F-12-016
September 2012
www.epa.gov/superfund/sites
www.cluin.org

Excerpts from: https://land8.com/5-best-plants-for-phytoremediation/ (Accessed October 28, 2021)

5 Best Plants For Phytoremediation

By Jay Boi on November 30, 2015 5 Comments / 107738 views

We take a closer look at 5 of best plants for phytoremediation. One of our most basic natural resource, soil, is threatened. The soil has been neglected and contaminated for decades now. Although, the global map of contamination is difficult to define, the European Environment Agency has identified heavy metals and mineral oil as the main soil pollutants. Knowing that just in Europe the number of polluted sites is expected to increase by 50% in the next 10 years, it seems clear that one of our biggest environmental challenges is under our feet. As landscape architects, should we not be aware of all our potential to play a role on the solutions side?

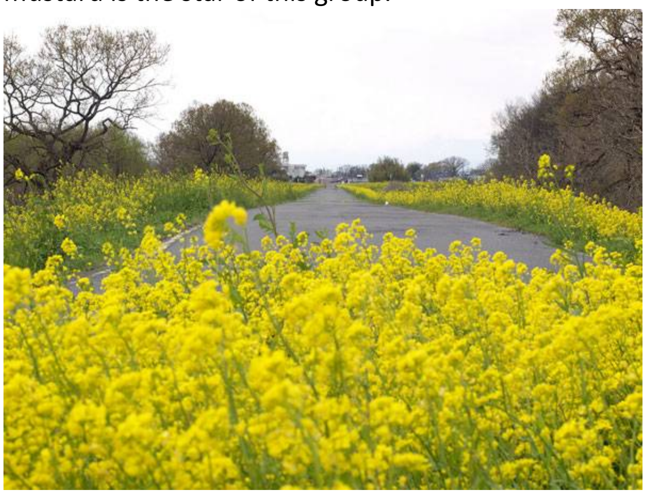
What is Phytoremediation?

Clean techniques to remediation are getting more popular, and most likely, you are already familiar to phytoremediation. Through this article, you will find a useful guidance on plants with proven qualities to naturally reduce, degrade or remove contaminants from soil and water. Advantages are outstanding: they do not involve visual impact, expensive engines and toxic chemicals. Do you remember Top 10 Reused Industrial Landscapes by Lisa Tierney? Landschaftspark, number five on the list, is a great model of phytoremediation in recreational projects.

Best Plants For Phytoremediation

1. Indian mustard (Brassica juncea L.) Info: Brassica juncea (L.) Czern. – Indian Mustard

As International Journal of Molecular Sciences has published, heavy metals affect not only industrial sites but also cultivated land, spreading risks for human health. Brassicaceae species are really useful to accumulate certain metals while producing high quantities of biomass in the process, and Indian mustard is the star of this group.



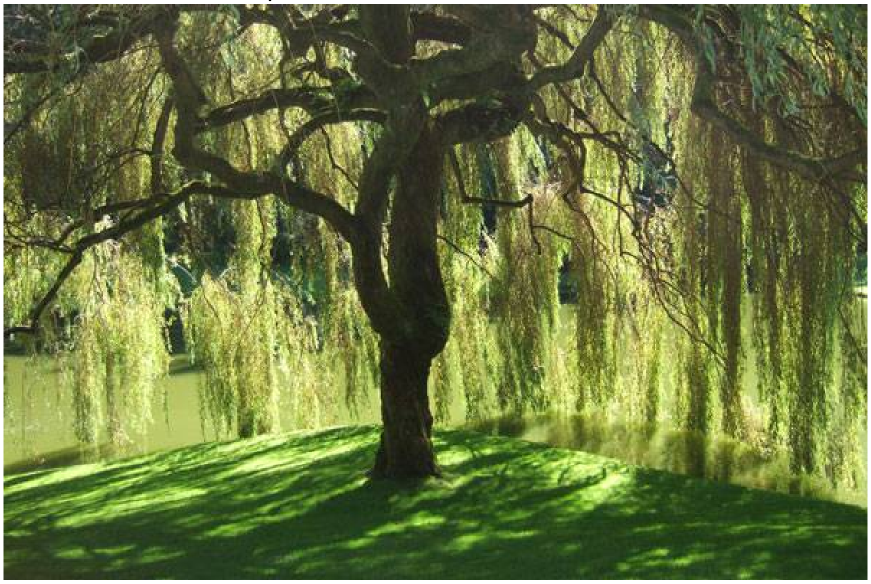
"Brassica juncea" by elminium. Licensed under Creative Commons 2.0 via Flickr

It can remove three times more Cd than others, reduce 28% of Pb, up to 48% of Se, and it is effective against Zn, Hg and Cu as well. However, what is unknown is that Indian mustard removed radioactive Cs137 from Chernobyl (Phytoremediation of Radiocesium-Contaminated Soil in the Vicinity of Chernobyl, Ukraine) in the 80´s as well.

"mustard" by Sajith T S. Licensed under Creative Commons 2.0 via Flickr

2. Willow (Salix species). (White Willow)

The water loving plants beautify landscapes, however, it's worth is not confined to its appearance only. They have a more interesting use for phytoremediation as well: their roots have demonstrated (Response of Salix alba L. to heavy metals and diesel) viability, accumulating lower levels of heavy metals than Brassicaceae, and they deal with Cd, Ni and Pb, and work even in mixed heavy metals like diesel fuel polluted sites.



"Bloedel Reserve Willow Tree" by Geaugagrrl – Own work. Licensed under Public Domain via Wikimedia Commons

Maybe you remember Westergasfabriek Park in Amsterdam, which LAN talked about in the article Westergasfabriek Park Goes from a Polluted Gas Factory to an Award Winning Design by Gerard De Silva. It shows recreational and remediation features of willows through ponds and aquatic gardens. Large-scale systems for urban waste water are also effective, as the Swedish projects mentioned in Willows for energy and phytoremediation in Sweden do.

Westergasfabriek Park. Image courtesy of Gustafson Porter

3. Poplar tree (Populus deltoides). (Populus deltoides W. Bartram ex Marshall eastern cottonwood)

The advantageous effect of poplar trees on soil and underwater has also been widely studied. Their secret lies in the naturally well-designed root system which take up large quantities of water.

"Populus deltoides" by Matt Lavin. Licensed under Creative Commons 2.0 via Flickr

Chlorinated solvents such as trichloroethylene, or the well-known carcinogenic carbon tetrachloride (95% of substance removed) are the organic pollutants that hybrid poplars face better, according to research from National Institute of Environmental Health Sciences. What is more, PhytoPet(Bioremediation of Aquatic and Terrestrial Ecosystems), the Canadian database for bioremediation methods, remarks that poplar trees can degrade petroleum hydrocarbons like benzene, toulene and o-xylene. Although they are not very common in public gardens, you have one sample of poplar tree integration in this interesting LAN article, The Sensational Hive Project by World Renowned Grant Associates written by Erin Tharp.

4. Indian grass (Sorghastrum nutans) (Sorghastrum nutans (L.) Nash)

Research looked at how this Midwestern U.S. native plant benefits soil and ground water around them. Many people can find Indian grass growing along the roadsides without noticing its power to detoxify common agro-chemical residues such as well-known pesticides and herbicides related to atrazine and metalochlor.

"Sorghastrum nutans (3912211191)" by Matt Lavin from Bozeman, Montana, USA – Sorghastrum nutansUploaded by Jacopo Werther. Licensed under CC BY-SA 2.0 via Wikimedia Commons

Indian grass is one of the nine members of the graminae family identified by PhytoPet(Bioremediation of Aquatic and Terrestrial Ecosystems), as capable to remediate petroleum hydrocarbons. The list includes other grasses like Common buffalo grass or Western wheatgrass, leading the ranking.

5. Sunflower (Helianthus Annuus L.) (Helianthus annuus L. common sunflower)

Experiments like Influence of the sunflower rhizosphere on the biodegradation of PAHs in soil reveals that sunflowers reduce different PAH level from soil, in an effective way, but what is really surprising is how varied range of contaminants they can accumulate. Heavy metals such as Pb, Zn (Heavy Metals Extraction Potential of Sunflower (Helianthus annuus) and Canola (Brassica napus)), N, P, K, Cd, Cu or Mn (Capability Of Heavy Metals Absorption By Corn, Alfalfa And Sunflower Intercropping Date Palm), seem to be its food, which is great news because sunflowers have a quick growth to start working soon.

In fact, one month old plants reached the incredible goal of removing more than 95% of uranium in 24 hours, (SUNFLOWER (Helinathus annuus L.) – A POTENTIAL CROP FOR ENVIRONMENTAL INDUSTRY) which shows their power to remove radioactive metals, including Cs and Sr from superficial underground water. When reinforcing the effect of sunflowers with other species, it seems highly successful for many sites, for example waste mining sites.

Quzhou Luming Park. Photos courtesy of Turenscape.

– New plants are discovered every year, and the already known ones are included in experiments to determine the effects of pollutants exposure. There is no fixed recipe, but as you have checked, the results are more than promising and economically viable. What plants would you choose for Phytoremediation?

Recommended Reading on Phytoremediation:

- Phytoremediation: Transformation and Control of Contaminants by Steven C. McCutcheon
- Phytoremediation: Role of Aquatic Plants in Environmental Clean-Up by Bhupinder Dhir

Article by Elisa García Nieto Return to Homepage
Published in Blog

2022 NCF-Envirothon Ohio

Soils and Land Use Study Resources

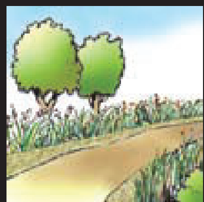
Key Topic 3: Soil Conservation and Soil Management

14. Compare different land uses and conservation practices and their impact on soils and erosion.
15. Describe the impacts of point and non-point source pollution on soils and apply that to soil management practices in the field.
16. Explain the impacts of buffers as a best management practice on soil conservation and apply them to field scenarios.

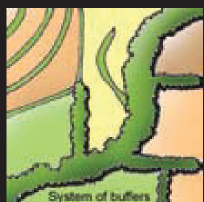
Study Resources

Resource Title	Source	Located on
Intro and Design Guidelines 1 from Conservation Buffers–Design guidelines for buffers, corridors, and greenways. Gen. Tech. Rep. SRS–109	*USDA NRCS, Bentrup, G. 2008*	Pages 72-85
Excerpt Definitions from the Clean Water Act and the USEPA definition of Nonpoint Source Pollution	*Basic Information about Nonpoint Source (NPS) Pollution, USEPA, updated July 8, 2021*	Page 86

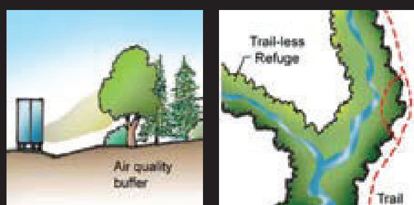
<u>Study Resources begin on the next page</u> ➡

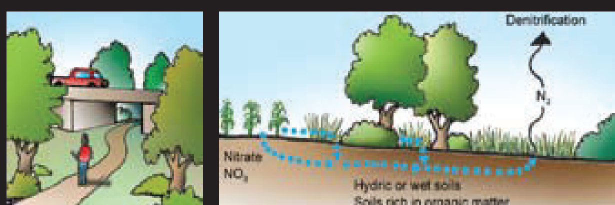


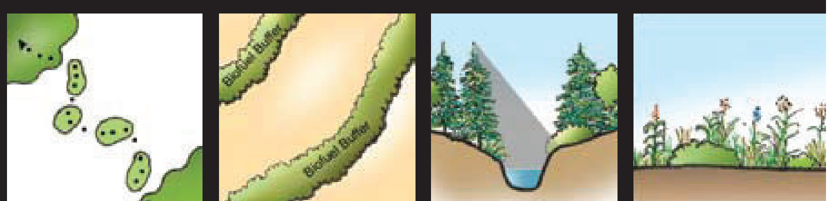
Conservation Buffers



Design Guidelines for Buffers, Corridors, and Greenways







USDA United States Department of Agriculture

Forest Service Southern Research Station

General Technical Report SRS-109
September 2008

PURPOSE OF THIS GUIDE

Conservation buffers are strips of vegetation placed in the landscape to influence ecological processes and provide a variety of goods and services to us. They are called by many names, including wildlife corridors, greenways, windbreaks, and filter strips to name just a few (fig. 1).

Benefits that conservation buffers provide to us include protecting soil resources, improving air and water quality, enhancing fish and wildlife habitat, and beautifying the landscape. In addition, buffers offer landowners an array of economic opportunities including protection and enhancement of existing enterprises.

A large body of scientific knowledge exists to help guide the planning and designing of buffers. Unfortunately, this information is widely dispersed throughout the vast repositories of research literature and is not easily accessible or usable for most planners.

The purpose of this publication is to provide a synthesis of this diverse knowledge base into distilled, easy-to-understand design guidelines.

Figure 1—Conservation buffers in an agricultural landscape.

Landscape Design Concepts

One method of describing landscapes divides a landscape into three basic elements: patches, corridors or buffers, and matrix (fig. 2).

Figure 2—The landscape described in basic landscape ecology terms.

Patch: A relatively small area that has distinctly different structure and function than the surrounding landscape.

Corridor or Buffer: A linear patch typically having certain enhanced functions due to its linear shape (see box on next page).

Matrix: The background within which patches and buffers exist.

In developed landscapes, patches are often remnant areas of woodland or prairie; corridors are linear elements such as windbreaks, fencerows, and riparian areas; and the matrix is often developed lands such as cropland or urban areas.

While this guide focuses on designing buffers, the patches and matrix areas must be considered in the design process to help achieve many desired objectives. Location, structure, and management of nearby patches and matrix influence the types of functions that buffers will perform and their effectiveness.

Buffer installations may be ineffective if they are designed without an understanding of landscape processes. For example, buffers installed for streambank stabilization may be ineffective in an urbanizing watershed unless they account for stream flows that are dramatically increasing due to impervious cover.

Buffers are only one tool in the planner's tool box. Planners need to be realistic in applying buffers, acknowledging both the strengths and limitations of buffers to solve and manage resource concerns.

Corridors, Buffers, and Greenways

A variety of terms are used to describe linear patches. These terms are often associated with specific resource issues (e.g., water quality with buffers, wildlife with corridors, and recreation and urban aesthetics with greenways).

The terms used in this guide are the terms commonly used in the literature for a particular resource issue. Planners should focus on the types of functions to be achieved rather than on terminology.

Planning Conservation Buffers

Functions

Conservation buffers improve resource conditions by enhancing certain landscape functions. Major issues that buffers can be designed to address and their associated functions are listed in table 1.

Most buffers will perform more than one function, even if designed with only one function in mind. Buffer design should take into account intended functions as well as unintended ones that may or may not be desirable.

Location

Location determines a buffer's juxtaposition to problem conditions in the surrounding landscape. It also determines important site characteristics, such as soil type and slope, that can influence how effective a buffer can be. One location may be better for one function, while a different location would be better for another function (fig. 3).

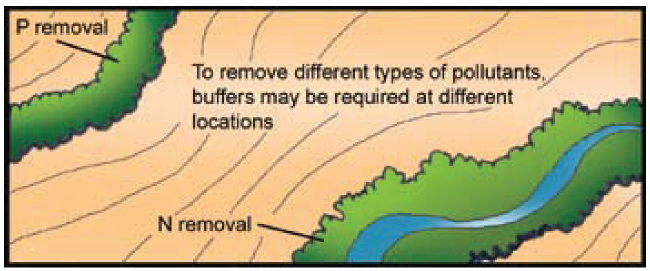


Figure 3—Buffer location will determine actual functions.

Geographic Information Systems (GIS) can be used for identifying suitable locations for buffers. By querying the landscape for site factors required for a desired function, better locations can be identified where an objective can be addressed with a buffer. GIS is particularly useful for identifying locations where a buffer can serve multiple functions.

For more information on GIS and buffer planning and design, go to www.bufferguidelines.net.

Table 1—Buffer functions related to issues and objectives

Issue and Objectives	Buffer Functions
Water Quality	
Reduce erosion and runoff of sediment, nutrients, and other potential pollutants Remove pollutants from water runoff and wind	Slow water runoff and enhance infiltration Trap pollutants in surface runoff Trap pollutants in subsurface flow Stabilize soil Reduce bank erosion
Biodiversity	
Enhance terrestrial habitat Enhance aquatic habitat	Increase habitat area Protect sensitive habitats Restore connectivity Increase access to resources Shade stream to maintain temperature
Productive Soils	
Reduce soil erosion Increase soil productivity	Reduce water runoff energy Reduce wind energy Stabilize soil Improve soil quality Remove soil pollutants
Economic Opportunities	
Provide income sources Increase economic diversity Increase economic value	Produce marketable products Reduce energy consumption Increase property values Provide alternative energy sources Provide ecosystem services
Protection and Safety	
Protect from wind or snow Increase biological control of pests Protect from flood waters Create a safe enviroment	Reduce wind energy Modify microclimate Enhance habitat for predators of pests Reduce flood water levels and erosion Reduce hazards
Aesthetics and Visual Quality	
Enhance visual quality Control noise levels Control air pollutants and odor	Enhance visual interest Screen undesirable views Screen undesirable noise Filter air pollutants and odors Separate human activities
Outdoor Recreation	
Promote nature-based recreation Use buffers as recreational trails	Increase natural area Protect natural areas Protect soil and plant resources Provide a corridor for movement Enhance recreational experience

Structure

Structural characteristics of a buffer such as size and shape and the structure of the vegetation largely determine how well a buffer is capable of functioning at a given location. Planners can manipulate these variables to achieve desired objectives. The guidelines in this publication address many of these design and management considerations.

Systems

Buffers are typically designed to achieve multiple objectives—objectives of individual landowners, the community, and general public. Often multiple objectives must be addressed by multiple buffers with different designs in different locations, creating a system of buffers.

Each objective has its own scale, and each buffer function operates at its own scale. It's a complex task to address multiple objectives and functions. A planning process is a structured method to organize and conduct this task and ensure that all objectives are addressed. The result is called a landscape plan.

A typical planning process includes the following steps:

- Identifying problems and opportunities
- Determining objectives
- Inventorying resources
- Analyzing resources
- Developing alternatives
- Evaluating alternatives and making decisions
- Implementing the plan
- Evaluating the plan

For more information on planning processes, go to www.bufferguidelines.net. Figure 4 illustrates a conceptual buffer landscape plan developed through a planning process. The following page provides a brief description of the plan.

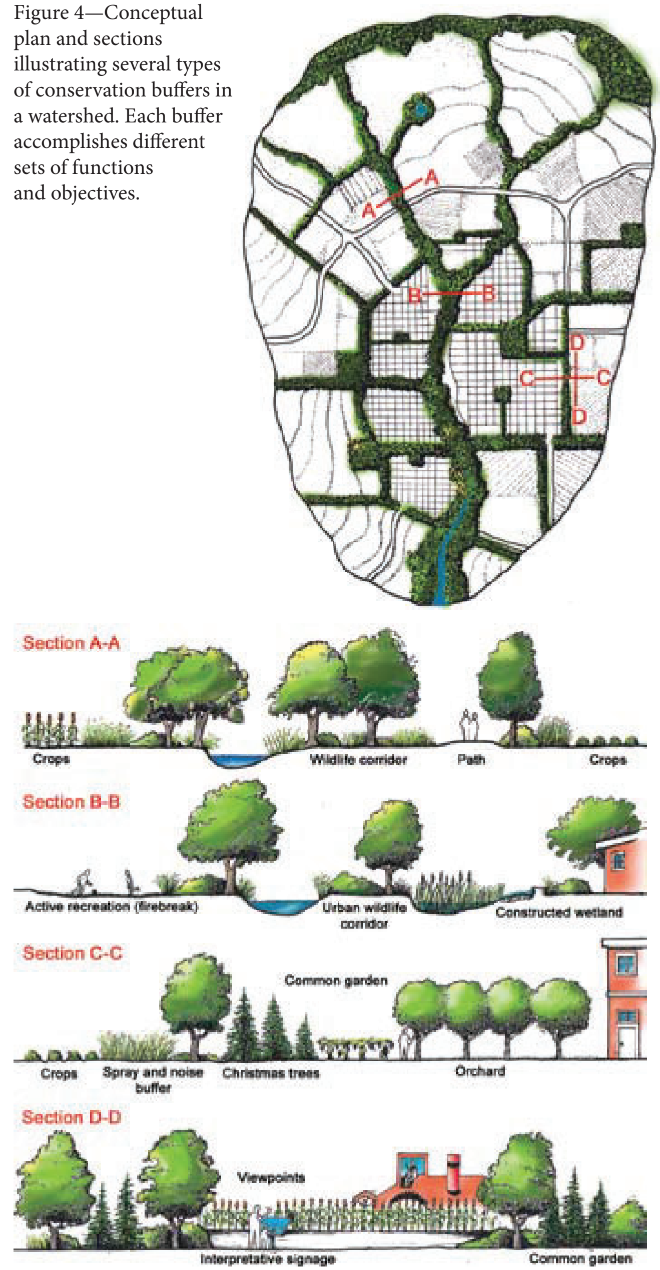


Figure 4—Conceptual plan and sections illustrating several types of conservation buffers in a watershed. Each buffer accomplishes different sets of functions and objectives.

The buffer plan (fig. 4) demonstrates how the buffer location in the watershed plays a key role in determining the functions and objectives for a particular segment of the buffer system.

Section A-A: a buffer designed to filter agricultural runoff to reduce a community's drinking water treatment costs. This buffer provides habitat and a conduit for wildlife while offering a public recreational trail.

Section B-B: a buffer in a more urbanized area. A constructed wetland in the buffer treats runoff before it flows into the stream. An active recreation area in the buffer provides a firebreak to protect homes. Wildlife still benefits from this buffer, but this objective plays a less significant role than in Section A-A due to the buffer location.

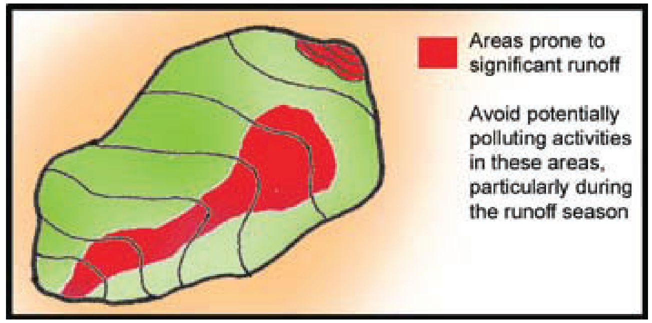
Section C-C: a buffer between an agricultural field and a residential area. This buffer serves as a common garden for both rural and urban residents. Noise control and protection from agricultural spray is also provided by the buffer. Products such as fruits, nuts, and Christmas trees can be harvested from the buffer.

Section D-D: a buffer illustrating how the buffer in Section C-C provides aesthetic views at selected locations. Other aesthetic considerations are incorporated in the design to encourage human use. Signage informs residents about conservation measures being used to protect natural resources.

In summary:

- Consider the landscape context when designing buffers
- Design each buffer for multiple objectives
- Be aware of potential unintended effects of buffers
- Recognize the benefits and limitations of buffers
- Use a planning process

To begin using this guide, refer to the **How to Use This Guide** section.



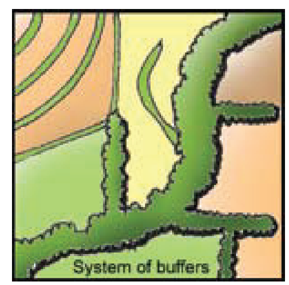
1.1 Buffers and land management

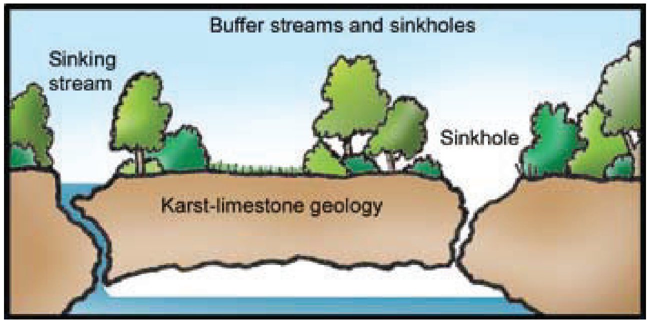
Water quality goals may not be achievable with buffers unless the adjacent land uses are also managed for better water quality. There are many ways that pollutant loads can be reduced from adjacent land uses. Refer to other publications for guidance. See general management considerations.

In some cases, it may be that inappropriate land management practices in just a few areas within a watershed are contributing a majority of the water quality problems. Targeting better land management practices in these few, select areas may yield significant improvements (see section 1.4).

General management considerations

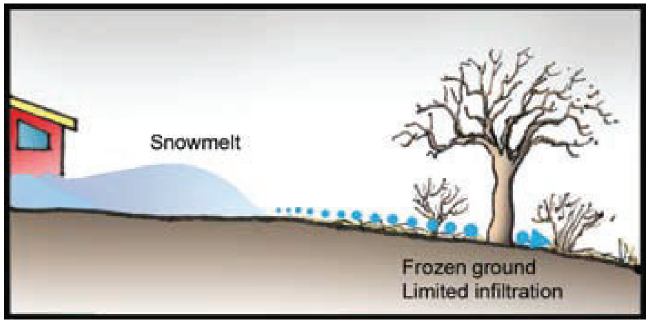
- Manage land to reduce runoff and increase infiltration.
- Maintain vegetative cover as much as possible.
- Avoid potentially polluting activities on areas most prone to generating significant runoff.
- Minimize potentially polluting activities during times of year most prone to generating runoff.
- Use a system of upland buffers to reduce runoff and pollutant load to riparian buffers.





1.2 Karst landscapes

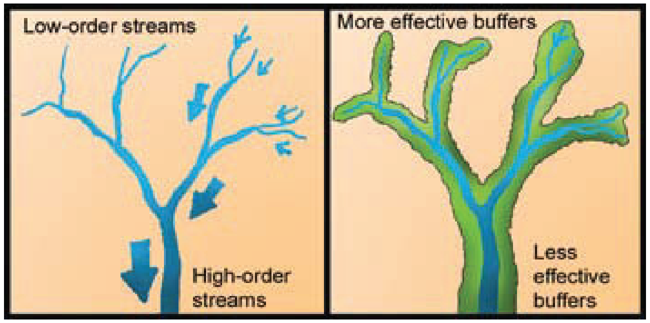
Karst or limestone dominated landscapes are particularly susceptible to water quality problems due to the direct and often short connections between surface water and groundwater. Buffers can be used around sinkholes and sinking streams to minimize polluted runoff entering directly into the groundwater system.



1.3 Frozen soils

In regions where runoff occurs while the soil is frozen, buffers will be much less effective due to limited infiltration. Other best management practices will need to be used in addition to buffers.

Water Quality

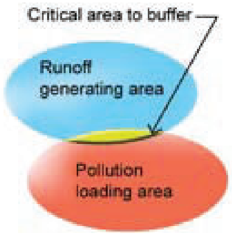


1.4 Target buffers in watersheds

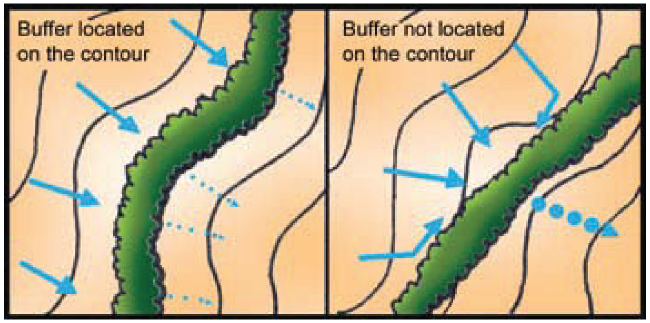
Water quality buffers will be more effective in some areas than in others. Targeting buffers to areas that have high pollutant loads and suitable characteristics for pollutant removal will generally have the greatest benefit on water quality.

General targeting considerations

- Riparian buffers will often be more effective along small or low-order streams than larger or high-order streams since most water delivered to channels from uplands enters along low-order streams.
- Groundwater recharge areas, ephemeral channels, and other areas where runoff collects are important areas to buffer.
- In some regions, surface runoff is generated primarily from areas that become saturated during storms. Where these runoff source areas correspond to a pollution loading area, such as a cultivated field, these areas should be buffered.

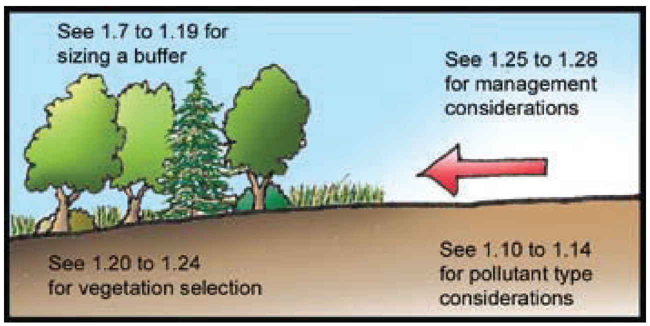


- Surface runoff from cultivated areas is higher where slopes are steeper and soils are finer-textured. These areas are important to buffer.
- GIS are useful for conducting landscape-scale assessments to target buffers.



1.5 Arrangement near sources

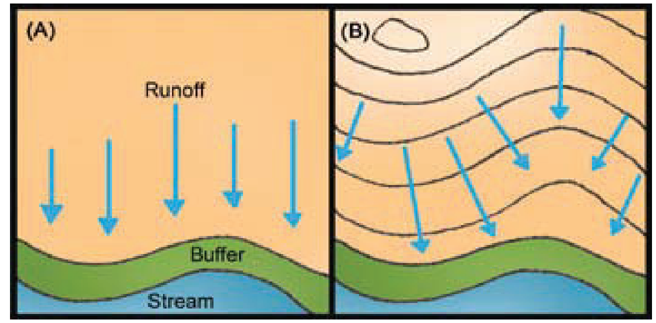
Buffers should be located as close as possible to the pollution source and should be placed along the contour to promote shallow flow across the buffer. If the contour is not closely followed, a buffer may increase concentration of runoff flow and reduce buffer effectiveness. Grass barriers can help spread out concentrated flows (see section 1.21).



1.6 Buffer site design

Important design elements for any buffer include its size, the kind of vegetation it contains, and how it is managed. Each of these elements is dictated by site factors including pollutant type and load, the buffer's capacity to trap and transform these pollutants and the desired level of pollution reduction. Use the figure above as a road map to guidelines on site design.

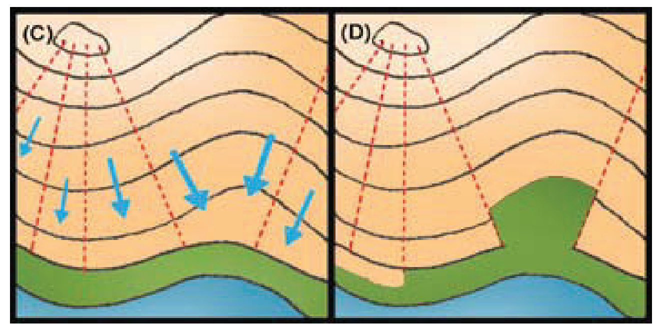
Water Quality



1.7 Variable buffer width

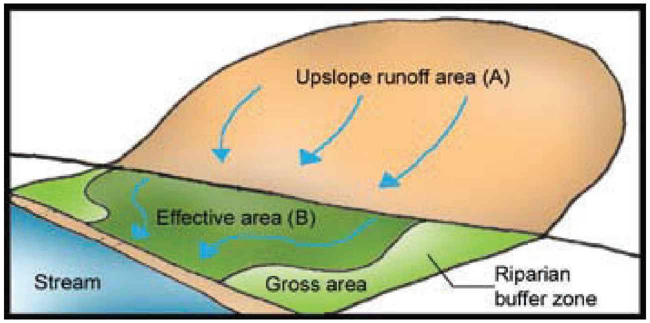
Buffers may have a fixed width where uniform runoff occurs (A). However, runoff is often nonuniform and flow is either diverging or converging due to topography, tillage practices, and other factors (B). A fixed-width buffer will be less effective in these situations.

Instead, buffer width should be variable by widening and narrowing the buffer as runoff loads and buffer site conditions vary.



Runoff areas and corresponding buffer locations to which they flow can be mapped (C). Buffer width can then be modified to account for differences in runoff loads (D). Buffers will need to be wider for upslope runoff areas that are larger and contribute greater loads.

The ratio of the upslope runoff area to buffer area can provide additional design guidance (see section 1.8).



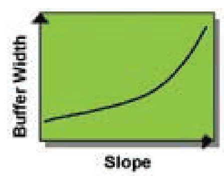
1.8 Effective buffer area ratio

The amount of runoff through an area of buffer should be low to achieve high pollutant removal. One consideration is to base the design on a ratio of upslope runoff area (A) to effective buffer area (B). Lower ratios (e.g., 20:1) can provide substantially greater pollutant removal than higher ratios (e.g., 50:1) in many cases. Note that the effective buffer area is the actual pathway that runoff travels to the stream and it may be smaller than the overall gross area of the buffer.

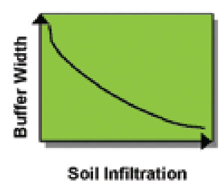
1.9 Slope and soil type adjustments

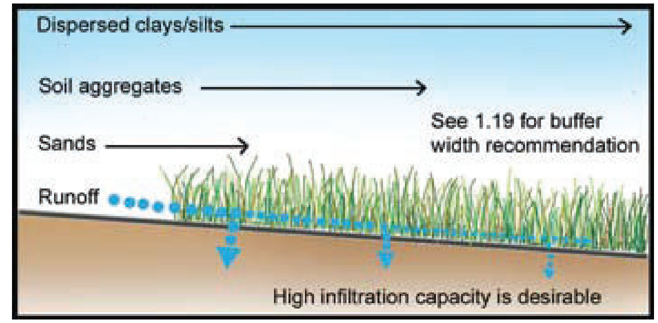
Land slope and soil type have significant impact on the ability of a buffer to remove pollutants from surface runoff.

Steeper slopes reduce performance by allowing greater pollutant transport and less time for infiltration. Steeper slopes will require wider buffers.



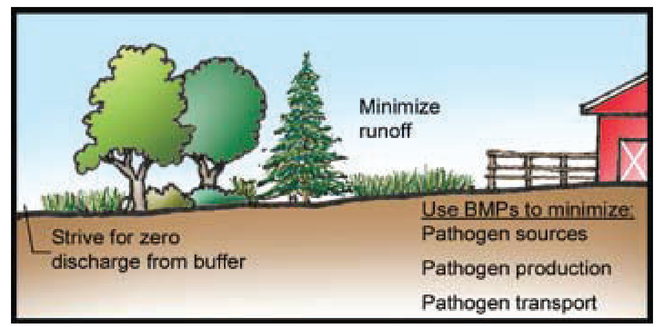
Soils with higher infiltration capacity can reduce runoff to a greater degree than soils having lower infiltration. Soils with lower infiltration capacity will require wider buffers. Finer-textured soils typically have lower infiltration than sandy soils.





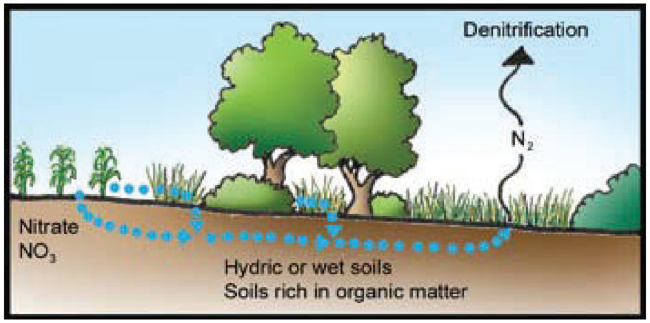
1.10 Buffers for sediment

Sediment is the pollutant most effectively removed from runoff by buffers. Coarse-textured sediments will settle out first while finer particles will require wider buffers to be removed. Buffers for sediment trapping should only be used as a final defense. Soils first need to be kept in place as much as possible with sediment and erosion control best management practices. See section 1.25 for managing sediment build-up.



1.11 Buffers for pathogens

Buffers can reduce pathogens in surface runoff from urban lands, pastures, manure-applied fields, and confined animal feeding operations but are generally ineffective by themselves to meet water quality standards. Buffers need to be combined with other best management practices to meet standards.



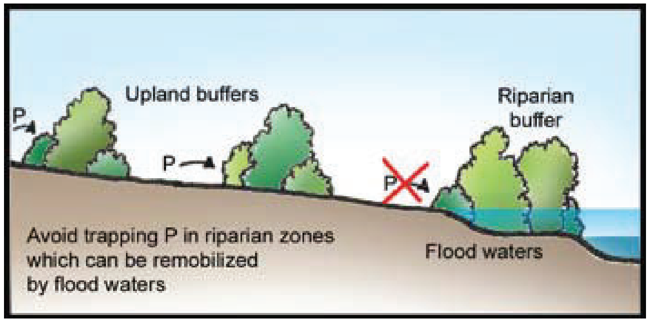
1.12 Buffers for nitrogen

Most nitrogen (N) is lost to surface water through overland flow and to groundwater by leaching of nitrate (NO_3). Plant uptake of N generally does not result in permanent removal as N is eventually returned to the soil upon death and decay of plants unless harvested (see section 1.26).

Denitrification is the primary process for permanently removing N with a buffer. In denitrification, anaerobic bacteria transform nitrate to nitrogen gas (N_2) which is released into the atmosphere. Below are some key site characteristics that promote effective denitrification with buffers.

Key design considerations

- Soils should be rich in organic matter, often provided by decaying plant material.
- Soils need to be wet or hydric.
- Soils should have moderate to high permeability to encourage infiltration and yet should be poorly drained to have anaerobic conditions. Deep coarse sands or gravel may allow dispersion to deeper groundwaters before denitrification occurs.
- Low temperatures and acidic soils will inhibit denitrification.
- See section 1.19 for buffer width recommendations for surface N runoff.
- See section 1.15 for shallow groundwater flow.



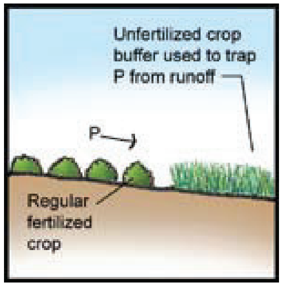
1.13 Buffers for phosphorus

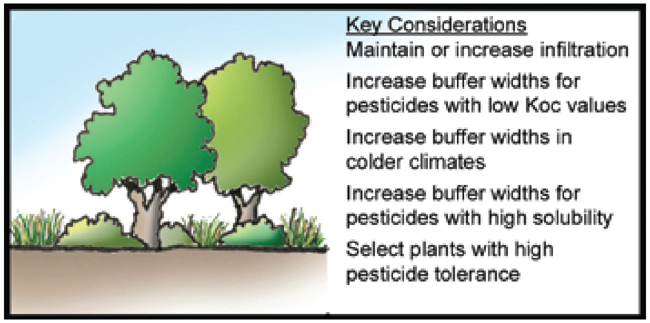
Phosphorus (P) in runoff occurs either as particulate phosphorus or as dissolved phosphorus. Particulate phosphorus is sediment-bound and can be moderately well trapped by deposition in buffers. Dissolved phosphorus must infiltrate with runoff water and be trapped in the soil.

Unlike N which can be released to the atmosphere through denitrification, P will accumulate in the buffer. Once a buffer is saturated with P, it can turn into a source for P. Other best management practices will be necessary to manage phosphorus.

Key design considerations

- Avoid trapping P in riparian buffers which can be remobilized by flood waters.
- See section 1.19 for buffer width recommendations.
- Buffers consisting of unfertilized crops or hayfields can trap and utilize P. Removing this vegetation through harvest may help export P, as well as N, out of the watershed (see section 1.26). Select plants with high nutrient demand.





1.14 Buffers for pesticides

Pesticides in runoff occur either as sediment-bound or in a dissolved form. Dissolved pesticides are generally the most susceptible to leaving an application area and becoming a pollution problem. Pesticide properties can provide some guidance on the mobility of the pesticide.

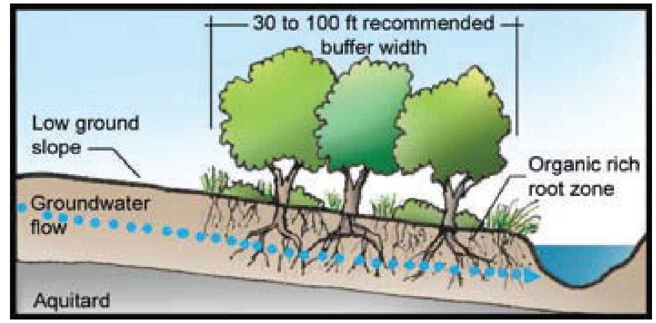
Key design considerations

- Some pesticides adsorb strongly to soils while others adsorb weakly as noted by the Koc value or soil adsorption index. See table below for recommendations.
- Pesticides with high water solubilities (e.g., > 30 ppm) will generally require wider buffers.
- Pesticides with longer half lives (e.g., > 30 days) may require wider buffers.
- Other pesticide best management practices should be used in addition to buffers (see sections 5.1 to 5.4).
- See section 1.19 for buffer width recommendations.

Pesticide properties can be found on product labels.

Koc Value Influence on Buffers for Pesticides

Koc Value	Adsorption and Movement	Buffer Recommendation
< 500	Adsorbs weakly, movement with water	Maximize water infiltration and runoff contact time with soil and vegetation Generally requires wider buffers
> 500	Adsorbs strongly, movement with sediment	Maximize sediment trapping in buffer Narrower buffers may be sufficient



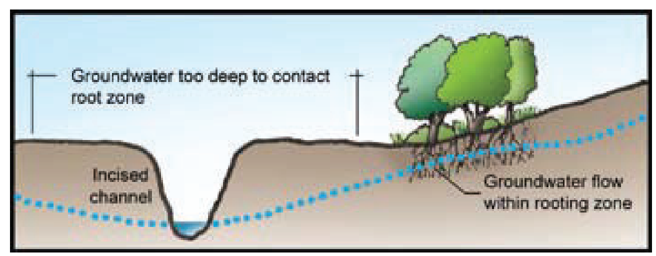
1.15 Buffers for shallow groundwater

Buffers may contact shallow groundwater and through various processes, remove some pollutants transported in it.

Nitrate	*Removal rates can be > 75 percent*
Dissolved phosphorus	*Not effectively removed*
Pesticides	*Limited data at this time*

Key design considerations

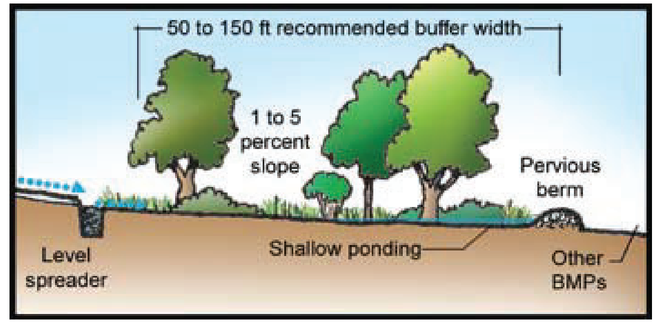
- Shallow groundwater is typically found near streams, lake shores, and wetlands. Buffers are effective where/when shallow groundwater flows toward the stream (and not vice versa).
- Where groundwater emerges as a spring or seep, it may flow across the buffer zone too quickly to be effectively treated. A wider buffer may be necessary to allow for reinfiltration.
- Buffers along deeply incised streams may not intercept groundwater. Groundwater may be shallower in locations farther away from these streams. These areas may be effective locations for buffers to filter groundwater.



Key design considerations *(continued)*

- Most nitrate reduction in shallow groundwater occurs within 30 to 100 feet of entering a buffer.
- The greatest nitrate removal occurs on sites where groundwater flow is confined within the root zone (shallower than about 3 feet) by a dense soil layer (aquitard) or bedrock.
- Select plants with adequate rooting depth to intercept the groundwater flow.
- Select plants tolerant of seasonal water table fluctuations and with higher root biomass.
- Because natural groundwater flow patterns can be very complex, consult with appropriate professionals.
- In areas where groundwater drainage has been augmented with drain tile pipes or ditches, groundwater flow will often bypass buffers untreated. Placing constructed wetlands at the end of tile drains or ditches can help reduce this problem.

Buffers for Shallow Groundwater Pollution	
Variable	**Factors Increasing Treatment Potential**
Slope	Lower ground slope (0 to 3 percent)
Depth to Water Table	Shallower water table (0 to 3 ft below surface)
Hydric Soils	Present and occupying significant width ($\geq$ 30 feet of buffer width)
Proximity to Source	Buffer closer to the source of pollution
Soil Drainage Class (natural)	Very poorly-, poorly-, and somewhat poorly-drained ratings
Organic Matter	Soils with higher concentrations of organic matter



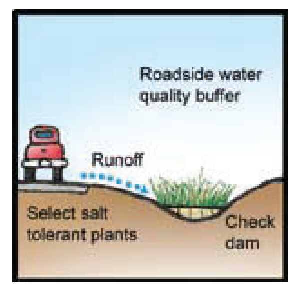
1.16 Urban runoff and roadsides

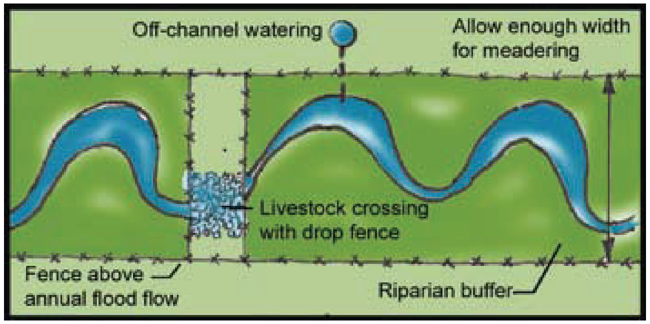
Buffers for urban runoff can be effective for trapping sediment but are generally less effective for dissolved pollutants. Buffers may be ineffective for urban stormwater where high runoff volume converges on and is channeled through the buffer. Buffers need to be designed to prevent flows from inundating or bypassing the buffer.

Key design considerations

- Buffers are best suited for low to moderate density areas (< 20 percent impervious cover).
- Flow length into a buffer should be < 150 feet for pervious surfaces and < 75 feet for impervious surfaces.
- A level spreader can be used to disperse concentrated flow along the width of the buffer.
- Other best management practices should be used with buffers including low impact development that minimizes impervious cover.

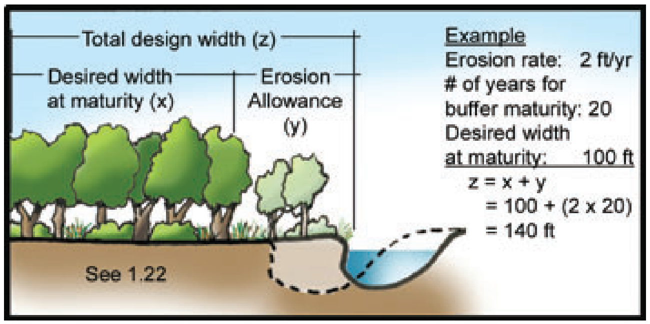
Vegetated roadside buffers can be used to improve water quality by filtering runoff. Use check dams to slow water movement and increase retention time. Select salt tolerant plants where road salt is used.





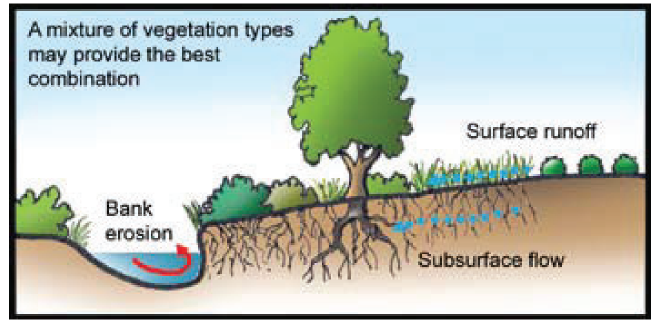
1.17 Buffers and grazing

Fencing riparian buffers from pastures is often necessary to protect water quality. Grazing has limited potential for nutrient removal from buffers (see section 1.26) and may accelerate bank erosion. Short duration grazing may be allowed within some riparian buffers. Grazing should not occur when soil is wet, when plants are emerging or setting seed, or when plant cover is limited or stressed by dry conditions.



1.18 Allowances for bank erosion

Buffers implemented for reducing streambank erosion may need to include additional width to allow for erosion while vegetation matures to the point where it becomes effective. Mature vegetation may not entirely halt streambank erosion since some erosion is natural. In severely degraded watersheds, vegetation alone will not reduce streambank erosion and other causes will need to be addressed.



1.20 Vegetation for removing pollutants from runoff

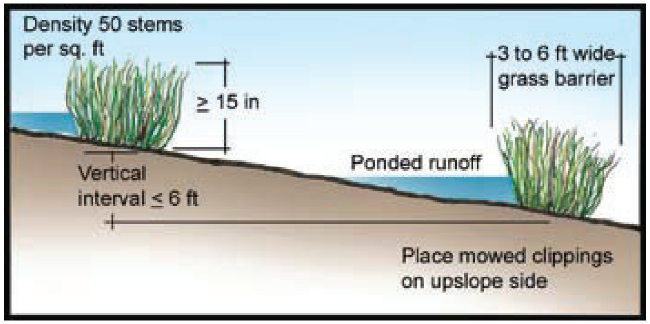
Pollutant removal functions of vegetation include reducing flow velocities, increasing deposition and infiltration, and providing nutrient uptake and organic matter for pollutant transformation.

Many types of vegetation can provide these functions. A mixture of herbaceous and woody species may provide the best overall combination (see table below). Vegetation selection should also be based on site capabilities and landowner preferences.

Other factors (e.g., width, slope, location, buffer area ratio, and soils) may play more important roles than vegetation type.

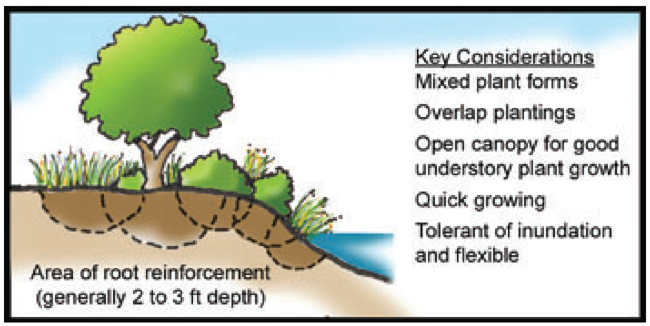
Vegetation Selection for Water Quality

	General Criteria
Surface runoff	High stem and debris density Stiff stems Tolerant of sediment build-up Tolerant of high nutrients levels and other pollutants Actively growing during runoff season
Subsurface flow	Plants with roots that intercept subsurface flow Plants with higher root biomass Tolerant of wet soils and high nutrient levels Avoid N-fixing plants
Bank Erosion	See 1.18 and 1.22.



1.21 Stiff-stemmed grass barriers

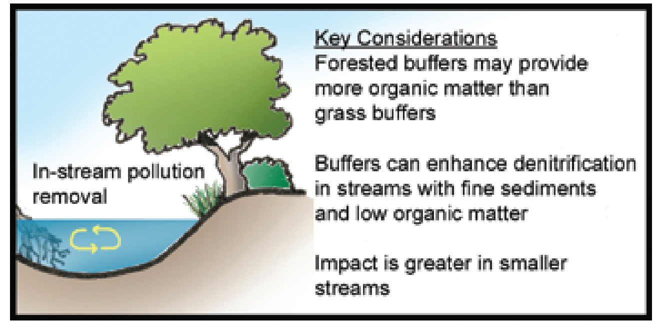
Grass barriers are narrow strips of tall, dense, stiff-stemmed grasses planted perpendicular to the slope. These barriers can slow and pond runoff, promoting infiltration and deposition of sediment. Used mainly where gullies would form on steep land and to slow and disperse concentrated flow.



1.22 Vegetation for bank erosion control

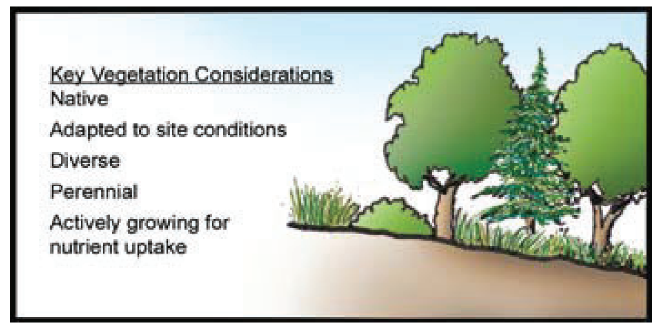
Herbaceous plants with fibrous root systems are better for protecting banks from surface erosion. Woody species with deeper roots will be better at increasing soil cohesion and reducing mass slope failure. Select woody species that resprout from roots or from broken branches. The best approach is often a combination of plant types.

Water Quality



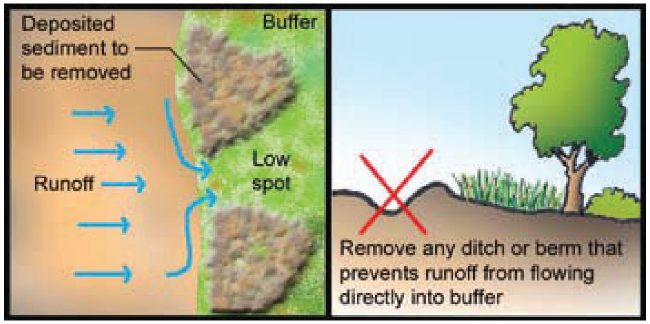
1.23 In-stream pollutant removal

Buffers can enhance in-stream processes that remove pollutants carried by streams. Plant debris supports denitrification and pesticide degradation while large woody debris promotes deposition of sediment (see section 2.11). In-stream pollutant removal rates are highly variable. Impact on stream pollution level is generally greater during low flows and in small streams.



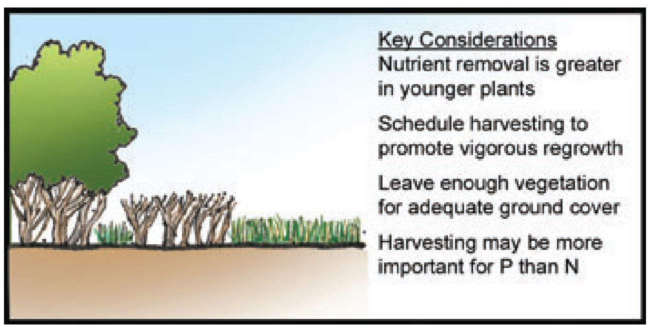
1.24 Species selection

Use historical native plant communities to guide vegetation selection, and select species adapted to site conditions. Use a diverse planting mixture to minimize pest and disease problems. Select perennial vegetation to provide permanent cover and to improve infiltration rates over time. Vegetation for nutrient uptake should be actively growing during the runoff season.



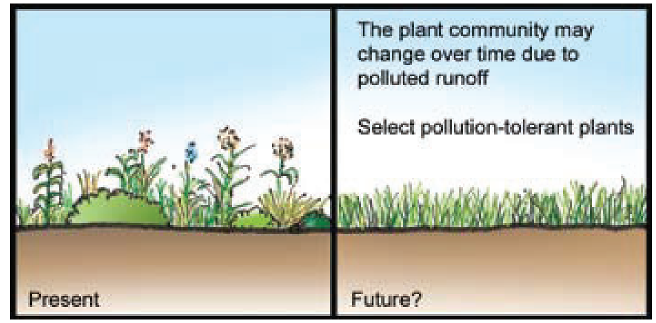
1.25 Sediment removal

Sediment trapped in a buffer will change flow into the buffer over time, often resulting in concentrated flows. Periodic removal of accumulated sediment may be necessary. Use erosion control practices in source areas to reduce sediment load and minimize the need for future sediment removal from the buffer. Prevent a ditch or berm from being created along the inflow length of the buffer due to tillage or deposition.



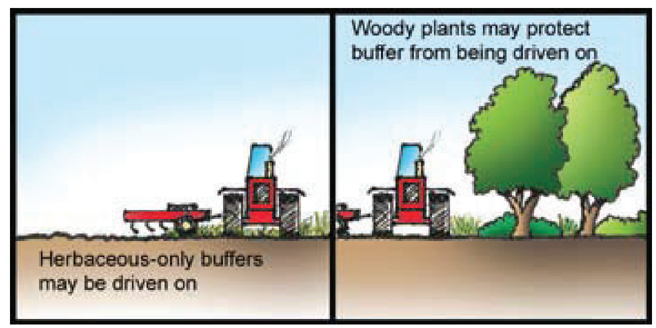
1.26 Harvesting for nutrient removal

Harvesting and removing buffer vegetation can encourage plant regrowth and nutrient uptake. Although grazing may be used to remove vegetation, up to 60 to 90 percent of the ingested nutrients will be returned to the system as feces and urine. Harvesting should be considered in context with other management options.



1.27 Plant succession

Polluted runoff favors plant species that are more tolerant of pollution and may change the buffer plant community over time. One may need to select plants tolerant of pollutant loading. Over time, trees and shrubs will naturally become established in herbaceous buffers. Periodic tree and shrub removal may be required to maintain dense herbaceous buffers or the desired mix of woody species.



1.28 Vegetation and traffic

Traffic in buffers will compact soil, reducing infiltration and vegetation density. Woody vegetation may protect a buffer from being driven on, preventing soil compaction. Herbaceous-only buffers are easier to remove thus making them more vulnerable to changes in land management.

Excerpt Definitions from https://www.epa.gov/nps/basic-information-about-nonpoint-source-nps-pollution, and the Clean Water Act

Clean Water Act Section 502: General Definitions

(6) The term "pollutant" means dredged spoil, solid waste, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, sand, cellar dirt and industrial, municipal, and agricultural waste discharged into water. This term does not mean (A) "sewage from vessels" within the meaning of section 1322 of this title; or (B) water, gas, or other material which is injected into a well to facilitate production of oil or gas, or water derived in association with oil or gas production and disposed of in a well, if the well used either to facilitate production or for disposal purposes is approved by authority of the State in which the well is located, and if such State determines that such injection or disposal will not result in the degradation of ground or surface water resources.

(12) The term "discharge of a pollutant" and the term "discharge of pollutants" each means (A) any addition of any pollutant to navigable waters from any point source, (B) any addition of any pollutant to the waters of the contiguous zone or the ocean from any point source other than a vessel or other floating craft.

(14) The term "point source" means any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged. This term does not include agricultural stormwater discharges and return flows from irrigated agriculture.

The USEPA defines Nonpoint Source Pollution as:

any source of water pollution that does not meet the legal definition of "point source" in section 502(14) of the Clean Water Act

NPS pollution generally results from land runoff, precipitation, atmospheric deposition, drainage, seepage or hydrologic modification. NPS pollution, unlike pollution from industrial and sewage treatment plants, comes from many diffuse sources. NPS pollution is caused by rainfall or snowmelt moving over and through the ground. As the runoff moves, it picks up and carries away natural and human-made pollutants, finally depositing them into lakes, rivers, wetlands, coastal waters and ground waters.

Nonpoint source pollution can include:

- Excess fertilizers, herbicides and insecticides from agricultural lands and residential areas
- Oil, grease and toxic chemicals from urban runoff and energy production
- Sediment from improperly managed construction sites, crop and forest lands, and eroding streambanks
- Salt from irrigation practices and acid drainage from abandoned mines
- Bacteria and nutrients from livestock, pet wastes and faulty septic systems
- Atmospheric deposition and hydromodification

States report that nonpoint source pollution is the leading remaining cause of water quality problems. The effects of nonpoint source pollutants on specific waters vary and may not always be fully assessed. However, we know that these pollutants have harmful effects on drinking water supplies, recreation, fisheries and wildlife.

2022 NCF-Envirothon Ohio

Soils and Land Use Study Resources

Key Topic 4: Soil Surveys and Interpretations

17. Generate soil interpretations and reports using Web Soil Survey.
18. Make land use management decisions in the field based on information obtained from a soil survey.
19. Identify online planning tools for the agricultural community and apply those tools to field management scenarios.

Study Resources

Resource Title	Source	Located on
Web Soil Survey brochure	*USDA NRCS, April 2020*	Pages 88-89
Free, Online Data and Tools for the Agricultural Community, FABE-552.04	*Sami Khanal, John Fulton, Ajay Shah, Scott Shearer, Elizabeth Hawkins, The Ohio State University, May 2018*	Pages 90-99

Study Resources begin on the next page ➡

Soil Survey Data

Soil survey data are a product of the National Cooperative Soil Survey, a joint effort of the USDA Natural Resources Conservation Service and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local participants.

Web Soil Survey (WSS)

The Web Soil Survey provides agricultural producers, agencies, Technical Service Providers, and others electronic access to relevant soil and related information needed to make land-use and management decisions. The WSS:

- Provides an alternative to traditional hardcopy publication,
- Provides the means for quicker delivery of information,
- Provides electronic access to full soil survey report content,
- Provides access to the most current data,
- Allows customers to get just the information they want, and
- Provides customers with the ability to download spatial, tabular, and thematic soils data for use in GIS.
- Additional help is available at "Contact Us" or by emailing soilshotline@lin.usda.gov.

Current, Custom

Soil Maps & Reports:

Fast.

Free.

Friendly.

Print a Hydric Soil Map

- Complete Steps 1, 2, and 3.
- From the **Soil Data Explorer** tab, click the **Suitabilities and Limitations for Use** tab.
- Click **Land Classifications**.
- Click **Hydric Rating by Map Unit**.
- Click the **View Rating** button.
- Click the **Legend** tab to open or close the map symbol legend.
- Click the **Printable Version** button.
- Click the **View** button.
- On the browser menu bar, select **File** and **Print**; or click the print icon.

Print a Soil Chemical Properties Report

- Complete Steps 1, 2, and 3.
- From the **Soil Data Explorer** tab, click the **Soil Reports** tab.
- Click **Soil Chemical Properties**.
- Click **Chemical Soil Properties**.
- Click the **View Soil Report** button.
- Click the **Printable Version** button.
- Click the **View** button.
- On the browser menu bar, select **File** and **Print**; or click the print icon.

Natural Resources Conservation Service

National Cooperative Soil Survey

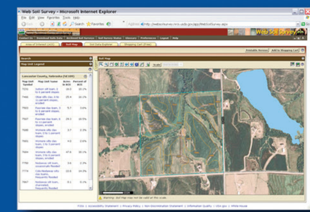
April 2020

USDA United States Department of Agriculture

Web Soil Survey

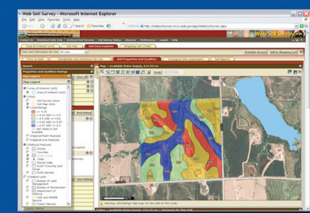
http://websoilsurvey.nrcs.usda.gov

Define.



Search / Locate

Collect.



Analyze Data

Develop.

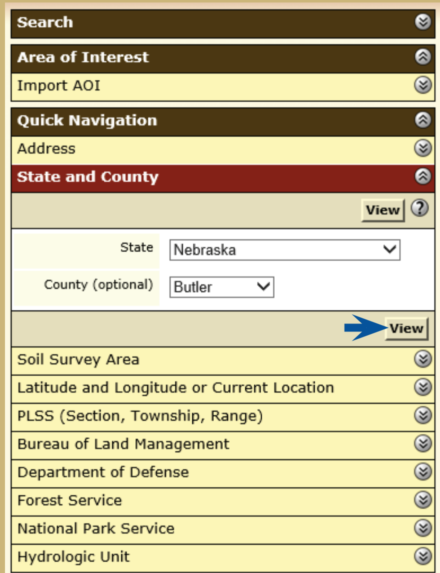
Custom Reports & Maps

"Helping People Help the Land"

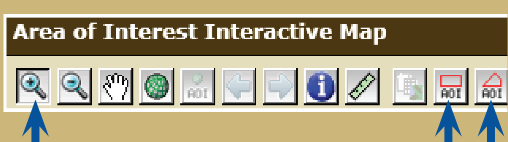
Accessing Web Soil Survey

- Open the Web Soil Survey (WSS) site at: http://websoilsurvey.nrcs.usda.gov and click the **Start WSS** button.

Step 1. Define Your Area of Interest (AOI)

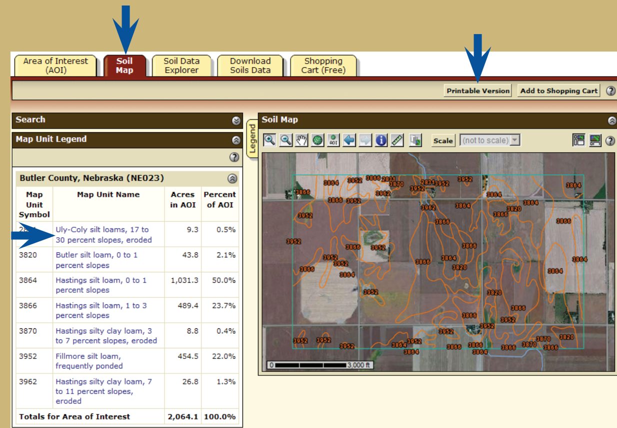


- Several methods are available to zoom into a geographic area of interest. You can enter an address; select a state and county; enter section, township, and range information; or import a boundary file from your local computer to set the AOI.
- Click the **View** button to see the area.



- Use the **Zoom In** tool (plus sign) to click and drag a rectangular box around a specific area. Repeat, as necessary, to zoom further.
- Select an **AOI** tool to draw a rectangular box or irregular polygon that defines the AOI and allows selection of associated soil data. Once the AOI has been defined, you can save it for use at a later date.

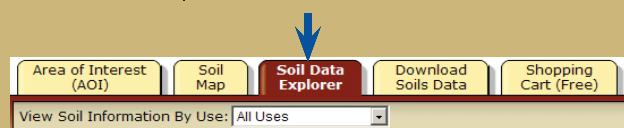
Step 2. View and Print Your Soil Map



- Click the **Soil Map** tab.
- Click a map unit name to view a map unit description. Click the **X** to close the narrative.
- Print your soil map by clicking the **Printable Version** button; then click the **View** button. On the browser menu bar, select **File** and **Print**; or click the print icon. Close the window.

Step 3. Explore Your Soil Information

WSS generates thematic maps of soil interpretations, ecological sites, and chemical or physical properties. Tabular data reports are also available.



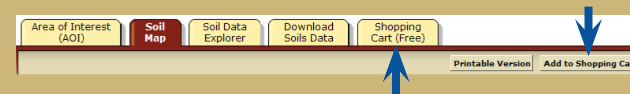
- Click the **Soil Data Explorer** tab.

- Click the tabs below **Soil Data Explorer** and explore available information (the default tab is **Suitabilities and Limitations for Use**).

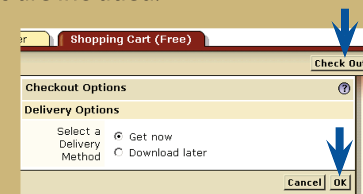
Step 4. Add Items to the Free Shopping Cart and Check Out

WSS allows you to collect a variety of thematic maps and reports in the Shopping Cart, then print or download the content into one file or document.

- Soil map, map unit legend, and map unit descriptions are automatically added.

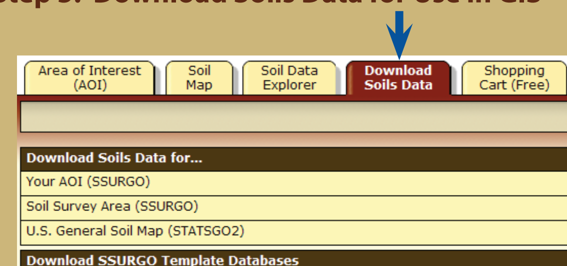


- Items viewed in Step 3 can be added by clicking the **Add to Shopping Cart** button.
- View your cart contents by clicking the **Shopping Cart (Free)** tab. Items checked on the Table of Contents are included.



- Get your Custom Soil Resource report.
  -- Click the **Check Out** button.
  -- Select a delivery option and click **OK**.

Step 5. Download Soils Data for Use in GIS



WSS allows you to download spatial and tabular SSURGO and STATSGO2 soils data for use in your local GIS. SSURGO data can be downloaded for your defined AOI or for a soil survey area. STATSGO2 data can be downloaded for individual states or for the whole United States.

NOTE: At any time during Steps 2, 3, 4, or 5, you can redefine the soil map location by clicking the **Area of Interest** tab and clicking the **Clear AOI** button. Repeat Step 1.

THE OHIO STATE UNIVERSITY
COLLEGE OF FOOD, AGRICULTURAL, AND ENVIRONMENTAL SCIENCES

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Free, Online Data and Tools for the Agricultural Community

FABE-552.04
Date: 05/17/2018

Sami Khanal, John Fulton, Ajay Shah, Scott Shearer, Elizabeth Hawkins

Today's agricultural community relies on data and tools to help support decision making at the field level. Data-driven insights help agronomists and farmers to predict what is coming, and decide how to act upon this information more effectively, which can improve on-farm decision making and execution. By integrating a farmer's experience with data collected via cutting-edge technologies, such as drones, satellites, GPS, and high-tech sensors, decisions can be more focused (i.e., field-specific), quicker, smarter and simpler. Data and tools can help locate areas of a field suffering from stress earlier than the human eye, and can provide recommendations to boost crop yields while minimizing environmental footprints. Hence, comprehensive databases that are easily accessible are essential to the agricultural community (Figure 1).

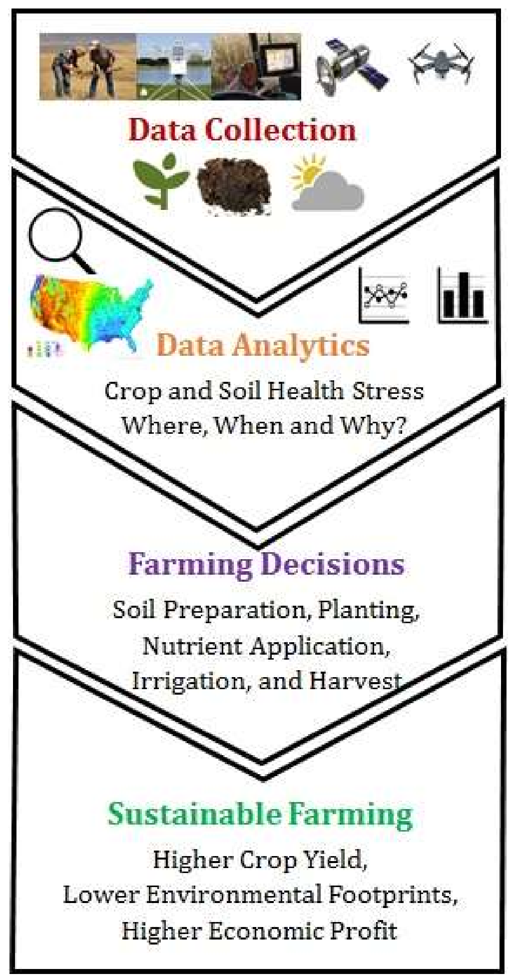


Figure 1. Data and tools for sustainable agricultural practices.

Several agricultural related data and tools are available from government agencies; however, many in the agricultural community may be unfamiliar with available data and their potential applications. This publication outlines some data, in particular spatial data, and tools that are available publicly at no cost, including information about their sources and how they may be usable within a precision agriculture (PA) database.

Types of Public Data

Digital Elevation Model (DEM)

What is a DEM? A DEM uses land surface elevations to produce a map that depicts the terrain surface. Typically, maps use contours or colors to represent elevations, slope, or other parameters.

Why is a DEM useful? It is useful for many applications such as:

1. Deriving landform characteristics such as slope and aspect (Figure 2).
2. Forecasting flash flooding.
3. Estimating soil erosion.
4. Estimating vegetation height.
5. Producing a 3D representation of the surface.
6. Identifying tile placement and land upgrades.
7. Identifying water catchment or contributing areas, as well as potential locations for best management practices such as grassed waterways.

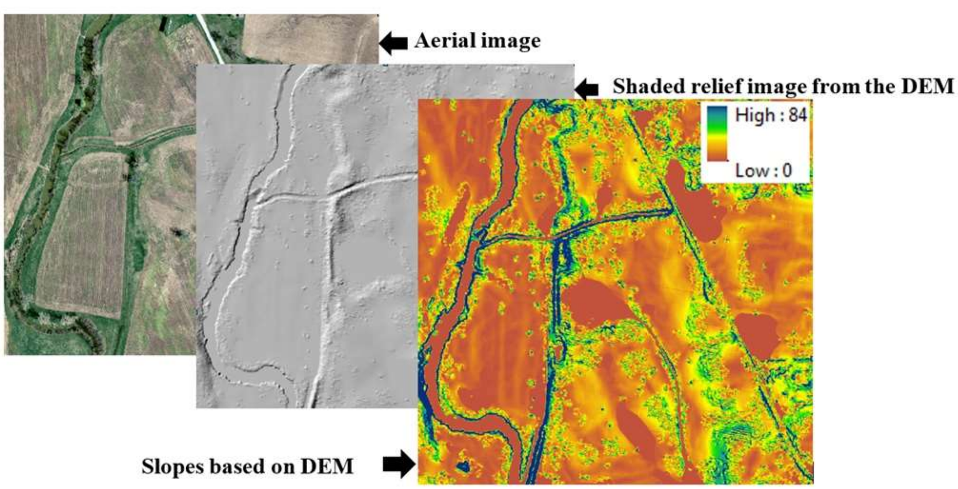


Figure 2. Aerial image, shaded relief image, and slopes (%) of a field near London, Ohio.

Where can I get DEM data? The U.S. Geological Survey (USGS) has developed the National Elevation Database, which is a seamless mosaic of the best-available elevation data. For the contiguous United States, DEM data are available at three different spatial resolutions—3, 10 and 30 meters. For some states, or areas within a state, higher spatial resolution (i.e., 1 meter resolution) DEM data are available. The websites that can be used for downloading DEM data are:

i. **USGS National Map**—Allows users to interactively select the region of interest for data download. It also shows the availability of various resolutions of DEM datasets for the region of interest (USGS, 2017).
ii. **USDA – Geospatial Data Gateway**—Offers a drop-down or list of options for selecting the region of interest for downloading the data (USDA-NRCS, 2017a).

Soil Survey Geographic Database (SSURGO)

What is SSURGO? The SSURGO database contains soil information collected by the National Cooperative Soil Survey over the course of a century. Soil data are available for most areas in the United States.

Why is SSURGO useful? It provides information on soil properties and qualities useful for evaluating and planning the use and management of land or soil. Examples include:

1. Land Classification: Specific land use and management groups can be assigned based on soil properties. For example, it can help determine prime vs. non-prime farmlands, or hydric (i.e., soil which is permanently or seasonally saturated by water) vs. non-hydric soils (Figure 3).
2. Land Management: Soil response (e.g., erosion, leaching, runoff) to various land management practices, including irrigation and equipment use, can be estimated.
3. Vegetative Productivity: SSURGO can be used to estimate potential vegetative productivity for a variety of land uses, including cropland, forestland, pastureland and other land types.
4. Water Management: It can help determine the suitability of the soil for various water management practices, including irrigation, grassed waterways and drainage.

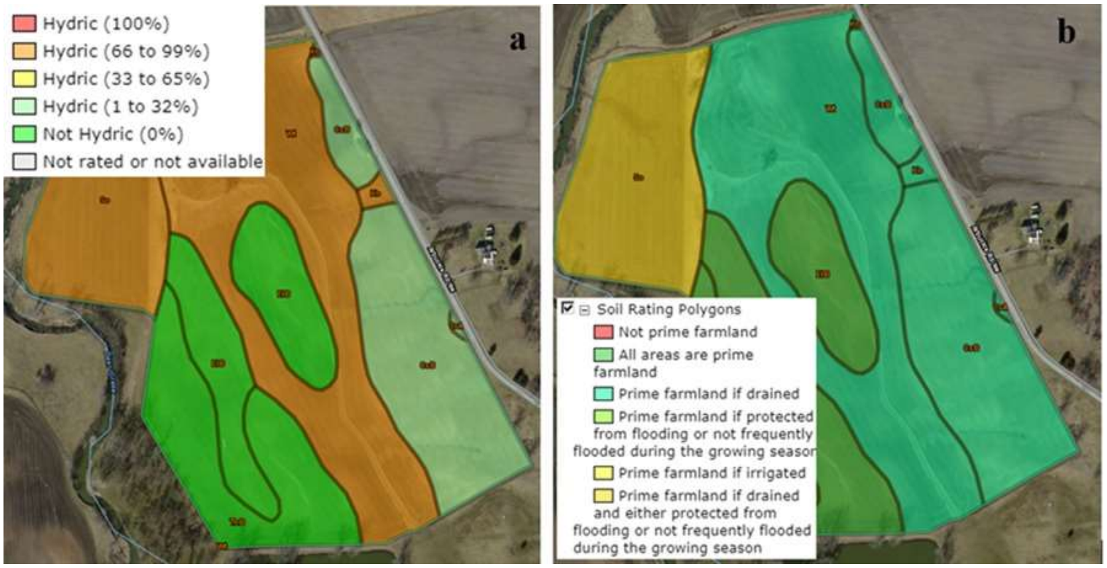


Figure 3. Visualization of soil characteristics—(a) hydric rating, (b) farm land classification using soil survey data.

Where can I get a SSURGO database? Soil data for a state, county or region of interest can be explored online or downloaded using the following websites:

i. **Web Soil Survey**—Allows users to interactively select the region of interest and to visualize soil properties and their derivatives (e.g., Figure 3) without requiring data downloading or special Geographic Information System (GIS) software. Reports or maps can also be generated instantaneously (USDA-NRCS, 2017b).
ii. **USDA – Geospatial Data Gateway**—Offers a drop-down or list of options for selecting the region of interest for downloading the data (USDA-NRCS, 2017a).

Climate Data

What are climate data? Climate data provide long-term atmospheric and weather conditions, such as extreme events, precipitation, or temperature.

Why are climate data useful? Climate and weather conditions have significant impacts on agriculture. Climate data can help inform and prepare producers to reduce the impact of adverse weather events, and provide opportunities to implement plans within favorable weather conditions. Some of the climate derived variables (see below) can be used to help track crop growth and mitigate crop stress. Examples include:

1. Growing Degree Days: A measure of heat accumulation that can help assess the phenological development stages of crop, including crop emergence and maturity, crop disease outbreaks, and frost risk.

2. Drought Index: A measure of dryness based on precipitation and temperature that can be used to examine the need for irrigation over the growing season.
3. Climate Normals: Three-decade averages of climate variables, including temperature, precipitation and storms, can be used for designing climate resilient conservation practices through assessment of the likelihood of an event, such as landslides and flooding.

Where can I get climate data? Historical climate data for a state, county, specific location, or weather station can be retrieved from the following websites:

i. **PRISM Climate Group**—Provides multiple spatial/temporal resolution climate data from 1895 to the present for the entire conterminous United States. Climate data between weather stations are spatially interpolated, and data are available in multiple forms including maps, csv, and text formats. Users can interactively select a region of interest to retrieve the climate data. Figure 4 shows the 30-year normal annual mean temperature and precipitation for the conterminous United States (PRISM Climate Group, 2017).

ii. **National Climatic Data Center (NCDC)**—Provides climate data for a state, county, location, or weather station in csv, pdf and text formats (NCDC-NOAA, 2017).

iii. **Midwestern Regional Climate Center (MRCC)**—Provides high-quality climate data, derived information, and data summaries for the Midwest, and prepares specialized historical climate datasets. It serves the nine-state Midwest region (Illinois, Indiana, Iowa, Kentucky, Michigan, Minnesota, Missouri, Ohio and Wisconsin) (MRCC, 2017).

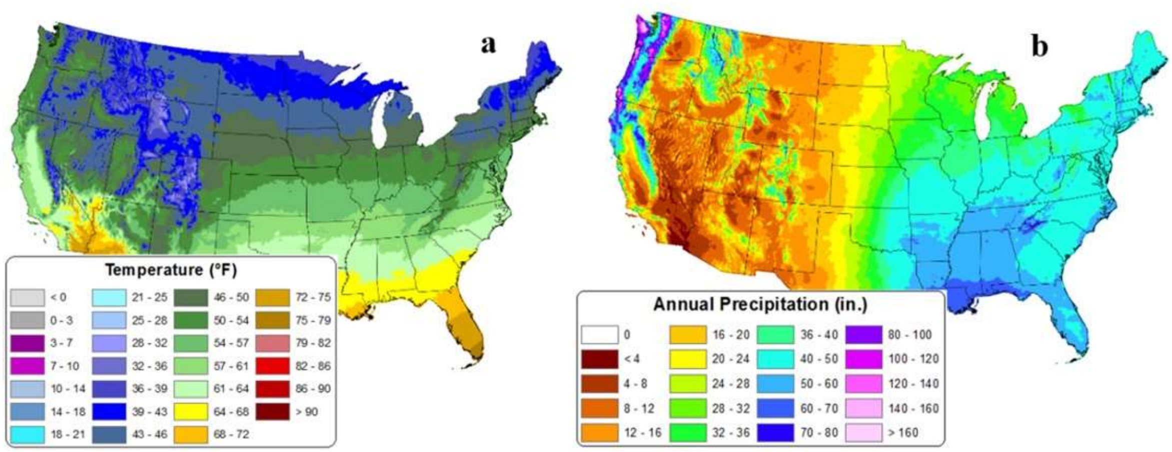


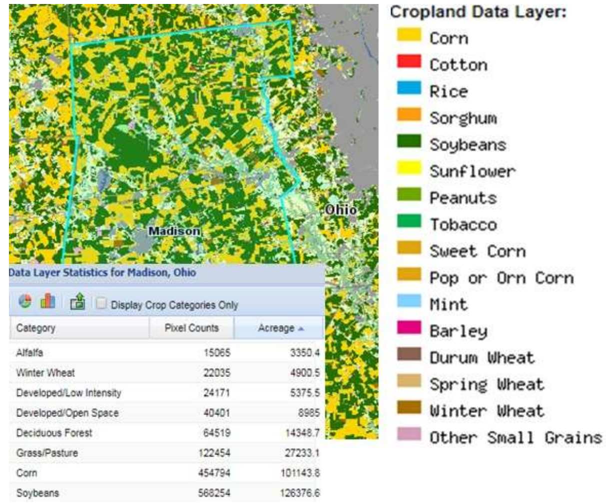
Figure 4. 30-year normal annual (a) mean temperature, (b) precipitation based on period 1981–2010 (Source: PRISM Climate Group).

Cropland Data Layer

What is a Cropland Data Layer? It is a map created using satellite imagery to provide spatial and temporal distributions of major crop commodities in the conterminous United States.

Why is a Cropland Data Layer useful? It can be used for:

1. Estimating acreage of specific vegetation or crop rotations.
2. Assessing changes in land use or land cover.
3. Planning and managing cropland.



Category	Pixel Counts	Acreage
Alfalfa	15065	3350.4
Winter Wheat	22035	4900.5
Developed/Low Intensity	24171	5375.5
Developed/Open Space	40401	8985
Deciduous Forest	64519	14348.7
Grass/Pasture	122454	27233.1
Corn	454794	101143.8
Soybeans	568254	126376.6

Figure 5. Example 2016 cropland data layer, and statistics for Madison County, OH. (*Source: CropScape*).

Where can I get Cropland Data Layers?

i. CropScape—Allows users to interactively select a region of interest, visualize the spatial distribution of vegetation, assess the temporal change in vegetation types, and generate statistics without requiring special type of GIS or image processing software (Figure 5) (USDA-NASS, 2017a).

ii. **USDA-Geospatial Data Gateway**—Offers a drop-down or list of options for selecting the region of interest for downloading data (USDA-NRCS, 2017a).

Vegetation Index (VI)

What is a Vegetation Index? It is an index useful for assessing density and vigor of crop. It is derived using spectral information from satellite imagery, which is acquired using sensors, at various wavelengths.

Why are Vegetation Indices useful? They allow users to characterize the health of vegetation. By analyzing the temporal and spatial distributions of vegetation indices, users can assess crop health conditions, locate areas of stress, and examine changes in vegetation.

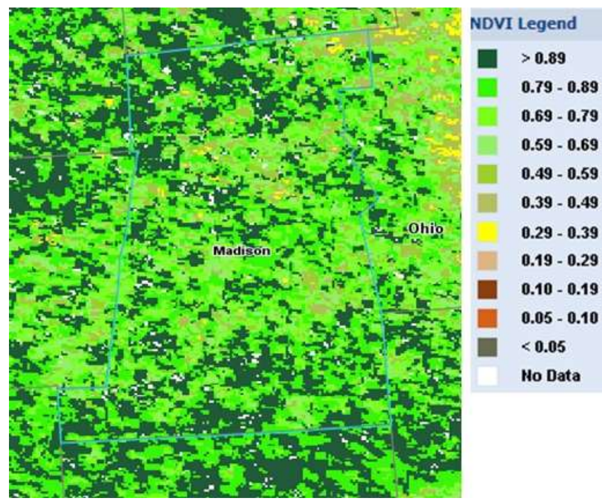


Figure 6. Normalized Difference Vegetation Indices (NDVI) of vegetation in Madison County, OH for 7/11/2017 (*Source: VegScape, 2017*).

Where can I download Vegetation Indices data?

- **VegScape–Vegetation Condition Explorer**—Allows users to explore, visualize, query and disseminate vegetation conditions without requiring users to download the data or use GIS or image processing software (Figure 6). It uses a normalized difference vegetation index, derived using 250 meter resolution MODIS satellite data, to represent the vegetation conditions. Data are available for the conterminous United States since 2000 (USDA-NASS, 2017b).

National Agricultural Statistics Service (NASS) Database

What is the NASS database? It is a comprehensive tool for accessing agricultural data published by the U.S. Department of Agriculture. These data, which include crop and livestock production figures and statistics, are based on either surveys or the agricultural census that is conducted every 5 years (Figure 7).

Why is the NASS database useful? It allows users to find agriculture survey and census data quickly. The search can be customized by commodity, location, or time period.

Where can I download NASS data?

NASS Database—Offers a list of options to access agricultural related data (USDA-NASS, 2017c).

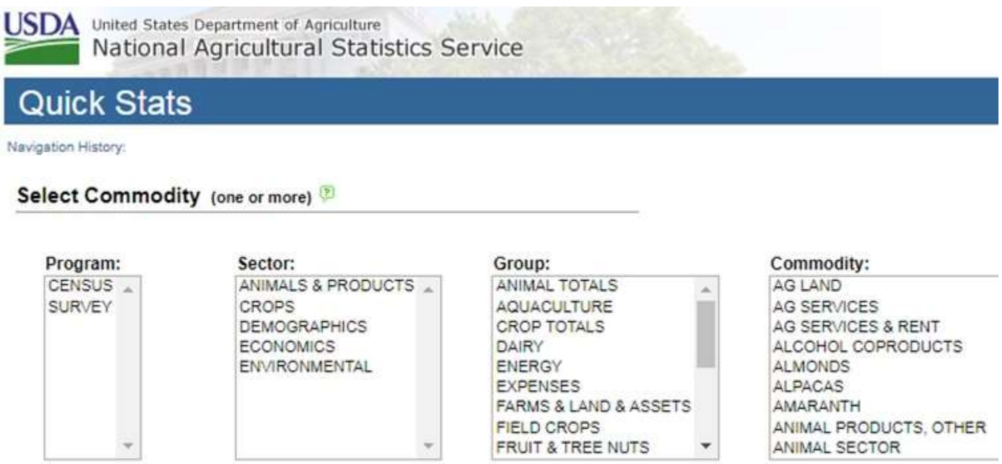


Figure 7. Graphic user interface of the NASS database.

Agro-Climate Tools

What is the Agro-Climate Tool? It is an online resource for the agricultural community in the north central region of the United States and is used to assess weather, climate, drought, and cropping data.

Why is the Agro-Climate useful? It provides a suite of decision support tools, including:

1. AgClimate View: Users can access historical climate and crop yield data for the U.S. Corn Belt, view graphs of monthly temperature and precipitation, plot corn and soybean yield trends, and compare climate and yields over the past 30 years (Figure 8).
2. Corn GDD: Tracks real-time and historical growing degree day accumulations; assesses spring and fall frost risk; and guides decisions related to planting, harvest, and seed selection.

3. Climate Patterns Viewer: Examines the effect of global climate patterns, such as the El Nino-Southern Oscillation and Arctic Oscillation, on local climate conditions and crop yields.
4. Corn Split N: Determines the feasibility and profitability of using post-planting nitrogen application or corn production.
5. Irrigation Investment: Explores the potential profitability of installing irrigation equipment at user-specified locations across the Corn Belt.

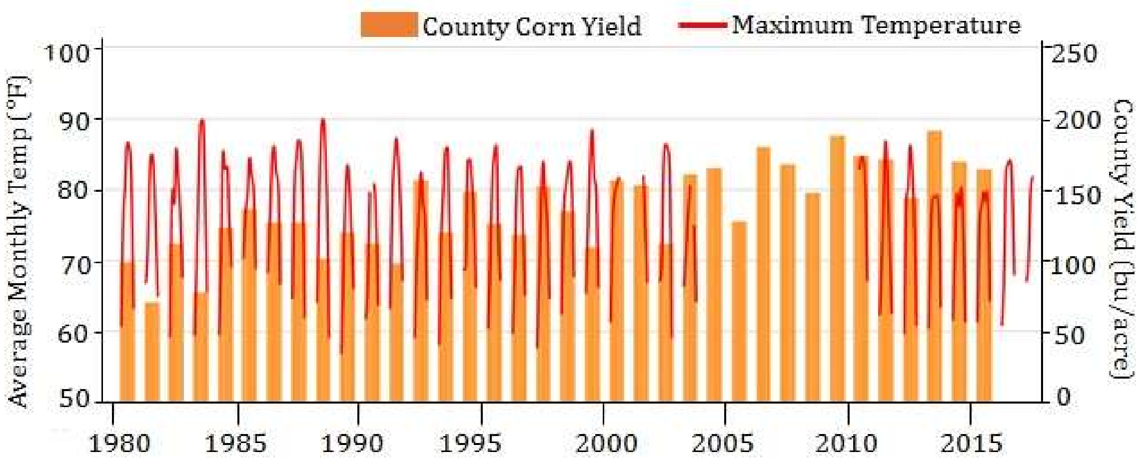


Figure 8. Maximum temperature and corn yield comparisons from 1980 to 2015 for Madison County, Ohio, based on AgClimate View.

Where to find this tool?

High Plains Regional Climate Center (HPRCC, 2017)—Offers a suite of decision support tools as discussed above.

Summary

Several agricultural datasets and tools exists that can either be freely downloaded or visualized online. These data and tools are mostly provided by federal agencies, recognizing that these data can be used for: daily decision making, such as where and when to plant; where to improve soil; when to apply fertilizer, pesticides and insecticides; and when to harvest. More data are anticipated to be available for public to use under the "open data" policy that is currently underway around the world. Use of these data help promote the efficiency and effectiveness in agricultural decision-making.

Acknowledgments
The authors thank Laura Lindsey, Assistant Professor, Department of Horticulture and Crop Science, and Margaret Kalcic, Assistant Professor and

Mary Wicks, Program Coordinator, both of whom are from the Department of Food, Agricultural and Biological Engineering for their technical and editorial reviews of the fact sheet.

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