Management of Wisconsin Soils

Fifth Edition
“If you are thinking a year ahead, sow seed. If you are thinking 10 years ahead, plant a tree. If you are thinking 100 years ahead, educate the people.”

_Gold Chinese saying_

**Introduction**

People look at soils differently. People may view soil in the home as a source of “dirt” or as a good medium for growing house plants. Construction engineers look at soil in terms of its ability to support a building or highway. But agriculturalists look at soil in terms of its ability to support the growth of plants. Obviously, this is its most important function because the soil ultimately supports nearly all plant and animal life.

Soil appears to be simply an inert mixture of different-sized particles. But this certainly is not the case. Living organisms by the billions, decaying and residual organic matter, a wide variety of minerals, and air and water interact to form a dynamic and exceedingly complex biological, physical and chemical system. For example, a teaspoon of soil may contain as many microorganisms as there are people on the earth. This same teaspoon of soil contains more chemical atoms than there are drops of water in Lake Superior and Lake Michigan combined!

The various chemical, physical, and biological processes taking place in the soil are complex and sometimes not easily understood. But for farmers and land managers to make wise decisions in the future, they must understand these processes. In this age of rapid technological change, we need to know why things happen—knowing only what to do is often inadequate.

Both grain and livestock farmers need to produce crops efficiently in order to succeed economically. And to produce crops efficiently, they must understand and use good soil management practices.

Growth of a colony of organisms, whether microbes, higher plants, animals, or people, is limited ultimately by exhaustion of the food supply or toxic accumulation of wastes. As the world population continues to grow, agriculturalists will be challenged as never before to increase production while managing wastes so as to recycle nutrients without polluting water supplies.

Good soil management is a key factor in maintaining the quality of our water resources. Protecting our surface water supplies requires that we follow a good soil and water conservation program. Runoff water and soil erosion losses account for much of the nitrogen and phosphorus entering our lakes and streams from rural areas. To protect groundwater we must develop nutrient management programs that support productive cropping systems and simultaneously reduce leaching of nutrients. If we are interested in agricultural sustainability and environmental protection, we must develop a conservation ethic and truly become “stewards of the soil.”

_Emmett E. Schulte_

_Leo M. Walsh_
Soil is a living entity: the crucible of life, a seething foundry in which matter and energy are in constant flux and life is continually created and destroyed.”

D. Hillel, Out of the Earth, 1991

What is soil?
Soil is the upper layer of earth which may be tilled and cultivated. More specifically, soils are the unconsolidated (loose) inorganic and organic materials on the surface of the earth which support the growth of plants. Weathered rocks and minerals make up the inorganic fraction of the soil and can supply all essential plant nutrients except nitrogen. Virtually all of the nitrogen, as well as a portion of several other essential plant nutrients, is stored in the organic matter.

Parent materials that make up Wisconsin's soils are (1) bedrock weathered in place, (2) deposits left by glaciers, (3) materials deposited by wind or water, and (4) decaying plant material.

The bedrock geology of an area often directly or indirectly influences soil formation. Soils in the west central and central parts of the state are the result of direct influence of bedrock. In these areas the weathering of the sandstone bedrock left predominately sandy soils. The bedrock has indirectly influenced those soils formed in glacial till. In northern and north central Wisconsin the glacial till is acid because the till was derived from the weathering of acidic granitic rock in northern Wisconsin; whereas, calcareous glacial till was developed in the southern and eastern parts of the state where the predominant bedrock is limestone. The map, Bedrock Geology of Wisconsin, shows the location of the different kinds of bedrock throughout the state. See the back side of the map for additional information on Wisconsin bedrock.

Glacial deposits and the action of glaciers in altering the landscape have profoundly influenced the formation of most soils in Wisconsin. Many soils are formed partially or entirely out of glacial "drift" or till. In these areas the soils have taken on many of the physical and chemical characteristics of the till. Acid soils are formed from acid till; stony soils are formed from stony
till; red-colored soils are formed from red-colored till, etc. The Ice Age Deposits of Wisconsin map shows the glacial deposits in Wisconsin. The back side contains additional information on the ice age in Wisconsin.

Materials deposited by wind and water have been important in the formation of many soils in the state. The wind-blown or aeolian silts (loess) are quite deep in the unglaciated area in western and southwestern Wisconsin. A silt cap of more than 4 feet is common near the Mississippi River. The silt cap or loess becomes progressively thinner as one moves in a northeasterly direction. Little, if any, silt cap exists on the soils in the eastern and northeastern parts of the state. Soils with a deep silt cap are very productive because they are usually well-drained and store relatively large quantities of available water. Also, they are generally easy to work and free from stones.

Alluvial soils have been formed as a result of materials being deposited by water. These soils are commonly found on stream terraces and range from silty to very sandy, and from well-drained to very poorly drained.

Decaying plant material in bogs and low-lying areas is the parent material of organic soils. The lack of oxygen in these saturated soils prevents decomposition, allowing organic material to accumulate. Generally, organic soils contain at least 20% of organic matter (by weight), and this organic layer is more than 1 foot thick. Organic soils occupy approximately 7.5% of Wisconsin’s surface and are often referred to as mucks or peats. Mucks are more highly decomposed than peats to the extent that the kind of plants from which they formed is not easily identified. Mineral soils contain less than 20% organic matter.

**Climate** is defined as weather as it exists over a long period of time. Climate changes with time, and soils often reflect the effects of past climates. Precipitation and temperature changes both help form soil. Water from rain and melting snow dissolves some soil minerals. Freezing and thawing break rocks and large soil particles into smaller pieces.

High temperatures and high levels of precipitation often speed weathering. The effect of climate can be seen best by comparing soils over large areas. For instance, the more intensive weathering in southeastern United States has resulted in the development of extensive areas of brick-red colored soil containing relatively low amounts of organic matter and high levels of oxidized iron. In contrast, most soils in the Midwest contain much more organic matter and lower amounts of oxidized iron. Soils in the northern Great Plains differ from soils in the north central region mainly because they developed in a drier climate. Soils formed in drier climates typically have a relatively high pH and more plant nutrients due to less leaching.

Even within Wisconsin there is enough climatic difference from the north to the south to produce noticeable variation in the soils. Northern Wisconsin’s cooler climate slows decomposition of organic matter on the surface of the soil. This slowly decomposing organic matter produces organic substances that promote leaching of minerals and nutrients from the soil. Northern Wisconsin soils are, therefore, more leached and tend to be less fertile than those further south.

**Climate** also influences the kinds of plants and animals that will grow in and on the soil. For instance, under natural conditions grasses and shrubs grow on soils where the climate is relatively dry while trees tend to grow in the more humid climates.

**Living organisms,** plants and animals, play an important role in soil formation. Plants extract nutrients from the subsoil as they grow. These nutrients are subsequently deposited on the soil surface when the plants die. Soil differences frequently can be related to the type of plants grown on them over long periods of time. In parts of southern Wisconsin, tall prairie grasses growing on soil produced a thick black layer of surface soil high in humus. Much of this humus came from the decay of grass roots. Trees, on the other hand, deposit their leaves, needles and twigs on the top of the soil, and tree roots do not die each year as most grass roots do. Therefore, most forest soils do not have thick black surface layers.

Fire has also played an important role in determining the native vegetation growing on our soils. For example, in southern Wisconsin the prairies burned frequently. Fire prevented the development of forests; thus, in these areas only a few large oak trees growing in fields of grass survived.

Bacteria and fungi, which are microscopic plants, are a vital part of the soil. They decompose organic matter and produce materials that bind soil particles together in aggregates, and they help make certain nutrients available for plants.

Animals have a lot to do with soil formation. Earthworms burrow through the soil making large holes that improve both water and air movement in the soil. They also consume large amounts of dead organic matter and often carry plant material from the surface down several inches into the soil. This hastens decomposition of organic matter and
tends to thicken the dark surface soil. Other small animals living in the soil also eat and partially decompose organic matter from leaves, grass blades, and other plant materials.

Humans have had an extremely important effect on soil formation—both beneficial and destructive. They can cause erosion, compaction and depletion of essential nutrients, or they can improve the physical and chemical conditions in soil by using sound tillage practices and by adding lime, fertilizer, manure, and crop residues.

**Topography** refers to the lay of the land—the patterns of hills, valleys, and plains. It strongly influences water flow across and through soils, and this has a major influence on soil formation. For instance, soils may be very shallow or “thin” where slopes are steep and serious erosion has occurred. In the eastern part of the state the topography has been strongly influenced by the glaciers. Many low-lying soils—peats and mucks, for example—occur in bogs and poorly drained depressions. Topography becomes especially important when soils are farmed. Steep slopes require excellent soil conservation practices, while low-lands and depressional areas need surface or tile drainage for optimum crop production.

**Time**, measured in thousands of years, is the final element in soil development. Most Wisconsin soils have formed since the glaciers retreated. With the exception of southwestern Wisconsin, most of the state has been covered by glaciers within the last 30,000 years, and much of the eastern, central and northern parts of the state were covered by ice or water within the last 8,000 to 15,000 years. Because of leaching and the weathering process, older soils tend to be less fertile than soils of relatively recent origin.

### Soil-forming processes

Many complex physical, biological, and chemical transformations occur in soils. Any set of events that intimately affects the soil in which it operates is a soil-forming process. There are many soil-forming processes active in soil. Only the more important processes will be discussed here. Not all processes are active in every soil. Some processes predominate in one soil, others in another soil. The terms defined below identify several of the more important soil-forming processes.

- **decomposition**—breakdown of a mineral or organic matter into its components.
- **eluviation**—downward movement of solid material, usually clay particles, within a soil profile.
- **erosion**—loss of material from the surface layer of soil by the action of water or wind.
- ** gleization**—reduction of iron under waterlogged soil conditions, giving subsols a blue-grey color.
- **humification**—transformation of raw organic matter into humus.
- **illuviation**—the accumulation of fine soil particles which move from upper layers of soil to the subsoil.
- **laterization**—chemical migration of silica out of the soil profile and concentration of oxides and hydroxides of iron and aluminum. Occurs in tropical regions.
- **leaching**—movement of soluble material through the soil in percolating water.
- **mineralization**—conversion of organic compounds into inorganic elements.

**salinization**—accumulation of soluble salts (usually sulfates or chlorides of calcium, magnesium, potassium and sodium). Usually found in semi-arid regions.

More than one soil-forming process can be active simultaneously or sequentially. It is the net effect of the active processes that give a soil its unique characteristics.

### Weathering

Weathering transforms parent materials in the process of soil formation. This weathering may be physical, chemical, or both. Chemical weathering is not very significant in large rocks because there is relatively little surface area exposed. Physical weathering is more important.

**Physical weathering** involves natural forces that break rocks into smaller pieces. These forces include temperature, wind, water, ice, and plant roots. Rapid temperature changes can cause rocks to crack. Rocks are made up of two or more minerals, each mineral expanding and contracting differently in response to temperature changes. Some early pioneers built fires on large rocks, then doused them with cold water to break them into smaller rocks that could be hauled away.

Wind strong enough to carry sand particles can sandblast rock surfaces. Moving water, especially that carrying sediment, is also abrasive. Pebbles on the bottom of a stream tend to be rounded or smooth as a result of the tumbling action of the water. Water freezing in cracks and crevices also causes disintegration by expansion. In Wisconsin, glacial activity broke rocks into smaller fragments and ground some rocks to silt-sized particles. Plant roots growing into cracks in rocks can also cause cracking and breaking.
Chemical weathering becomes significant once physical weathering reduces parent materials to the size of sand or smaller particles. The most important chemical reactions are solution, hydration, hydrolysis, decomposition, and complexation.

Solution refers to the dissolving of a solid in a liquid. Water is the liquid in soils and is considered a universal solvent. Every solid is soluble in water to some extent. Most rocks and minerals are negligibly soluble. Most chloride and nitrate salts are highly soluble; whereas many phosphate compounds are only slightly soluble. When the solubility of a dissolved substance is exceeded, it precipitates or solidifies and drops out of solution. For example, when hard water is heated, calcium carbonate precipitates to form lime on the walls of a teakettle. Also, some dissolved materials may be adsorbed or attached onto the surfaces of existing soil particles.

Hydration is the addition of water to a substance. For example, the addition of water to dry calcium sulfate (CaSO$_4$) results in gypsum (CaSO$_4$·2H$_2$O), with two water molecules bound to each calcium sulfide molecule.

Hydrolysis is a form of decomposition in which the hydrogen-hydroxyl (H-OH) bond in water is split, and the resulting ions combine with a reactant. For example, feldspar (KAlSi$_3$O$_8$) and water (H$_2$O) react to form silicic acid (HAlSi$_3$O$_8$) and potassium hydroxide (KOH).

Decomposition involves the breakdown of a substance into its component parts. Organic matter, for example, is broken down into carbon dioxide and nutrients which can be recycled for new plant growth.

Oxidation, a form of decomposition, is the combination of oxygen with a substance, as in burning. Organic matter decomposes (oxidizes) in soils. Also, some elements such as nitrogen, sulfur, iron, and manganese undergo oxidation in well-aerated soils. Under waterlogged conditions, reduction—the reverse of oxidation—can occur. Under these conditions, the removal of part of the oxygen from iron and manganese oxides makes them more soluble, allowing them to be leached.

Complexation refers to the surrounding of metallic ions by groups of anions or neutral molecules. Ammonia, for example, forms a complex with copper by surrounding a copper ion with four ammonia molecules. Organic molecules can form complexes with metallic ions. Some large organic molecules form two or more bonds with the same metallic ions. These are known as chelates (Greek: chele = claw). Some chelates, such as ZnEDTA, make good fertilizers because they prevent precipitation of the metallic ion, keeping it more available to plants. In chemical weathering, chelates help make the metals in rocks and minerals slightly more soluble.

Soil classification

The factors and processes of soil formation discussed above have produced many kinds of soil in Wisconsin. Soils vary considerably from place to place, sometimes even within a small field. Soils are classified in a manner similarly to how plants and animals are classified. Instead of genus and species, however, the lowest or most specific unit of soil classification is the soil series. Higher levels of classification include the family, subgroup, great group, suborder, and order. The classification system implies that one soil differs from another sufficiently to make classification meaningful.

Soil horizons

A body of soil is three-dimensional (figure 1-1). The depth is the lower limit to which native perennial plant