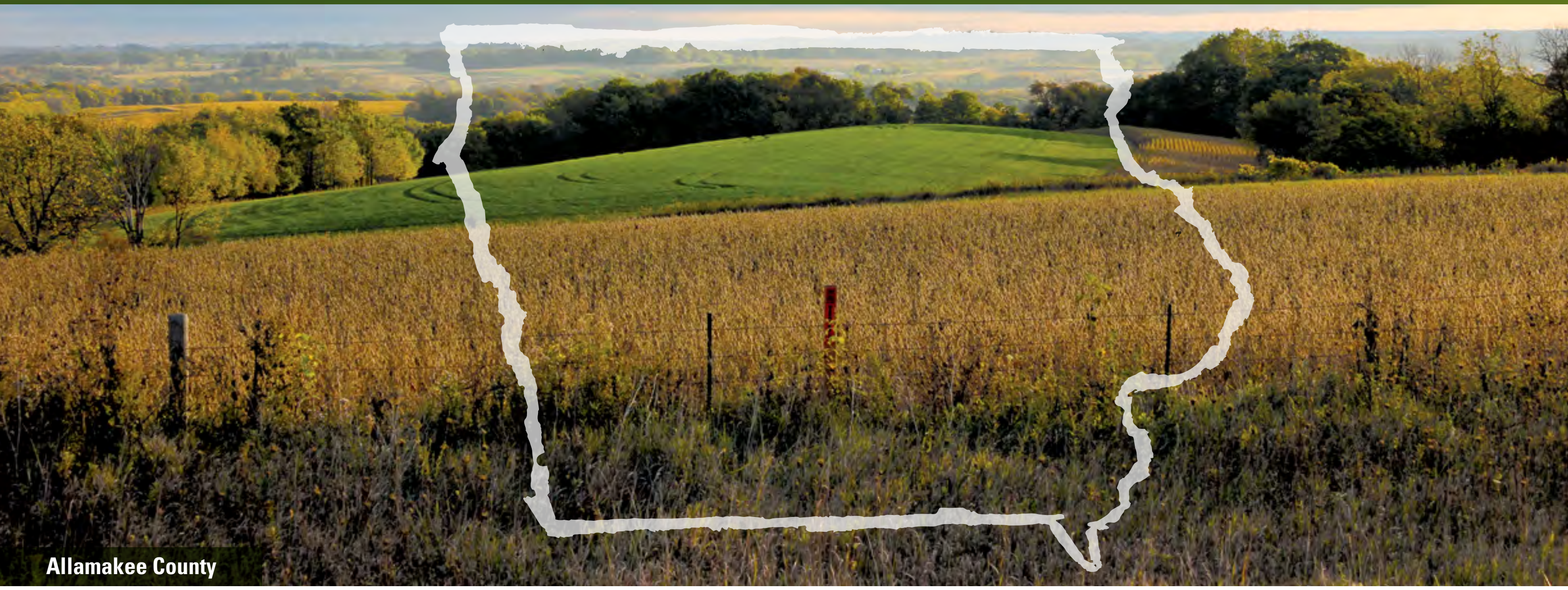
Iowa's NATURE SERIES

SOILS



Allamakee County

> **"The soil is deep, of exhaustless fertility…there is no place on the continent where the soil is more certain to yield an ample reward for the labor bestowed upon it, than in Iowa."**
>
> Iowa Board of Immigration, 1870

Soil, like air and water, is an essential natural resource. Iowa's dark, black topsoils are famously called "black gold" due to their high fertility and ability to grow crops. Iowa's soils do it all: They store carbon, filter water of impurities, provide habitat for many organisms, store and provide water and nutrients to plants, support food production, archive human history, and provide the very foundation for our everyday activities, including supporting the buildings in which we live and work. Despite soil's importance to all life, we typically don't pay attention to what is happening under our feet. Fascinating processes are happening right under us in Iowa's soil every day.

SOIL PROPERTIES

Soils are not uniform. Both gradual and rapid processes have created them over time. Across a landscape, even within a single field, soil properties can change over very small distances. For example, a prehistoric river may have created a narrow band of sandy soil by depositing sediment trapped in fast-moving flood waters just inches from a more clay-rich soil derived from glacial deposits. A hillside exposed to the erosive properties of rain, wind, and gravity could have half the topsoil thickness of a location just a few feet downslope. The soil particles (sand, silt, or clay) that are present, how those particles were brought to Iowa, the dominant vegetation and resulting organic matter, or even recent human activities in the area, can all impact how soil looks and functions.

Soil Texture

One way to describe soil is by using the size of the mineral soil particles, called soil texture. To describe a soil's texture, soil particles are typically sorted by their size into three categories: sand is the largest, silt is intermediate, and clay is the smallest. Sand is perhaps the most familiar soil mineral particle, generally ranging from 0.05-2 mm in diameter. Because of its size,

Horizon	Horizon Description	Color	Clay Content	Structure	Organic Matter Content
O	Organic				more
A	Mineral				
E	Mineral zone of loss		less		
B	Zone of clay accumulation		more		
C	Parent material				less
R	Bedrock				

Soil properties by horizon.

sand particles do not pack together well, leaving plenty of space between each particle for air, water, and roots. Silt is the intermediate size of soil mineral particles, ranging from 0.05-0.002 mm. When held, silt particles feel floury or soft. They are helpful in holding water for plants and are generally associated with better conditions for plant growth. Clay is the finest size of mineral particles, under 0.002 mm, and is more like sheets of paper in a book. It has a lot of surface area to interact with water and nutrients. It also sticks together and can be dense, without a lot of space for air.

The mixture of particles creates a soil's texture and influences how soil functions. For example, water and nutrients easily flow through sand. Clay, by contrast, tends to pack together tightly, which leaves little room for pockets of air and prevents water from easily passing through. Plants that grow in soils that have lots of sand or lots of clay have unique adaptations that help them deal with these different conditions. A balance of sand, silt, and clay (for example 40% sand, 40% silt, and 20% clay), called a loam, is generally favored for the average plant.

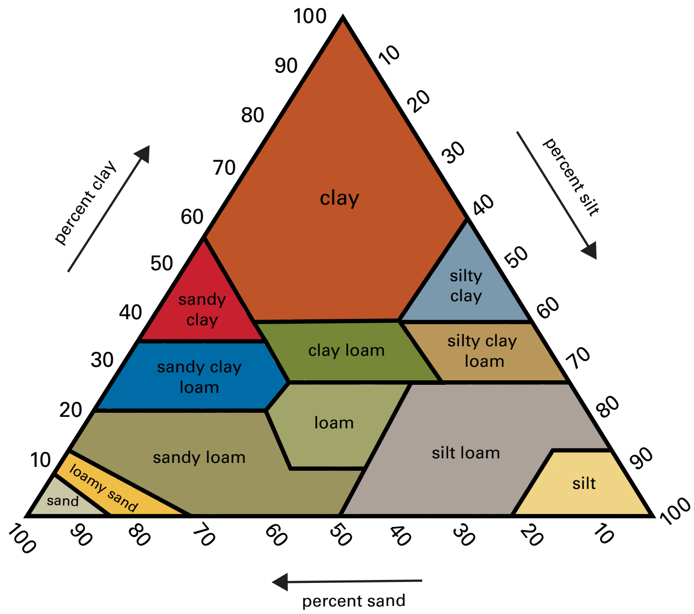
Soil Structure

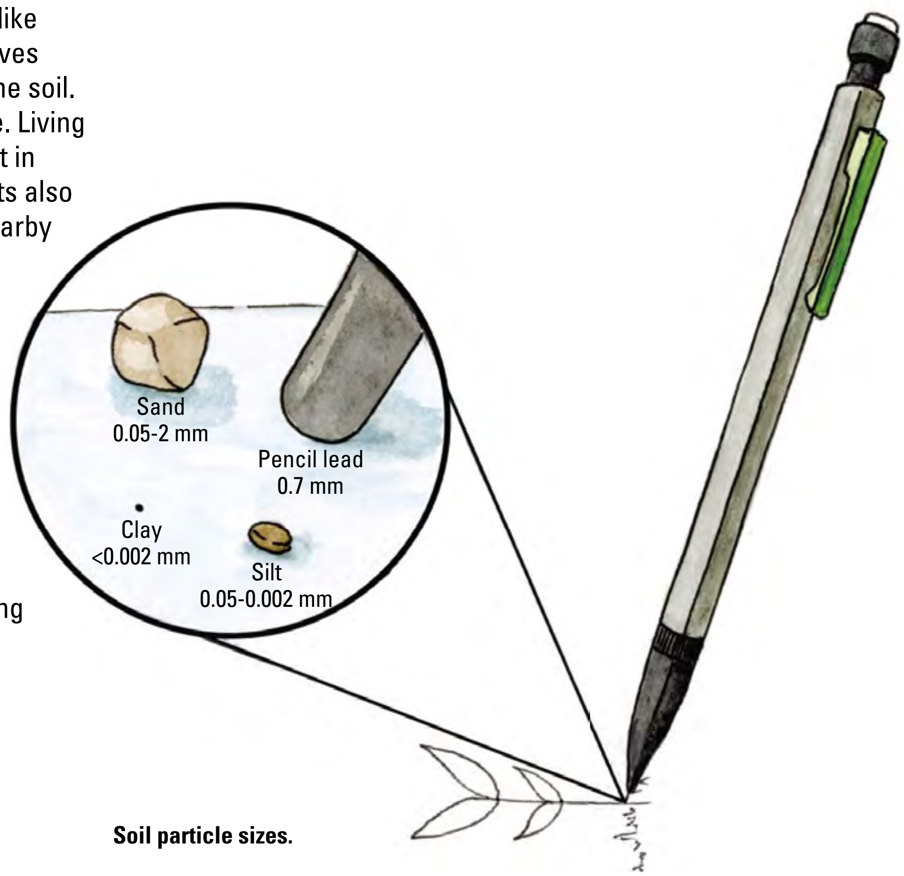
To understand the critical role of soil structure, it's helpful to think of an analogy to a house. A good house needs solid walls, but also hallways and rooms to live in. If you compressed the house down, taking away that open space, the house would no longer be livable. Likewise, the soil requires both solid structure, provided by the soil particles, and open spaces for air, water, roots, and organisms. These spaces are where life happens in the soil.

Soil structure is always being created and changed through natural processes. Human management, like tilling a garden, may temporarily add air, but removes the supports that create the natural structure of the soil. Biological activity is key for creating soil structure. Living plants develop structure by sending their roots out in many directions to seek nutrients and water. Plants also release nutrients from their roots to share with nearby soil microbes, which play an important role in soil structure formation. Root-like fungal hyphae can physically hold or chemically glue soil particles together. The nutrient calcium can also serve as a glue. Organisms like invertebrates, moving through the soil, can add additional open spaces necessary for healthy soil functions. The life and death of organisms as they acquire nutrients and water and contribute their bodies to soil organic matter creates soil structure. Physical processes such as freezing and thawing, or wetting and drying contribute to a soil's structure as well.

	SAND	SILT	CLAY
Water holding capacity	Low	High	High
Feel when moist	Coarse/ gritty	Floury/soft	Sticky
Desirable properties for plants	Aeration	Available water	Nutrient holding capacity

Table 1: Properties of soil particles.





Soil particle sizes.

Soil pH

Soil pH is a measure of how acidic (low pH) or basic (high pH) conditions are within the soil. Soil scientists sometimes call the pH of soil the master variable because it is so important in regulating other soil properties, like nutrient availability or soil microbe activity. Values of soil pH range from three (acidic) to ten (basic). Iowa's soils are typically close to neutral with their pH measuring around seven. However, some areas of high pH exist due to glacially-deposited materials that included ground-up limestone. Additionally, soils in areas with frequent water pooling and evaporation, like those found in ephemeral or short lived wetlands, can have higher pH levels.

Like soil structure, soil pH varies due to natural causes, but has also been altered by human activities. Soil pH changes consistently with time, and over thousands of years it changes from more basic to more acidic. Leaching of basic nutrients, or bases, which are naturally removed when water flows through the soil, results in a lower pH over time. Vegetation also changes soil pH. Lower pH levels are more likely to be found in areas that are or once were forested, especially under coniferous trees. The nutrient cycling, which is tied to the life cycle of the plants, is significantly different under prairie systems where plant tissues grow and die much quicker than in forest systems. These plant life cycles affect the retention of nutrients which result in soil pH changes, with base retention being higher in prairie ecosystems. Human activities also alter pH. Humans can accelerate the decline in soil pH in agricultural fields by adding synthetic fertilizers and removing nutrients with crop grain and biomass removal. To combat these declines in soil pH, farmers often apply lime, generally calcium carbonate, to increase pH to near neutral.

Soil Organic Matter

Soil organic matter includes the living and decomposing material from organisms. Even though soil organic matter usually comprises a significantly smaller percentage of the soil than mineral soil particles, it is one of the most important soil properties. In Iowa, organic matter typically makes up less than 2% of the soil in disturbed or eroded areas. In contrast, it is the primary component in wetland soils and the uppermost layer of forest soils. Organic material plays a crucial role in soil's ability to hold water and nutrients. Additionally, greater organic matter is associated with many other benefits and is considered a key aspect of soil health. Generally, greater organic matter means greater nutrient storage, more soil microbial biomass and activity, lower soil densities (less compaction), and better soil structure.

Soil Horizons

Like layers in a cake, soils change as you travel down from the surface and deeper into the ground. Soil scientists classify the major soil layers into horizons that describe the primary process or changes occurring in each successive layer. The combination of layers is called a soil profile.

Soil profile showing A, B, and C horizons.

In the uppermost root zone, processes of organic matter accumulation and biological activity create the A horizon. Excess water moving deeper into the soil alters the minerals and structure causing a B horizon to form. In the C horizon, the soil has been largely unaffected by organic matter and precipitation due to depth below the surface. In some cases there are additional horizons present in soils. For example, O horizons form where tremendous amounts of organic matter accumulate, like where a thick layer of leaves have decomposed in a forest. In some cases an E horizon will form between the A and B horizons when water has washed the clay down into the lower layer of soil.

Soil Horizon Definitions

O – Primarily organic material, accumulates in areas with low decomposition vs. production of organic material, such as forest floors or wetland areas.

A – Mineral enriched with organic material. Zone of highest expected biological activity.

E – Intensely weathered zone without significant organic or clay material.

B – Zone transformed by additions like clay, calcium, or minerals from other horizons.

C – Layer relatively unchanged from deposition, also called parent material.

R – Bedrock layer, rarely exposed in Iowa.

Soil Color

In addition to the color changes from dark to light as soil horizons transition from A to C, other soil colors can be observed depending on local conditions. Dark colors are generally associated with higher organic matter and more fertile conditions. These dark colors are typically found in the A horizon. Gray colors are associated with anaerobic conditions, in which there isn't available oxygen, which often occurs when the area is under water. Some areas alternate between anaerobic and aerobic conditions, either seasonally with changes in rainfall, or when something like a root channel in the soil allows oxygen to enter in one area but not another. Colors do not immediately respond uniformly to a change, such as drought, and are a long term record of prevailing soil conditions.

SOIL FORMATION

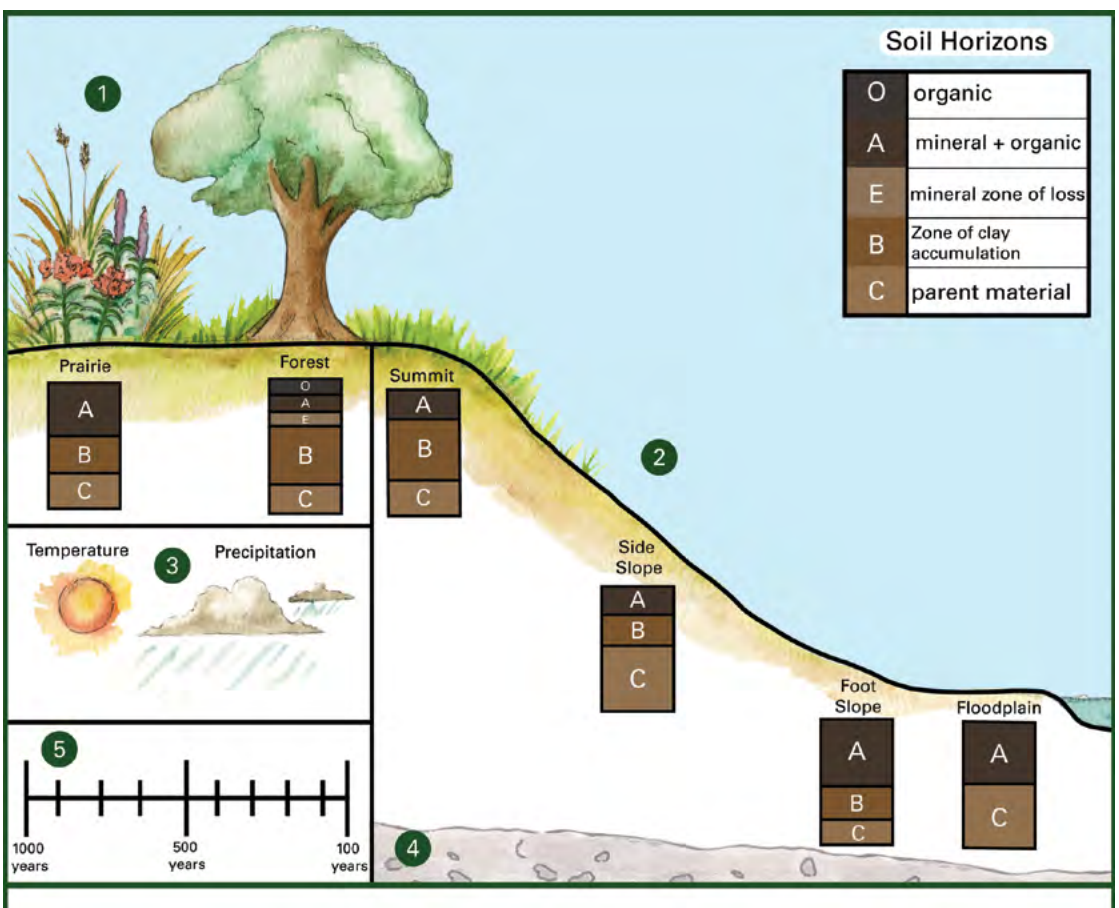
Most of Iowa's rich, dark soils developed in what geologists and soil scientists consider relatively young materials (thousands of years old rather than millions) including glacial deposits, wind-deposited dust called loess, and sediment deposited by flood waters, called alluvium. Overall, Iowa's deposits are generally rich in organic matter, highly productive for plants, and have few stones.

To fully understand the properties of any soil, we must also understand the conditions that gave rise to those properties, which is what soil scientists call soil formation. Soil formation is the product of five conditions or factors: parent material, climate, biota (plants and animals), relief (slopes and elevations), and time.

Dark black soil indicates high organic matter.

Gray soil indicates a lack of oxygen, which often occurs when an area is underwater.

Soils like this sample show both anaerobic and aerobic conditions. The gray portions were formed when there was a lack of oxygen. In this sample when oxygen became available again it reacted with iron resulting in the reddish color.



Soil Forming Factors:

1. Parent material
2. Topography
3. Climate
4. Biota
5. Time

Parent Material

Parent material refers to the natural geology of a place and the material that forms the soil. More details on Iowa's geology can be found in the WL17a: Landforms and Geology article in this series. The material might be deposited from a flood, wind, or a glacier, or it can form from bedrock breaking down. Parent material has a significant influence on how soil will form, with some materials developing into more fertile or productive soils than others. Different parent material can contain different minerals with unique chemistries and textures. These characteristics, combined with locations on different landforms, all influence the soil's formation and its properties. Iowa has a variety of parent materials found throughout the state, which are described in Table 2.

PARENT MATERIALS	DETAILS	TYPICAL LOCATIONS IN IOWA
Glacial Till	Mixed-materials (sand, silt, clay, gravel, boulders) deposited by a glacier	Found throughout much of Iowa
Alluvium	Deposited by running water and sorted materials	River and stream valleys
Loess	Wind-blown silt materials	Statewide, but especially pronounced in western Iowa
Aeolian Sand	Wind-blown sand materials	Near and down wind from river systems
Lacustrine	Lake-bed deposits, fine materials	Drained lakes or places where a lake was once found, especially in north central Iowa
Colluvium	Any type of material found on the bottom of a slope that has been moved downhill by gravity	At the bottom of slopes
Residuum	Soil developed out of bedrock with properties dictated by the rock type	Northeast Iowa

Table 2: Properties of parent materials found in Iowa.

Climate and Biota

Soil is formed when climate and biota – plants, microorganisms, and animals – actively alter the parent material. Sometimes the activity of climate and biota cause new soil minerals to form as elements in the soil break down and re-form into more stable structures. The two main components of climate are rainfall and temperature. Iowa is in a humid continental climate, which means it has a wide range of temperatures from cold winters to hot, humid summers and has precipitation throughout the year. There tends to be more precipitation in the southeast part of the state than in the northwest. Precipitation, like rain or melted snow, generally moves downward through the soil, taking minerals, like calcium, with it and also causing some of the minerals already in the soil to dissolve and move. The water can also move parent material around via erosion and sedimentation. Temperature controls the speed at which minerals are changed, with warmer temperatures generally increasing the rate of change.

Rainfall and temperature also influence what biota thrive on any given soil. Biota, in turn, influence the amount and depth to which organic matter will accumulate as roots grow and die or animals move soil. Prior to the mid-1800s, Iowa's land was covered with three major natural ecosystems: tallgrass prairie, savanna, and deciduous forest. The most prominent of these was the tallgrass prairie, which overlapped with the savanna ecosystem that has a mixture of grass and woodland vegetation. Savannas often served as buffers to the deciduous forest which grew along most of the major river valleys and many uplands of the Mississippi River.

North central Iowa is part of the prairie pothole ecosystem, a region dotted with shallow wetlands within the greater tall grass prairie ecosystem. The biota that once lived in these ecosystems influenced the soils that exist in different areas of the state. Soil scientists categorize these different types of soils, just like biologists categorize animals into groups like birds and mammals. This is called taxonomy.

There are 12 major soil categories called soil orders. Mollisols dominate the area of the state that was formerly prairie, while Alfisols dominate in tree-covered landscapes, as can be seen in the map on the next page. In addition to Mollisols, which cover about 70% of Iowa, and Alfisols, which cover about 20% of the state, Iowa has four other soil orders. Entisols cover about 5% of the state and the remaining 5% is made up of Inceptisols, Vertisols, and Histosols.

Soil Orders

Mollisols

Generally prairie-derived soils known for their thick, dark, fertile topsoil.

Alfisols

Generally under forest or formerly forested areas, these soils have different horizons and thinner topsoil.

Entisols

Young soils lacking a B horizon, commonly found on floodplains or otherwise recently disturbed or extremely eroded areas.

Inceptisols

Young soils with a B horizon, found on stream terraces or other young areas lacking a thick A horizon required for a Mollisol.

Vertisol

High shrink-swell clay soils, generally found in the slackwater areas of floodplains in Iowa.

Histosols

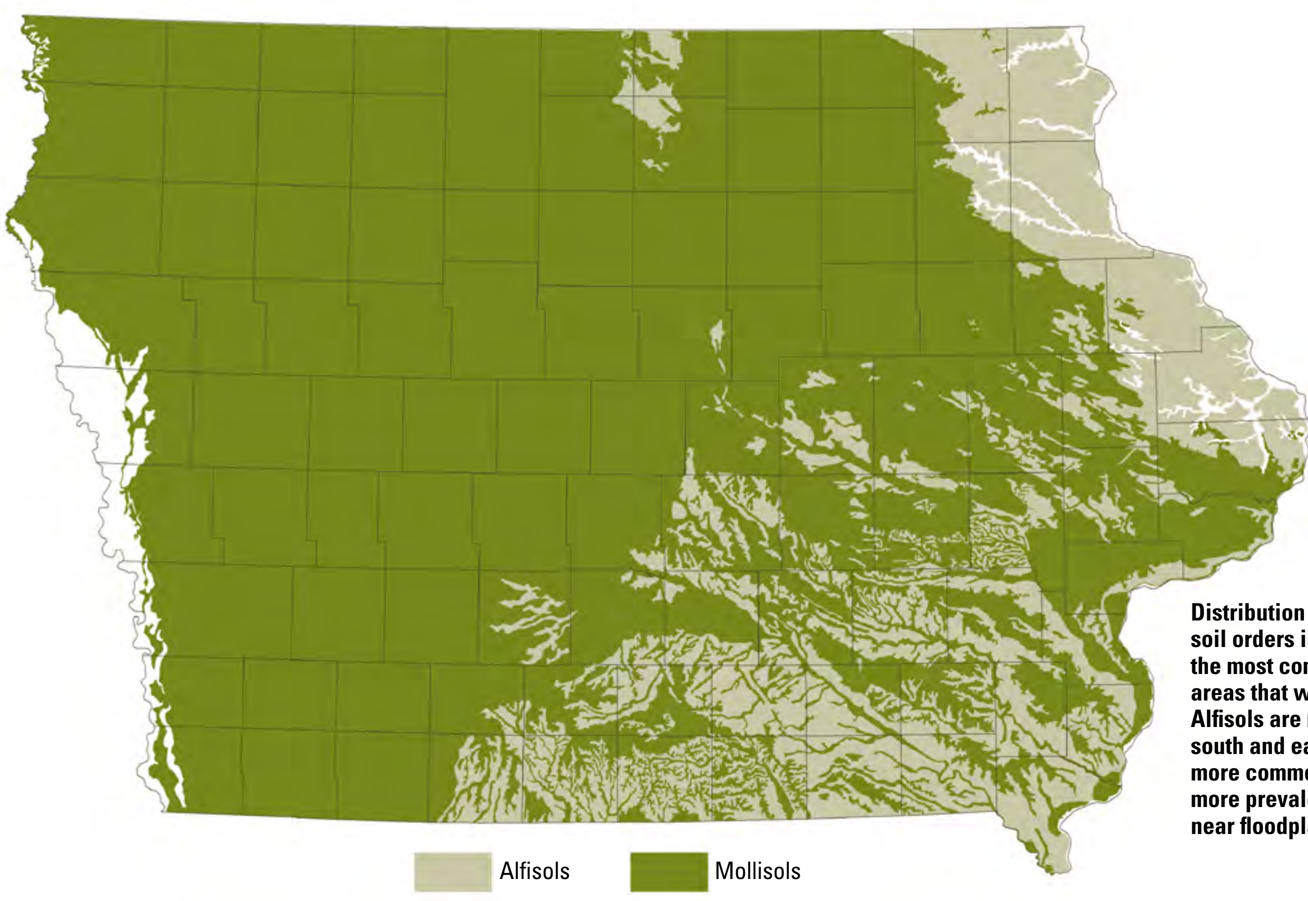
Organic, rather than mineral soils, while not common, can be found in extremely wet conditions where organic matter cannot decompose, like marshes.

Relief

In the context of soil formation, topography or relief refers to the slopes and elevations of a landscape. When considering relief, think of a hill's summit being connected to its side slope which continues down across a footslope and into a valley. Often the summit soils are being highly formed (deep, thick black A and brown B horizons) as water easily and deeply percolates, while the side slopes have less formed soils and thinner A and B horizons. Footslope soils tend to have thick A horizons due to sediment accumulation from upslope over gray B horizons with the gray color indicating wetness. Low areas may flood and therefore have change interrupted by additional materials, frequently resulting in no B horizon forming. Soil scientists call these different soil features found to repeat across the landscape a toposequence or a *catena* (from chain or linked in Latin). See the soil forming factors illustration at the beginning of this section.

Time

Time is an important soil forming factor because soils change with time. Soil profiles become more pronounced over time. Their properties change as more and more mineral weathering and acidification occur, in turn changing the biota that thrive in the soil. When new material is deposited, such as during a flood event, this process of change starts over at the surface. Soil formation is a part of natural history since, over time, climate, biota, and relief each change, which drives more changes in the soil.



Distribution of the two dominant soil orders in Iowa. Mollisols are the most common and are found in areas that were historically prairie. Alfisols are more abundant in the south and east where forests were more common. Other soil orders are more prevalent in eroded areas or near floodplains.

LANDFORM REGIONS OF IOWA

Soil properties and soil formation factors come together to create a diverse soil landscape in Iowa, and this diversity is based on differences in Iowa's landform regions. We typically think of landform regions as the geology of the state, but they also play an important role in what type of soil formation factors are present. Different landform regions have different parent material deposits and had different historic landcover. Some of Iowa's landform regions consist of hills and others are more flat, which relates to relief. It is important to understand Iowa's various landform regions to create a full picture of its soils.

North central Iowa consists of the 12,000-square-mile Des Moines Lobe. The most recent glacier that existed in Iowa left behind 800 billion tons of pulverized, weatherable mineral-rich parent material in this region. In the past 8,000 years following the retreat of the glacier, prairie covered this part of Iowa. Most Des Moines Lobe soils are found on fairly flat, gently rolling landscapes and have loamy textures and organic matter from prairie making them good for plant growth. The majority of Des Moines Lobe soils are Mollisols. Many of the Des Moines Lobe soils are poorly drained because streams have not had time to extend into this flat, geologically young landscape. The combination of poor soil drainage, prairie vegetation, and a young landscape means there has been little mineral weathering. As a result, the natural soil pH is typically neutral and even alkaline near prairie pothole wetlands that are characteristic of this region.

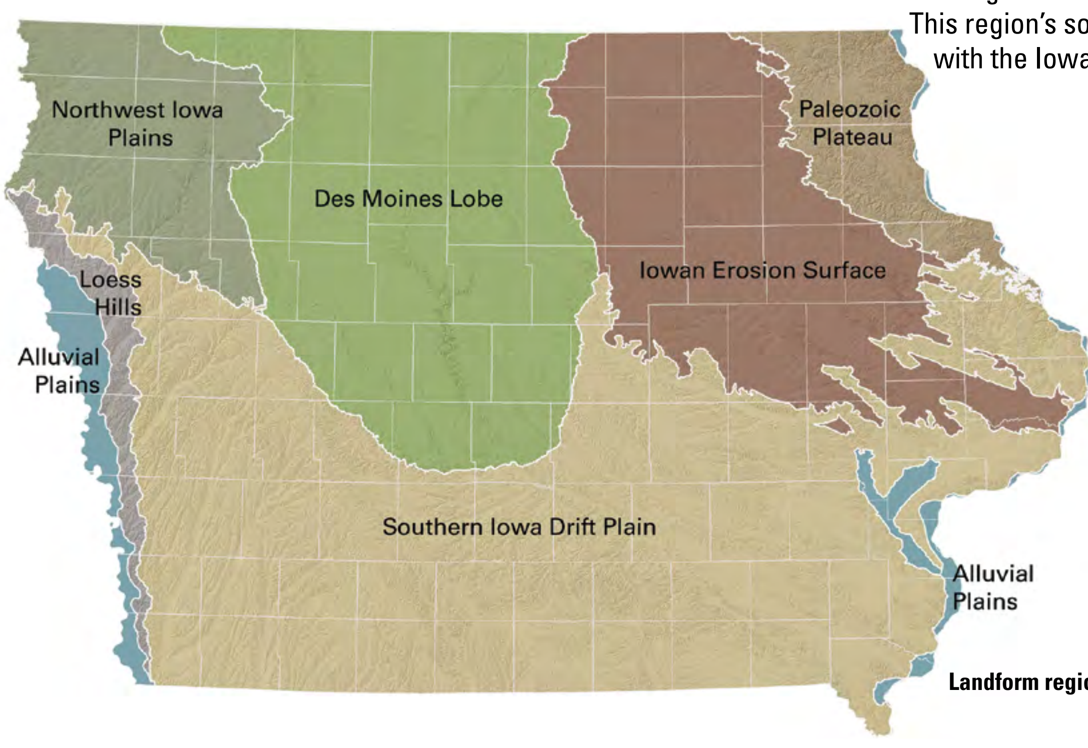
A diagonally-oriented region east of the Des Moines Lobe is the Iowan Erosion Surface, which covers about 9,000 square miles. This region formed as intense natural erosion carved the landscape over the past 20,000 years, creating long, gentle slopes interspersed with a few large hills called pahas and river valleys with associated sand dunes.

The majority of soils on the Iowan Erosion Surface formed under tallgrass prairie which contributed a lot of organic matter, making the soils very fertile and productive. They generally have loamy textures and are Mollisols that are only slightly more deeply developed or changed than the soils in the Des Moines lobe.

Outside of the Des Moines Lobe and Iowan Erosion Surface, most of Iowa's soils are formed partially or entirely from wind-deposited silts called loess, or stream deposits called alluvium. Iowa's thickest loess is next to its primary source, the Missouri River Valley. This part of Iowa is an internationally renowned landform called the Loess Hills. Indirectly, almost all of the 600 billion tons of loess covering Iowa originated from the glacier associated with the Des Moines Lobe. As a result, this deposit contains the same weatherable minerals found in north central Iowa.

The Paleozoic Plateau of northeast Iowa covers about 5,000 square miles and is characterized by rolling uplands and steep, deeply dissected stream valleys. The valley walls expose beautiful cuts of limestone, sandstone and shale bedrock while thin loess creates a shallow mantle of soil on the uplands and older stream terraces. The loess found in this region weathered into soil while deciduous forests or tallgrass prairie grew on and in it. Forest predominated in the Paleozoic Plateau region of Iowa because of more rainfall and steep valleys that impeded the spread of fires that could kill trees. The soil profiles here are moderately changed and often have a clay-rich, neutral to acidic B horizon, suited to a mix of vegetation and land uses.

The Northwest Iowa Till Plain covers around 4,500 square miles. Like the Paleozoic Plateau, its soils formed from shallow loess, but here, the loess buries young, glacial sediments. The soils formed under tall grass prairie, with the lowest average amount of rainfall annually in the state. This region's soils share many characteristics with the Iowan Erosion Surface.



Landform regions of Iowa.

The soils of southwestern to south central Iowa are best understood in a west to east pattern. They represent progressively thinner loess as one moves east across the state and away from the Missouri River Valley. As the loess becomes thinner, the landscape gradually flattens and ancient, previously-covered soils are exposed on hillslopes. As the loess gets thinner, the clay content increases, reflecting natural sorting (finer particles travel further in the same wind) in the loess and more soil weathering caused by increased rainfall in eastern Iowa. The higher rainfall also correlates with an increased proportion of forest-derived soils in southeast Iowa.

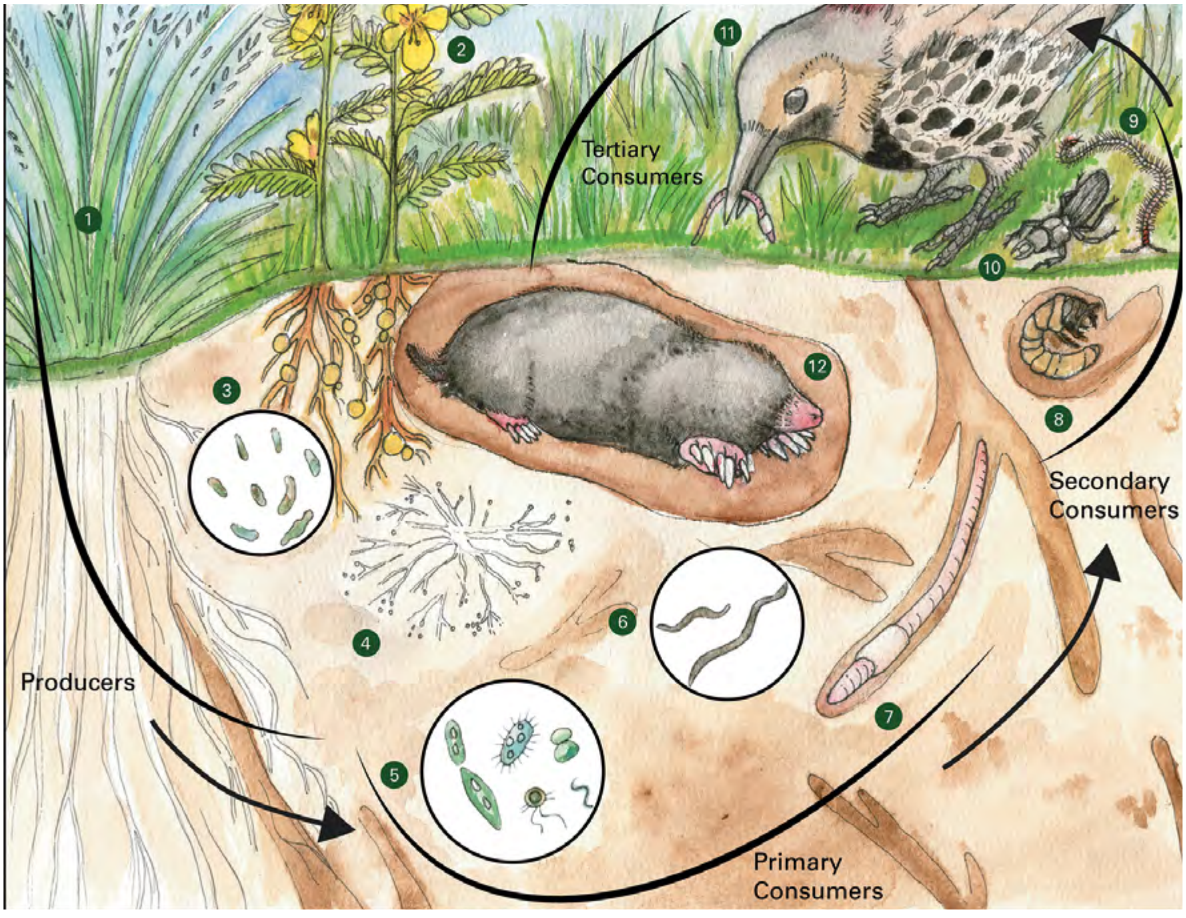
The Tama-Muscatine (loess) region of east central Iowa does not cleanly fit into the preceding discussion. Historically, it is Iowa's most productive region for crops. It covers about 4,000 square miles. It is a gently rolling landscape of fairly thick loess (ten feet and deeper) and had lush tall grass prairie as its native vegetation.

The remaining 2,000 square miles of Iowa has soils formed from alluvium. Alluvial soils are developed in materials deposited from rivers and streams and occur throughout the state. These soils are extremely fertile, but are also located in areas prone to flooding.

Life in the Soil

Soils are teeming with living organisms ranging in size from microscopic microorganisms like bacteria, to soil-dwelling mammals like moles. One teaspoon of soil has millions of bacteria and fungi cells. The energy that drives the soil food chain comes mostly from plant materials. These materials are decomposed by soil microbes and larger organisms, called shredders, that break apart plant residue in smaller pieces so they can easily be colonized and decomposed by the microbes. There are larger organisms in the soil that prey on soil microorganisms, called meso-fauna, and then larger predators above them, called macro-fauna.

If all of the soil organisms from one acre of Iowa soils were placed on a scale, they would roughly equal the weight of two African elephants. The decomposition of plant residues and the life and death of these organisms, leave plant nutrients in their wake. The increased understanding of the crucial role of these organisms in soil functioning has led to the accelerated interest in soil health.



PRODUCERS
1. Little bluestem
2. Partridge pea
3. Nitrogen-fixing bacteria

PRIMARY CONSUMERS
4. Fungi (decomposers)
5. Bacteria
6. Nematodes
7. Earthworm

SECONDARY CONSUMERS
8. Tiger beetle larva
9. Soil centipede
10. Ground beetle

TERTIARY CONSUMERS
11. Northern flicker
12. Eastern mole

SOIL HEALTH

In Iowa, the five soil formation factors combined give us rich, highly-productive soils. However, humans have caused significant changes to soil over a relatively short period of time compared to the natural processes associated with soil formation. These changes have occurred since the mid-1800s with the rise of intensive cultivation and are primarily associated with declines in organic matter, a vital component of healthy, rich, life-supporting soil.

This decline in soil organic matter was largely brought about by three major factors:

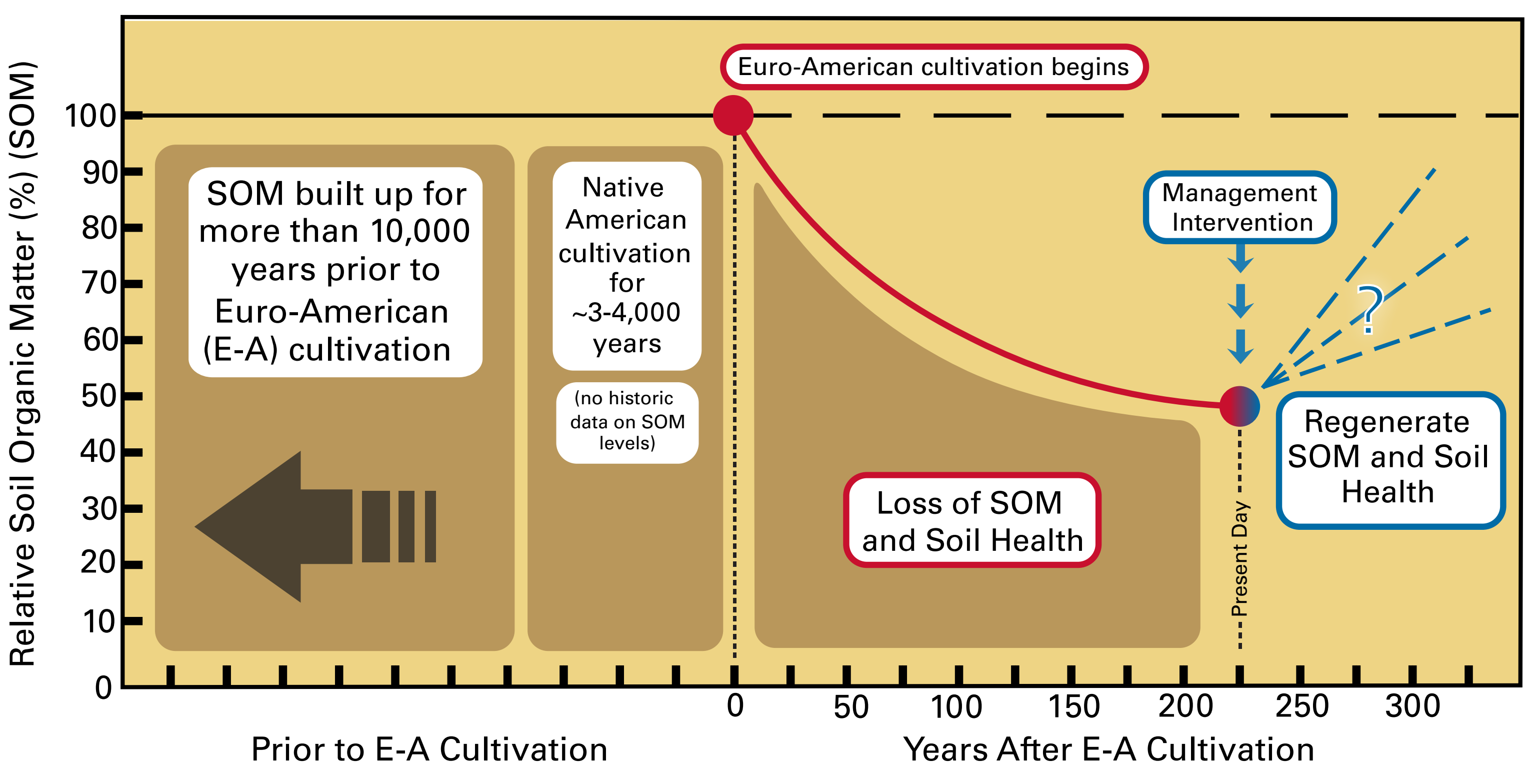
1. Erosion of topsoil due to repeated tillage and soil being left bare in the winter
2. Lack of plant inputs to the soil and accelerated loss of soil organic matter
3. Extensive sub-terranean drainage - this has left approximately 50% of the original concentration of soil organic matter present under native ecosystems

Humans have significantly increased the rate at which erosion occurs. This human-influenced erosion can happen in rural agricultural areas as well as urban or suburban areas. Often erosion occurs where the natural ecosystem previously present is significantly altered and soil is left bare of plant material. Agricultural fields that lack full vegetation coverage leave the soil particles unprotected and easily washed or blown away. Soil erosion also occurs are in places where the landscape has been altered through reshaping or removing the topsoil, or compacting soil with equipment or human traffic. Construction sites are commonly prone to erosion because, not only is the soil bare, but heavy equipment traffic compacts the soil, preventing water from entering into the ground. This causes the water to wash over the top very quickly, taking soil particles with it. Soil erosion can even happen in your backyard under the downspouts of your house.

> **"Soil health, also referred to as soil quality, is defined as the continued capacity of soil to function as a vital living ecosystem that sustains plants, animals, and humans."**
>
> -Natural Resources Conservation Service

Soil erosion is an issue because the top layer of soil generally contains the most nutrients and organic matter. When topsoil is lost through erosion, its ability to support plant life and function as a healthy ecosystem decreases. Additionally, soil erosion can decrease the quality of drinking water sources and wildlife habitat, especially when soil and fertilizers are washed into rivers, streams, and lakes.

In addition to increased erosion, some farming practices also have a significant impact on soil functioning and the concentration of organic matter. The most widespread management practice is tile drainage, which is little more than buried perforated pipe, spaced and connected in a drainage network similar to the roots of a tree. This has a significant impact on hydrology in the state, as the average square mile of farmland is estimated to contain



Changes in land use affects soil organic matter over time.

between 25 to 50 linear miles of perforated plastic pipe buried about four feet deep. The natural wetlands or wet prairies that existed in the state, particularly in north central Iowa, have been largely drained by tile and replaced with crop fields. Other common practices include tillage and surface additions, such as agricultural lime or fertilizers that are an organic or synthetic source of nutrients. Fertilizer and lime inputs, tillage, and altered drainage increase the rate at which soil microorganisms decompose soil organic matter. This increased rate of soil organic matter decomposition occurs much faster than organic matter can be replenished and leads to a net loss.

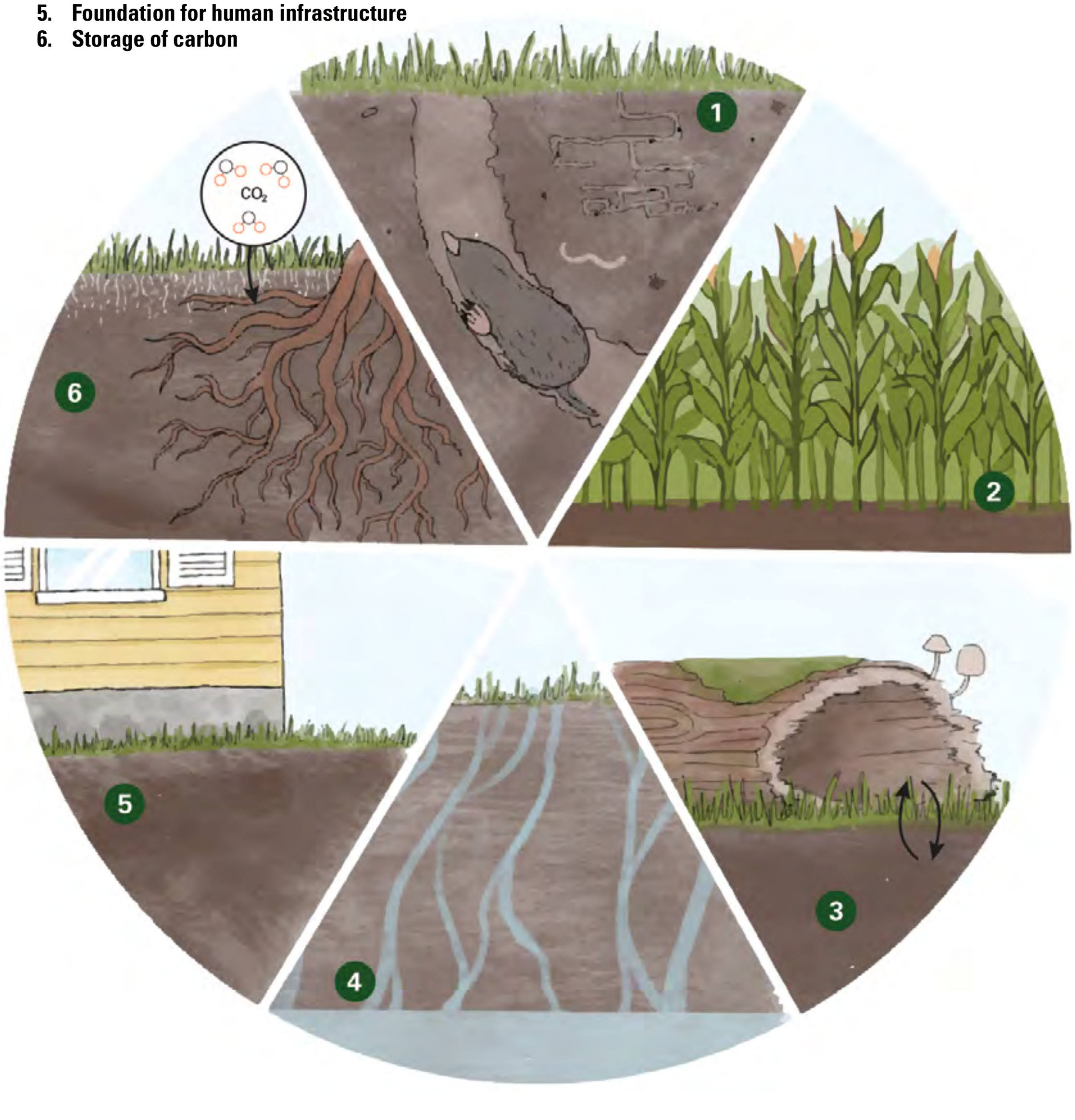
Preventing and managing soil erosion and organic matter loss is extremely important. Soil provides numerous important benefits that are affected by its decline. These benefits are called soil ecosystem services, and soil organic matter is central to many of them.

Iowans are adopting more practices that reduce erosion and maintain or increase soil organic matter, including: reduced-tillage or no-tillage systems, using terraces or prairie strips, planting perennial plants in less-productive parts of crop fields, incorporating cover crops between traditional annual crop rotations, using more diverse annual crops in rotation, and (re)-integrating livestock into cropping systems. These practices can balance crop productivity while regenerating soil organic matter by mimicking the natural processes that originally created Iowa's rich soils. Erosion control methods such as silt fences and temporary seeding are also used to help reduce soil erosion in urban and suburban areas.

Scientists and land managers alike are becoming increasingly interested in managing soils to regenerate organic matter and revive soil health that accompanies it. With education, economic incentives, and monitoring that support sustainable, regenerative, management practices, we can achieve soil organic matter levels closer to what our soils held before intense cultivation.

Iowa's soils provide these critical services:

1. **Habitat for organisms**
2. **Provisioning of food, fiber, and fuel**
3. **Nutrient cycling**
4. **Water infiltration and storage**
5. **Foundation for human infrastructure**
6. **Storage of carbon**



Soil profile showing a thick black organic matter layer from a pasture contrasted with a thin soil organic matter layer from the adjacent crop field.

SUMMING IT UP

Iowa soils are incredible in their beauty, formation, functionality, and value to human civilization, as well as to plants and animals. Naturalists and other conservation educators have a special responsibility to teach the value of embracing natural processes and reminding everyone- "Don't treat soil like dirt!" Iowans embracing soil health and soil conservation practices, as well as protecting and restoring natural areas such as remnant prairies, will have immeasurable benefits. With effort and awareness, Iowa farming can mimic natural ecology. This will result in improved soils, water and nature, while also ensuring continued food production.

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Illustrations

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