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Soil **Organic Matter** Does Matter

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What is soil organic matter?

We hear all the time that organic matter is one of the most important components of soil. But what is it, exactly? One textbook definition is: **The organic fraction of the soil that includes plant, animal, and microbial residues in various stages of decomposition, biomass of soil microorganisms, and substances produced by plant roots and other soil organisms** (Weil and Brady, 2017).

Basically, it is the material in soil that is derived from living organisms, whether it is a carcass, waste product or other substance released from living organisms. Even though microbial cells are alive, they experience rapid population turnover — much like dead residues — and often are included in the definition of soil organic matter.

Figure 1. A Histosol soil. (Bockheim and Hartemink, 2017)

Soil Organic Matter or Soil Organic Carbon?

Sometimes the terms **soil organic matter** and **soil organic carbon** are used interchangeably. That is because carbon makes up the majority of organic matter mass. Researchers estimate that carbon makes up about 58% of soil organic matter (Howard and Howard, 1990). Hydrogen, oxygen, nitrogen, phosphorus and other nutrients make up the remaining mass. If you see a report that lists soil organic carbon (scientists often do this), you can convert it to organic matter by multiplying by **1.7**.

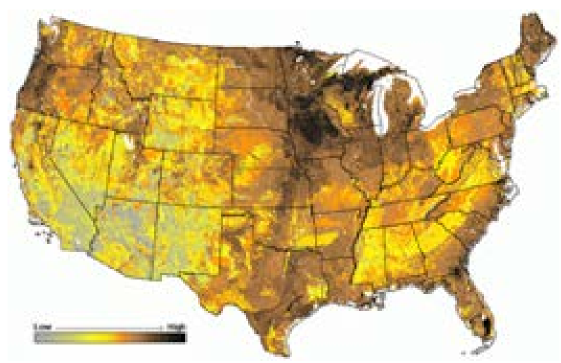

Figure 2. Soil organic matter content across the U.S. (Hargrove and Luxmore, 1988)

Soil Organic Matter Levels

The soil organic matter level in most mineral soils ranges from trace amounts up to 20%. If a soil has 20% or more organic material to a depth of 16 inches, then that soil is considered organic and is termed a peat or muck, depending on the extent of decomposition. These soils are described taxonomically as a Histosol (Figure 1).

Histosols make up only about 1% of soils worldwide (Buol et al., 2003), and most soils have a much lower content of soil organic matter. Soils in the northern Great Plains of the U.S. have some of the highest organic matter levels of all soils that aren't Histosols, commonly ranging from 4% to 7% of the total soil mass (Figure 2).

Most of the Midwest soils fall into the Mollisol classification, which is distinguished by the accumulation of organic matter in the shallow horizons of the soil (Figure 3).

Figure 3. A Mollisol soil near Forman, N.D. (Jodi DeJong-Hughes, University of Minnesota)

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Why are the Upper Midwest soils so rich in organic matter?

Soils in the Upper Midwest have higher levels of soil organic matter relative to the rest of the world for several reasons.

Glacial Activity

The soils of this region are relatively young, having been exposed to the elements only since the glaciers receded and the glacial lakes, such as Lake Agassiz in the present-day Red River Valley (Figure 4), dried up. Because glaciers covered the soil, these soils have not had as much exposure to wind and water. These erosive elements strip and weather the soil organic matter away through time. In areas that don't have a history of glaciers, soils have had more time to weather and they are more depleted in organic matter.

Native Vegetation

After the glaciers receded, prairie vegetation occupied much of this area until about 150 years ago. Deep perennial roots contributed large amounts of organic matter to the soil (Figure 5). In a prairie, the above-ground material may produce about 0.2 ton of biomass per acre, but the root yield is closer to 2.2 tons of biomass per acre (Ovington et al., 1963). The root yields of prairie grasses contributed greatly to the high soil organic matter levels of Great Plains.

Climate

Finally, the short growing season and frigid winters of the northern Great Plains prevent decomposition of organic matter for part of the year. Soil organisms aren't active during long periods of freezing conditions, which allows the organic matter in soils to accumulate and remain at high levels.

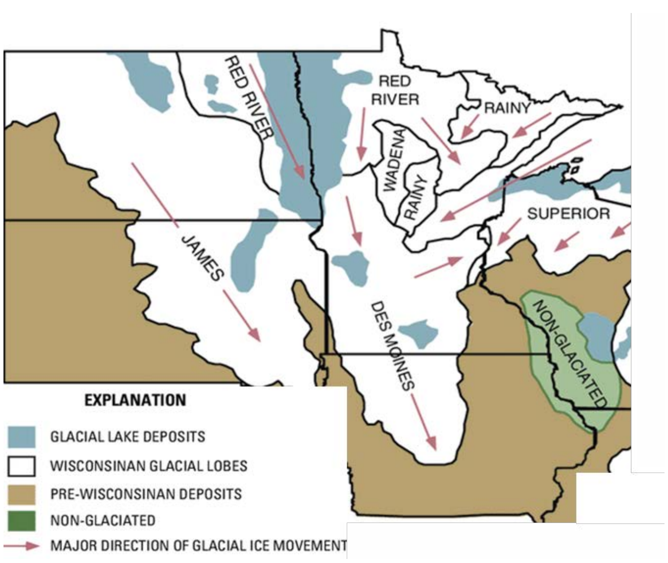


Figure 4. Glacial geologic map of the upper Midwest states and names of major glacial lobes. (Ayotte et al., 2007)

Figure 5. Above- and below-ground biomass of prairie Indian grass. (Jim Richardson)

Classifications of Organic Matter

Many different materials in soil fall under the definition of organic matter; however, not all organic matter is created equally. For example, a mouse carcass and a rotten log are considered organic matter, but they are very different in their chemical nature and how fast they decompose. While different organic matter descriptions (or fractions) are based on their chemical properties, we'll use a more simplified way to think about organic matter: active and stable organic matter.

Active Organic Matter

You can think of **active organic matter** as the portion that is decomposing. Active organic matter is a small portion of the total organic matter in the soil (10% to 20%, summarized by Weil and Brady, 2017), but it is an important portion because it fuels microbial activity and releases nutrients into the soil.

Active organic matter contains nutrients that are easy for microbes to digest and use for their metabolism. These materials are quite young – usually less than five years in the soil.

Fresh crop residues are a good source of active organic matter. The bits of roots, leaves and insect carcasses that you see as you look at a handful of soil are good examples of this, even if they already have started to degrade (Figure 6).

Active organic matter contains sugars, oils, cellulose, and proteins, which are excellent sources of energy and nutrients for soil organisms. The amount of active organic matter in soil is sensitive to residue additions (and removal), crop species, biomass production and soil disturbance. It can change from year to year, and even within a growing season.

Figure 6. Roots and leaves in the soil are a good source of active organic matter. (Jodi DeJong-Hughes, University of Minnesota)

"The microbial biomass is the eye of the needle through which all organic matter must pass."

Jenkinson, 1977

Stable Organic Matter

The active organic materials are different from **stable organic matter**, which makes up a much larger portion of the total soil organic matter (60% to 90%). As soil organisms digest and decompose material, several things happen:

- The chemistry of the organic matter is modified
- Nutrients are removed as microbes decompose the material
- Organic matter sticks to soil particles

The most stable organic matter from Lamberton, Minn., (typical for a prairie-derived Midwestern Mollisol) was 1,510 years old in the top 8 inches of soil (Paul et al., 2001). This ancient, stable C likely has survived thousands of microbial ingestions and transformations. When microbes die, the nutrients and carbon in their bodies are released to be consumed by other microbes, or they may become fixed to clay particles, which makes them more resistant to further decomposition.

The dark brown or black color of topsoil is caused by organic matter coatings on soil particles. The dark soils of the northern Great Plains hold a lot of stable organic matter, and you can detect it by just looking at the soil color (Figure 7).

Stable organic matter accumulates when active microbes continually are decomposing organic matter. It provides a number of chemical benefits, and we'll talk about those later.

Figure 7. Examples of soil with less than 1%, 2% and 3.5% organic matter. (Jodi DeJong-Hughes, University of Minnesota)

Aggregation

Aggregation is another process that stabilizes organic matter in soil. As soil particles stick and bind together, they form aggregates (Figure 8). Small pieces of organic matter — active and stable forms — can be trapped inside of these aggregates. When this happens, the soil particles that make up the aggregate act like armor and protect the organic matter from attack by decomposers. This physical stabilization (also called occlusion) is another way in which organic matter can accumulate in soil, but it is dependent on aggregate formation and stability.

Figure 8. Example of a well-aggregated soil. (Caley Gasch, NDSU)

Soil organic matter accumulates during long periods of time — years to decades to centuries. The majority of soil organic matter is the result of decomposition and aggregation that has occurred during a long time.

In fact, most of the material added to soil as residue is consumed and respired through decomposition within weeks to a few years. Only a small portion of organic matter makes its way into the stable pool each year (Sylvia et al., 2005). See the inset for an illustration of this cycle.

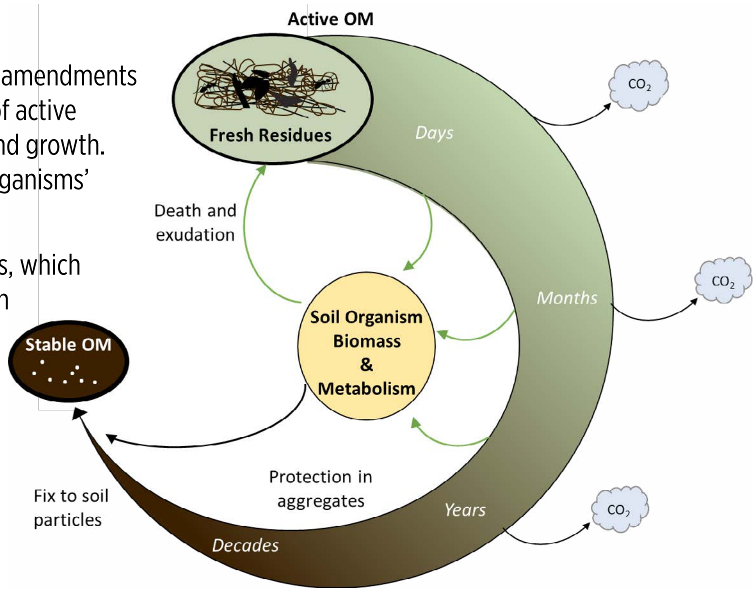
Healthy soil has a mix of active and stable soil organic matter. A steady supply of organic inputs, such as crop residues and manure, helps build and maintain active and stable organic matter pools, which provide a wide array of benefits to the soil.

Even though we think about above-ground residues as contributing to soil organic matter pools, most of the active organic matter that cycles and functions in the soil comes from plant roots. For leaves and shoots to become stable organic matter, they need to be consumed by insects and microbes, which mostly reside near the soil surface. Crop residues that have been incorporated into soil using tillage are considered organic matter only after they have started to decompose and fragment into smaller pieces.

Organic Matter Cycling

When organic materials, such as residues (leaves and roots) or organic amendments (manures and composts), are added to the soil, they provide a source of active organic matter, which is consumed by soil organisms for metabolism and growth. Through this process, the mass of the residue decreases, it feeds soil organisms' growth and carbon dioxide (CO2) is respired into the atmosphere.

The processes of decomposition and biomass turnover release nutrients, which are used by plants and microbes. The stabilization of organic matter can occur through occlusion (entrapment in aggregates) and by sticking to soil particles. Fresh residues will decompose during short time periods (days, months, years), while stabilized forms of organic matter have longer turnover times (decades).



Benefits of Organic Matter

Even though soil organic matter may make up a small portion of the overall soil mass, it has a disproportionally large influence on soil function. Here's why:

Water Management (Retention and Drainage)

Soil organic matter increases the ability of a soil to receive and hold more water. The particulate organic matter in soil serves as a lightweight, low-density bulking agent, similar to a sponge. This material helps the soil create and maintain large pore spaces and channels that allow water to infiltrate and drain and small pore spaces that hold on to water. In addition, plant residues that are spongy and absorptive also can swell and retain water.

Residues on the surface protect the soil surface from the atmospheric elements of wind, rain, and sun. They can protect the surface against forming a hard crust and reduce erosion risks by slowing water and air movement across the surface (Figure 9).

Because organic matter acts like a sponge, it can drain excess water as well as hold water that can be used for plant uptake. Figure 10 shows the water content of different textured soils at organic matter levels of 1% through 5%.

As the organic matter increases, so does the ability of all soils to hold more water. This is important for consistent moisture uptake by the growing crop.

Hudson found that a corn crop used an estimated 0.25 inch of soil moisture a day while growing. In a silt loam soil, corn could go three more days before needing a rain event by increasing the organic matter content from 3% to 4% (Figure 11).

This figure also illustrates why the hilltops dry up much faster than the low-lying areas of the field.

The light tan hilltops of Minnesota and eastern North Dakota generally have an organic matter content of less than 1%. The darker, low-lying areas of these same fields can have organic matter in the 3% to 5% range.

Taking the average of 4%, corn in the low-lying areas of a silty clay loam soil can go five more days before needing a rainfall event. Water stress during corn tasseling can reduce kernel set, resulting in a loss of corn grain yield from 3% to 8% for each day of stress (Lauer, 2006).

Figure 9. Soil protected with a blanket of residue (top) and soil exposed to the elements (bottom). (Jodi DeJong-Hughes, University of Minnesota)

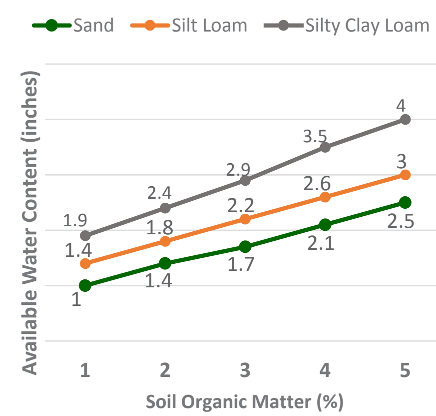


Figure 10. Comparisons of available water content based on soil texture and organic matter percent. (Hudson, 1994)

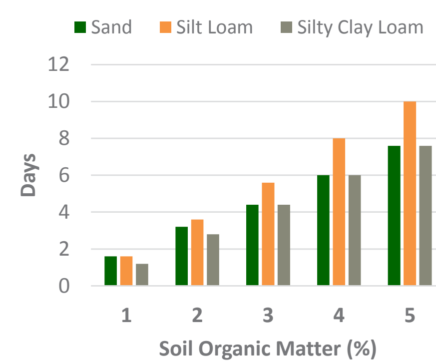


Figure 11. Additional days of available water content based on corn daily usage of 0.25 inch. (Hudson, 1994)

Soil Structure

Plant exudates and microbial byproducts — both considered active organic matter — can be sticky substances that help soil particles hold together to form and stabilize aggregates. This organic matter "glue" directly helps soil develop and maintain aggregate structure.

Organic matter also feeds microbes that help them grow and metabolize. These activities further promote soil aggregation.

The physical benefits of this increased aggregation include:

- **Better aeration** — Plant roots and soil organisms need oxygen, too! By promoting air exchange with the atmosphere, the soil community can stay active and healthy, and important chemical reactions that impact fertility can occur.
- **Better friability or tilth** — This means that the soil is crumbly rather than compacted and hard. The ability of the soil to crumble will make placing seed and fertilizer easier and will create an ideal rooting medium for plants.
- **Less crusting** — If the soil is well aggregated, it is less likely to crust. Crusting prevents water and air movement into the soil. It also can prevent seedlings from emerging, and it promotes water runoff (Figure 12).
- **Better infiltration, drainage and water storage** — Aggregated soils will allow water to enter and drain into the soil by creating a network of pores and channels throughout the soil profile. A well-aggregated soil has a variety of pore sizes and shapes. After a wetting event, some pores will drain completely and fill with fresh air, while others are small enough to hold onto the water, which will be available for plant uptake. This structure helps a soil buffer against extreme fluctuations in water content during long periods of saturation or drought.

The biological benefits of increased aggregation include:

- **A home** — Soil microbes, worms and insects all need a place to live, and aggregates help provide habitat for these organisms. Because an aggregated soil has pores of all shapes and sizes, it has space for everyone (Figure 13).
- **Food storage** — Because organic matter is incorporated into aggregates as they form, aggregates serve as a slow-release source of food for microbes and other soil organisms. Even though they might need to wait until aggregates break apart after wet/dry or freeze/thaw cycles, aggregates guarantee that a snack always is in the cupboard.

Figure 12. Corn growing in crusted soil. (Jodi DeJong-Hughes, University of Minnesota)

Soil Resilience

Soil resilience refers to the ability of a soil to resist or recover its healthy state in response to destabilizing influences (drought, excess moisture and tillage).

Figure 13. A well-aggregated soil provides many micro-habitats for soil microbes. (Jodi DeJong-Hughes, University of Minnesota)

Nutrient Cycling and Retention

What about the nutrient benefits of active organic matter? Active organic matter is full of fresh, accessible nutrients (Table 1). As soil organisms break down and decompose soil organic matter, the nutrients will be consumed by the soil organisms and released into the soil solution. There, it is free for uptake by plants and other organisms or lost to leaching or volatilization. As long as active organic matter is decomposing, it will provide a slow and steady supply of nutrients into the soil solution (mineralization).

If you're curious how much organic matter can contribute to your soil's fertility level, check out the fertilizer recommendations from NDSU and the University of Minnesota, which take soil organic matter content into account:

- **North Dakota Corn Nitrogen calculator** — Play with the organic matter levels to see how they affect the recommended nitrogen application rate.
- **Fertilizing Corn in Minnesota** — Organic matter content is built into the recommendations. Also see the Corn nitrogen rate calculator.

Table 1. Nutrient content of soil organic matter and associated fertilizer value (NRCS.USDA.gov). Available nutrient amounts per year are lower and require mineralization to be taken up by plants. Assumptions: 2 million pounds in the top 6 inches of an acre of soil and 1% organic matter weighs 20,000 pounds.

Nutrient	Average pounds per 1% OM per acre	Fertilizer cost ($ per pound)	Fertilizer value per 1% OM per acre
Nitrogen	1,000	0.45	$450
Phosphorus	100	0.38	$38
Potassium	100	0.30	$30
Sulfur	100	0.42	$42
Carbon	11,500		
			Total $560

Cation Exchange Capacity (CEC)

The plant-available form of most nutrients is an ion, an atom or molecule that has a charge. An ion that has a positive charge is called a **cation**, while an ion that has a negative charge is an **anion**. An ion's charge will determine how it behaves in soil.

The cation exchange capacity (CEC) measures the soil's ability to hold onto different cations temporarily, and many nutrients in the soil are cations. Soil in the northern Great Plains has a net negative charge and can hold onto positively charged ions such as calcium (Ca++), magnesium (Mg++), zinc (Zn++), potassium (K+) and ammonium (NH4+). However, the soil has difficulty holding onto anions such as sulfate (SO4=) and nitrate (NO3-).

Soil organic matter provides between 20% and 80% of the CEC in mineral soils (Sylvia et al., 2005). The net CEC of a soil depends on its texture — percent of sand, silt or clay in the soil — and the nature of the organic matter, but it is mostly that stable pool of organic matter that provides this function (Table 2). In general, the higher the organic matter content in soil, the higher the CEC, and the more likely the soil will retain nutrients.

Another benefit of CEC is that it exchanges hydrogen ions, which determines the pH of the soil solution. A higher CEC allows the soil pH to be more resistant to rapid and large changes, which also protects nutrient availability and plant health in soil.

Table 2. The range of CEC for each soil texture and organic matter. (University of Minnesota, Lamb et al.)

Texture	**CEC** (cmol/kg)
Organic matter	40-200
Sand	1-5
Sandy loam	2-15
Silt loam	10-25
Clay loam/silty clay loam	15-35
Clay	25-60

Microbial Diversity and Resiliency

Organic matter is the main food source for many organisms in the soil. That a steady supply of active organic matter into the soil will support an active and diverse community of microbes comes as no surprise. Soil microbes are important for driving nutrient cycles and influencing the availability of nutrients to the plant; we rely on their activities to make fertilizers available for plant uptake and produce healthy crops.

Microbial diversity is important because different species can perform the same function, such as converting organic matter into plant-available nutrients. If the soil conditions are not comfortable for one species, another species that can tolerate those conditions may be able to step in to do the job. This is called "functional redundancy." Soils are notorious for hosting a great deal of microbial diversity, making them resilient to a wide range of ever-changing conditions.

In addition to providing a source of nutrients and energy to microbes, soil organic matter also is important for creating and maintaining soil microbial habitat. Supporting species and metabolic diversity requires a variety of habitat conditions in the soil, including:

- Aerobic and anaerobic conditions
- Wet and dry conditions
- Nutrient-rich and nutrient-poor conditions
- Large and small pore spaces

Organic matter helps create a mix of these conditions and a variety of homes to support the diversity that we rely on for soil function.

Crop Yield

A recent review of yield and soil organic matter indicated that soil organic matter content can influence crop yield, but only to a point (Oldfield et al., 2018). In corn and wheat production systems, yields increased as soil organic carbon increased, but those benefits diminished after the organic carbon content exceeded 3.45% organic matter.

When organic matter levels are higher, other factors may become more important for influencing yield. These might include other nutrient limitations, climate, and plant genetics. While increased organic matter may impact yield to a point, its collective benefits on soil productivity, structure, and health are substantial and should not be ignored.

Building Organic Matter

Soil organic matter clearly is vitally important for promoting soil health. Soil microbes play a big role in that, as well. For the microbes to grow and do their many jobs, they need (1) food, (2) a strong house and (3) freedom from drastic physical and chemical disturbances.

These same characteristics provide conditions for increasing a soil's organic matter levels. When you want to build organic matter, build the below-ground habitat.

Building soil organic matter depends on keeping a stable flow of carbon through the soil. As long as microbes are incorporating plant residues (active organic matter) into their bodies, the stable soil organic matter pool will grow, too. Living roots are a great way to keep microbes happy, giving them a high-quality food source to boost their activity.

Food — As we learned earlier, active organic matter is a food source for microbes. This readily decomposable and diverse food source promotes a healthy, resilient biological community. Several practices will create a food source for microbes as well as build soil organic matter:

- Leave crop residue on the soil surface.
- Add perennials or cover crops to maximize plant and root growth.
- Reduce soil disturbances.
- Add organic materials such as manure and organic byproducts

Strong house — A well-aggregated soil provides many housing options for microbes, while an aggressively tilled soil breaks apart soil pores and aggregates. Aggressive tillage isolates more individual soil particles with small pore spaces, limiting the types of microbes that can live in this environment. To promote soil aggregation, the soil will need minimal disturbance and a variety of growth habits throughout the entire season.

Freedom from drastic changes — Tillage is an example of a drastic change that may inhibit microbial growth and diversity. It moves, fluffs and breaks apart soil aggregates. Rapid changes in soil moisture or temperature, and an increase of wind or water erosion, are direct effects of tillage. The more aggressive, deep, and frequent the soil is tilled, the more the microbes are affected. To protect the soil from drastic changes in moisture and temperature, the soil needs to be covered with crop residue or living crops, including cover crops.

In addition to providing the resources to support microbial activity, considering the **quality** and **quantity** of organic matter inputs into a soil is important. As mentioned earlier, a healthy soil has a steady supply of active and stable forms of organic matter. This means that building organic matter in soil requires (1) the time and space that are occupied by plant roots and residues is maximized (quantity), and (2) plant residues with a variety of C:N ratios (quality).

Figure 14. The beginning of aggregates being created on plant roots. (Caley Gasch, NDSU)

Residue Quantity

Your choice of a tillage system can influence residue **quantity**. In a Minnesota study, three tillage systems ranging in soil disturbance were compared with no till: 1) moldboard plow, 2) disk harrow and 3) chisel plow. In this study, wheat residue from the previous cropping season added 2,844 pounds of organic matter per acre to the soil.

When the soil was moldboard plowed (MP), the soil lost more than 3,800 pounds of organic matter per acre within 19 days after the primary tillage pass. This is 1,000 pounds more than what was added by the previous crop's entire organic matter contribution.

In addition, this system will continue to lose organic matter in the spring when the field is tilled to prepare for planting. If this system is used year after year, the organic matter content will decrease dramatically through time.

These organic matter loss values are substantially more than the no-till (NT) treatments, which lost only 767 pounds of organic matter per acre due to natural carbon cycling processes. The disk harrow (DH) and chisel plow (CP) were in the middle range of organic matter lost (Figure 15).

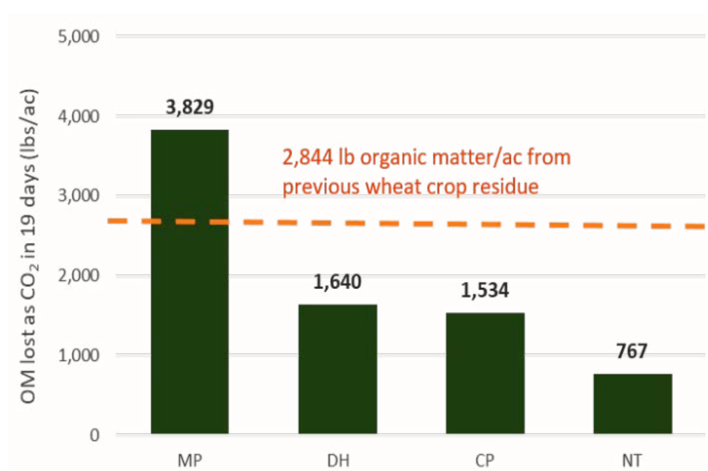


Figure 15. Pounds of carbon dioxide lost to the atmosphere under four tillage operations. (DeJong-Hughes and Daigh, 2018)

Residue Quality

The selection of crops in a rotation, use of cover crops, or added composts and manures can influence residue **quality**. What makes sense is that more types of food will support more types of microbes, which will work hard to turn that food into stable organic matter.

As humans, we can't get all of our nutrients from one type of food, and we don't all like to eat the same types of food. We need lots of variety to keep everyone healthy and happy.

In the same way, providing microbes with a variety of foods — residues that range in C:N ratios — will help build organic matter in the soil. You can consider some of the following options to achieve these goals:

- Include three or more crops in a rotation in a three-year timespan. A tight rotation offers lower quality and fewer food choices.
- Incorporate a perennial crop such as grass or legume forage into your rotation.
- Add cover crops and green manures during periods that would otherwise be fallow.
- Apply composts, manures, or other organic materials.

To illustrate, two types of fields were sampled at the West Central Research and Outreach Center in west-central Minnesota: 1) fields that traditionally had been manured and 2) fields that had not received manure. The manured fields had 45% more microbial biomass (an early indicator of changes in total soil organic carbon), 40% more fungi and 43% more bacteria (Table 3).

Manure offers a diverse food source for the soil microbes and their populations responded. Any of these strategies, or a combination of them, will help you build organic matter in soil.

Table 3. Microbial indicators from a manured and non-manured field in west-central Minnesota. (University of Minnesota Extension)

	Microbial Biomass (ug/g)	**Fungi** (cfu/g x 1,000)	**Bacteria** (cfu/g x 1,000)
Manured soil	371	29.6	2,920
Non-manured soil	204	17.8	1,670

Soil Organic Matter Terminology

Active soil organic matter — Active soil organic matter primarily is made up of fresh plant and animal residues that break down in a very short time, from a few weeks to a few years. This kind of organic matter is associated with a lot of biological activity because it is an excellent food source for decomposers. Sometimes active organic matter is referred to as "labile," which just means that it has a relatively rapid turnover time.

Carbon-to-nitrogen ratios — C:N is a ratio of the mass of carbon to the mass of nitrogen in a substance. It is important because it has a direct impact on residue quality, decomposition rates and nitrogen cycling in our soils.

Humus — Humus is an old name for stable organic matter, based on chemical extraction of a dark, complex mixture of organic substances from soil. We used to think that it was the major form of organic matter in soil, but we now know that stable organic matter comes from microbially derived products that can be simple or complex. The terms humus and humification still are widely used, and the humus can be interpreted as a complex, stable pool of organic matter.

Occluded organic matter — Occluded organic matter may be any form of organic matter (active or stable) that is physically bound in soil structure. Structural units, such as aggregates, protect the organic matter from decomposition, much like armor.

Particulate organic matter — POM is readily decomposable, is a source of food for soil organisms and provides nutrients for plants. POM enhances soil structure, leading to increased water infiltration, aeration and resistance to erosion. POM also can be considered as "active soil organic matter."

Soil organic carbon — SOC is a measureable component of soil organic matter. About 58% of the mass of organic matter exists as carbon. We can estimate the percentage of soil organic matter from the SOC percent by using the conversion factor 1.7.

Stable soil organic matter — Stable organic matter mainly is defined by its long residence time in the soil. It contains partially degraded compounds and substances that have been synthesized by soil organisms. Usually, the majority of total soil organic matter is relatively stable through time.

Destroying Organic Matter

Soil organic matter has a natural tendency to build when the soil is occupied by vegetation and not disturbed. For example, soil organic matter levels slowly increase with time in native prairie or forest soils. Soils managed for crop production are a different story. As we work the soil, remove crops and residues, and intensively manage these soils, the natural tendency to build organic matter is overcome and these soils experience losses instead of gains. This is a challenge that can be minimized with management, but to understand how to minimize these losses, we need to understand why the losses occur.

Physical Disturbance

When a soil is disturbed physically, such as with tillage, the soil structure that holds and protects organic matter is broken. The combination of exposing that protected organic matter (carbon) to decomposers and soil aeration results in a rapid loss of organic carbon as carbon dioxide (CO_2). Even one tillage pass will reduce soil organic matter.

With more frequent and intense disturbances, soil organic matter will be reduced even further. Additionally, as the home of soil microbes is destroyed and fungal hyphae are ripped apart, microbial activity slows. Organic matter will take some time to recover after soil is disturbed.

Soil mixing also impacts soil organic matter levels. Picture how tillage mixes up that rich shallow topsoil with the deeper layers. Because the deeper layers have a much lower soil organic matter content, mixing has a dilution effect on soil organic matter in the rooting zone. This redistribution and homogenization of the soil organic matter diminishes its benefits and sets the clock back on soil organic matter accumulation.

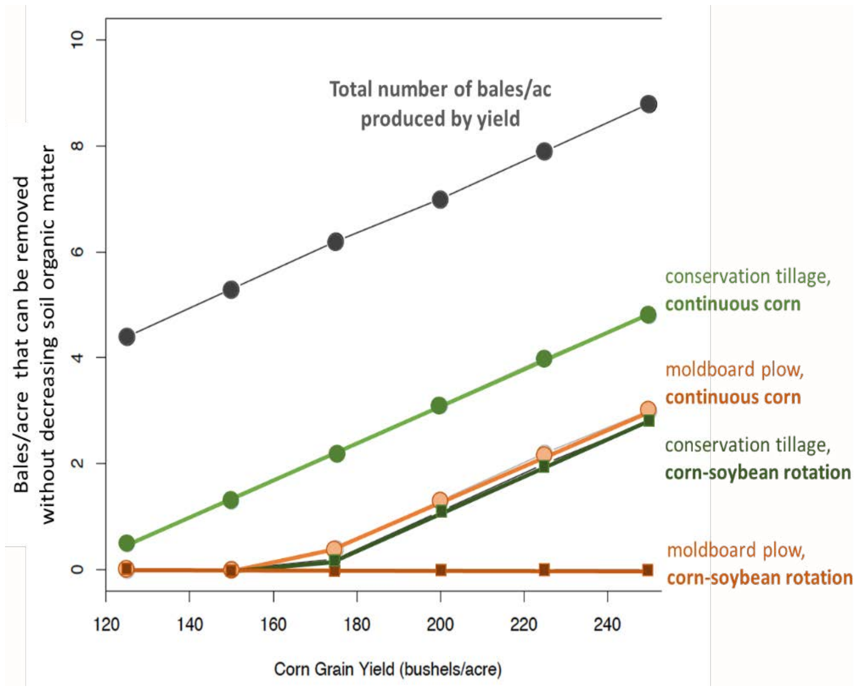


Figure 16. The amount of corn residue that could be removed while still maintaining soil organic matter varies with yield, tillage and crop rotation. (U.S. Department of Agriculture-Agricultural Research Service)

Residue Removal From Fields

Because we know that a continuous supply of residue into soil is important for building soil organic matter, we need to be cautious about how much residue we remove from a field. The amount of corn residue that can be harvested sustainably in the absence of supplemental carbon - manure, organic byproducts, perennials or cover crops - depends on the crop rotation and tillage system (Figure 16).

Tillage affects the amount of residue that can be harvested. With more aggressive tillage, more residue and air are incorporated into the soil. This, in turn, promotes the decomposition of crop residues and soil organic matter by soil microorganisms (especially bacteria).

As decomposition takes pace, the majority of the carbon in crop residues and soil organic matter is released into the atmosphere as carbon dioxide. The potential for sustainably harvesting crop residue is much greater in a continuous corn system.

If grain yields are consistently 200-plus bushels per acre (bu/ac), then 44% of the corn residue could be harvested annually without severely impacting soil organic matter (Figure 16). In comparison, only 19% of the corn residue could be harvested sustainably with a moldboard plow tillage system in continuous corn.

Typically, more residue is produced with higher grain yields. Therefore, when moldboard plowing in a continuous corn system, no residue harvest is recommended when grain yield is 150 bu/ac or less. If yields are more than 250 bu/ac, then three large round bales per acre could be harvested without diminishing soil organic matter. Because yield levels can fluctuate greatly from one year to the next, producers should take this into account and possibly adjust the quantity of residue harvested from year to year.

Figure 17. Wheat residue baled for livestock feed. (Jodi DeJong-Hughes, University of Minnesota)

Erosion

Soil erosion refers to the wearing away of a field's topsoil by the physical forces of wind and water, which is accelerated through forces associated with farming activities such as tillage. The topsoil has the highest concentration of organic matter and nutrients, and it is where most of the soil's biological activity occurs.

Soil that is not protected by residue or living cover is subject to erosion. Practices that increase soil erosion (excessive, aggressive tillage, low-residue crops and compaction) also reduce organic matter.

Soil samples collected in March in western Minnesota county ditches show an average of 9.1 tons/acre (or 18,200 pounds/acre) of soil gathered in an area measuring half a mile by 16 feet (one acre). Not only did the wind blow soil from the field (Figure 18), nutrients such as nitrogen, phosphorus and potassium were blown away as well. When soil blows or washes away, the best soil leaves the field, never to return, and the nutrients within it will not be available to the crops in that field.

Soil loss via wind erosion cuts your profits and the field's productivity by removing a non-renewable resource (soil) and nutrients. Both of these things are necessary for crop production, and they are irreplaceable or expensive to replace.

Figure 18. Soil that has been blown from neighboring fields into the road ditch. (Jodi DeJong-Hughes, University of Minnesota)

Table 4. Pounds of soil and nutrients removed via wind erosion in six west-central Minnesota ditches. (DeJong-Hughes et al., 2015)

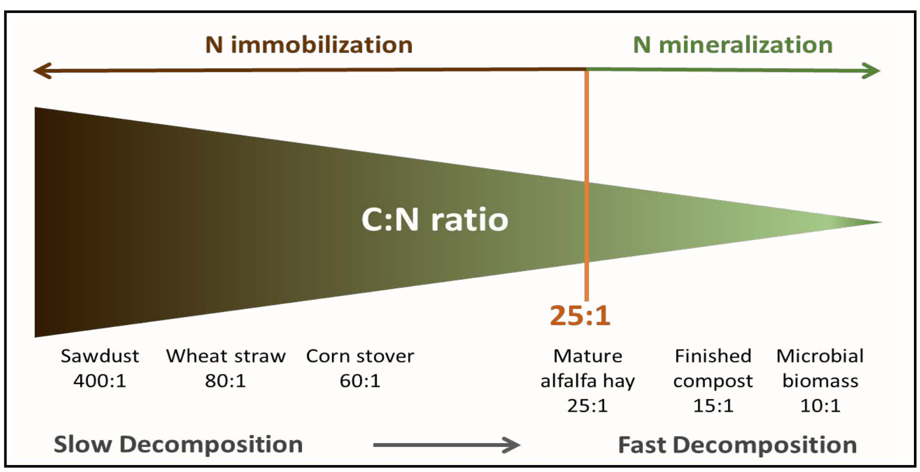
	Ditch Soil	Total Nitrogen	Total Phosphorus	Total Potassium
	(#/Ac)	(lbs./ac)	(lbs./ac)	(lbs./ac)
1	5,200	10.3	3.2	8
2	5,600	12.1	3.6	8.7
3	3,200	8.4	1.9	4.9
4	65,200	172.9	46.9	124.4
5	11,000	23.5	7.2	18
6	18,600	102.6	12.9	56.3
AVE	**18,200**	**55**	**12.6**	**36.7**

Carbon-to-nitrogen Ratios

Carbon-to-nitrogen ratios (C:N) influence decomposition speed. The ratio also determines whether nitrogen will be mineralized (released) as the material is decomposed or if nitrogen will be immobilized (tied up) by the decomposer community as it breaks down the material.

Different types of residues have different decomposition speeds, but why? The answer lies in the differences in residue chemistry and the nutritional requirements of decomposers.

A residue with a C:N of about 25:1 provides the perfect balance of energy and nutrients for soil microorganisms. Residues with a higher C:N, such as sawdust (about 400:1), wheat straw (80:1), or corn stover (60:1), will not provide enough nutrients to support high microbial biomass and activity. In those cases, residues are slow to break down because microbes depend on other sources of nutrients for their activity to proceed. These decomposer microbes will scavenge any free nitrogen in the soil (or immobilize it in their bodies) as they chew through high-carbon materials.



Residues with a C:N that is lower than 25:1, such as manure (20:1) or alfalfa (12:1), will supply plenty of nutrients to microbes — enough that surplus nitrogen is released (or **mineralized**) into the soil. In these cases, the decomposers have all the nutrients that they require in the residues, so they remain active and decomposition occurs quickly.

At any given time, soil organic matter is a mix of different types of residues, each with different C:N and decomposition speed. The C:N levels of residues are different than those of a soil sample. Soil C:N ratios are typically low (around 12:1), and that reflects the C:N of the mineral, organic and living portions of the soil.

Why does corn residue break down more slowly than soybean residue?

Continuous corn has more total root and shoot residue than a corn-soybean rotation. In addition, corn residue has a higher carbon:nitrogen ratio, when compared with soybean residue, making it more resistant to decomposition than soybean residue.

Points to Ponder

- Balancing our soil

  We can think of the soil as a bank. We want to make more carbon deposits than withdrawals. Deposits of carbon include adding cover crops, perennials in rotation, manure or compost, leaving crop residues on the field, and reducing tillage intensity by adopting no till or strip till. Withdrawals include multiple tillage passes with aggressive equipment, tight crop rotations, and wind and water erosion. It's a balancing act and one that will be different for each farmer.

- It takes time

  Have realistic expectations for how long building soil organic matter will take. Organic matter buffers the soil from chemical, physical and biological changes. This means that lower organic matter soils (0% to 2%) may see changes within three to five years of changing management, while higher organic matter soils (4% to 7%) may take seven to 10 or more years to see a change.

  This process also is limited by a region's climate and growing season length. While the organic matter may change slowly through time, other benefits will be more immediate. These include better water infiltration, improved crop resiliency with weather extremes and increased soil carrying capacity.

- What organic matter level is ideal?

  Organic matter is based on many factors. Soils with higher levels of silt and clay usually have higher levels of organic matter than those with a sandier texture. For example, 2% organic matter in a sandy soil is very good and difficult to reach, but in a clay soil, 2% indicates a depleted situation.

- How to monitor your soil

  If you're interested in measuring and monitoring the soil organic matter status of your soil, you don't need to go much farther than a standard soil test. Most fertility packages will include a measure of soil organic matter percentage alongside nutrient content.

  Be sure to remove surface residues and plant material from the soil sample before submitting the sample because that material will inflate your soil organic matter values.

  Remember that soil organic matter levels do not change rapidly, and you may see increases of only a fraction of a percent in a few years.

  Commercial labs also are increasingly offering additional soil health tests, including "active carbon" and "aggregate stability." Based on what you've read here, you can use these tests to supplement your standard soil tests to track changes in soil in response to management, crop type, or new practices.

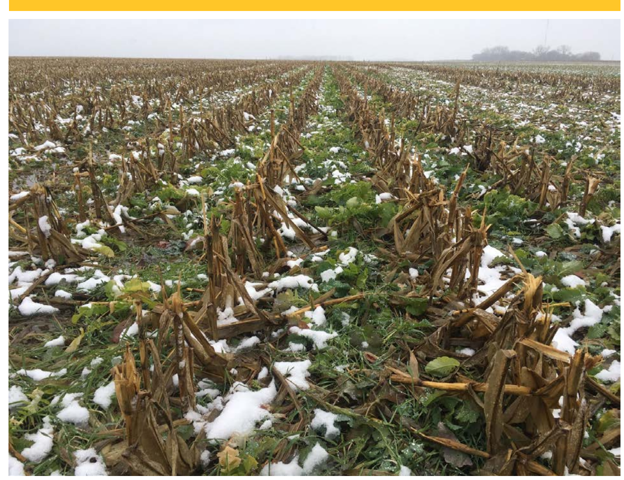
  Expect active carbon measurements to fluctuate within a growing season and across growing seasons because it is much more dynamic than total organic matter. You can expect aggregate stability to respond within three to five years, depending on soil texture (clay soils will aggregate faster and more strongly than loam and sandy soils). If you have difficulty interpreting these tests, reach out to the lab or university Extension personnel to help you.

Summary

The bottom line is that soil organic matter matters a lot. Soil organic matter is responsible for maintaining a healthy, productive soil by providing food and a house for microbes (which run the show in the world beneath our feet). Soil organic matter also helps protect our soils from erosion losses, which is important because soil is a non-renewable resource.

Practices that are good for building and maintaining organic matter levels in the soil result in a cascade of benefits that complement one another to keep the soil healthy. A healthy soil will capture and filter water, retain nutrients and make them available for plant uptake, and provide housing for the vast beneficial biodiversity in soils.

While changing a farming system can be a challenge, a soil managed with organic matter in mind is a soil that will be strong, healthy, and resilient long into the future — and that should matter!



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