soil Organic Matter

Soil Quality Kit – Guides for Educators

United States Department of Agriculture
Natural Resources Conservation Service

Soil organic matter (SOM) is the organic component of soil, consisting of three primary parts including small (fresh) plant residues and small living soil organisms, decomposing (active) organic matter, and stable organic matter (humus). Soil organic matter serves as a reservoir of nutrients for crops, provides soil aggregation, increases nutrient exchange, retains moisture, reduces compaction, reduces surface crusting, and increases water infiltration into soil. Components vary in proportion and have many intermediate stages (Figure 1). Plant residues on the soil surface such as leaves, manure, or crop residue are not considered SOM and are usually removed from soil samples by sieving through a 2 mm wire mesh before analysis.

Soil organic matter content can be estimated in the field and tested in a lab to provide estimates for Nitrogen, Phosphorus and Sulfur mineralized available for crop production and adjust fertilizer recommendations. Soil organic matter impacts the rate of surface applied herbicides along with soil pH necessary to effectively control weeds. Soil organic matter impacts the potential for herbicide carryover for future crops, and amount of lime necessary to raise pH.

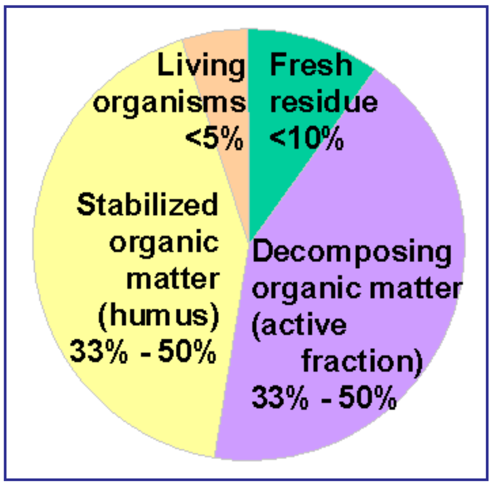

Figure 1. Major soil organic matter components (Source: The Soil Food Web, USDA-NRCS).

Inherent Factors Affecting Soil Organic Matter

Inherent factors affecting soil organic matter such as climate and soil texture cannot be changed. Climatic conditions, such as rainfall, temperature, moisture, and soil aeration (oxygen levels) affect the rate of organic matter decomposition. Organic matter decomposes faster in climates that are warm and humid and slower in cool, dry climates. Organic matter also decomposes faster when soil is well aerated (higher oxygen levels) and much slower on saturated wet soils (refer to soil respiration guide Figure 2 for more information).

Soils formed under grass (prairie) vegetation usually have organic matter levels at least twice as high as those formed under forests because organic material is added to topsoil from both top growth and roots that die back every year. Soils formed under forests usually have comparably low organic-matter levels because of two main factors listed below:

1. Trees produce a much smaller root mass per acre than grass plants, and
2. Trees do not die back annually and decompose every year. Instead, much of the organic material in a forest is tied up in the tree's wood rather than being returned to the soil annually.

A general map of soil organic matter distribution across the United States is shown in Figure 2 (darkest represents the highest level).

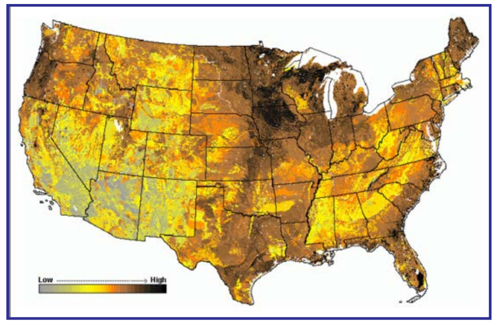

Figure 2. Soil organic matter content; STATSGO Database (USDA-NRCS)

Soil Organic Matter Management

Soil organic matter generally increases where biomass production is higher and where organic material additions occur. Plant residue with a low C/N ratio (high nitrogen content) decompose more quickly than those with a high C/N ratio and do not increase soil organic matter levels as quickly. Excessive tillage destroys soil aggregates increasing the rate of soil organic matter decomposition. Stable soil aggregates increase active organic matter and protect stable organic matter from rapid microbial decomposition. Measures that increase soil moisture, soil temperature, and optimal aeration accelerate SOM decomposition.

Management measures utilized on the field you are evaluating can either degrade or increase SOM. Some key management measures that can increase SOM are shown below.

- Use of cropping systems that incorporate continuous no-till, cover crops, solid manure or other organic materials, diverse rotations with high residue crops and perennial legumes or grass used in rotation.
- Reducing or eliminating tillage that causes a flush of microbial action that speeds up organic matter decomposition and increases erosion.
- Reduce erosion using appropriate measures. Most SOM is in the topsoil. When soil erodes, organic matter goes with it. Saving soil and SOM go hand in hand.
- Soil-test and fertilize properly. Proper fertilization encourages growth of plants, which increases root and top growth. Increased root growth can help build or maintain SOM, even if you are removing much of the top growth.
- Use of perennial forages provides for annual die back and re-growth of perennial grasses and their extensive root systems and aftermath contributing organic matter to soil. Fibrous root systems of perennial grasses are particularly effective as a binding agent in soil aggregation.

Soil Organic Matter Relationship to Soil Function

Under average conditions in temperate regions approximately 1.5 percent of SOM mineralizes yearly for most crops (2% spring planted row crops, 1% small grains, and 0.5% perennial grass; Ray Ward, 2012) while maintaining current organic matter levels on soils with 2 to 5% SOM (Doran 2012). Depending on site conditions, management, and climate mineralization rates and loss of SOM can increase dramatically if temperature, aeration, and moisture conditions are favorable. Key soil functions SOM provide for include:

- Nutrient Supply. Upon decomposition, nutrients are released in a plant-available form. While maintaining current levels. Each percent of SOM in the top 6 inches (15.2 cm) of a medium textured soil (silt and loam soils with a bulk density of 1.2) releases about 10-20 pounds of nitrogen, 1 to 2 pounds of phosphorus, and 0.4 to 0.8 pounds of sulfur per acre per year.
- Water-Holding Capacity. Organic matter behaves somewhat like a sponge. It has the ability to absorb and hold up to 90 percent of its weight in water. Another great advantage of organic matter is that it releases nearly all of the water it holds for use by plants. In contrast, clay holds great quantities of water, but much of it is unavailable to plants.
- Soil Aggregation. Organic matter improves soil aggregation, which improves soil structure. With better soil structure, water infiltration through the soil improves, which improves soil's ability to take up and hold water.
- Erosion Prevention. Because of increased water infiltration and stable soil aggregates erosion is reduced with increased organic matter.

Estimating Organic Material Needed to Increase Soil Organic Matter

The term **steady state** is where the rate of organic matter addition from crop residues, roots and manure or other organic materials equals the rate of decomposition. If the **rate of organic matter addition** is less than the **rate of decomposition**, SOM **will decline** and, conversely if the rate of organic matter addition **is greater** than the **rate of decomposition**, SOM will **increase**.

An acre of soil 8 inches (20.3 cm) deep weighs approximately 2,000,000 pounds, which means that 1 percent SOM weighs about 20,000 pounds per acre. Under average conditions it takes at least 10 pounds of organic material to decompose into 1 pound of organic matter, so it takes at least 200,000 pounds (100 tons) of organic material applied or returned to the soil to add 1 percent stable organic matter under favorable conditions ("What Does Organic Matter Do In Soil", Funderburg 2001, Samuel Roberts Noble Foundation).

What management measures are being used do you predict will affect soil organic matter?

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What impact do you expect these practices will have on soil organic matter and why?

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Measuring Soil Organic Matter

Materials Needed to Measure Soil Organic Matter

____ Soil color chart for estimating organic matter

____ Plastic bucket and probe for gathering and mixing soil samples

____ Squirt bottle with water (to moisten soil if dry)

____ Pen, field notebook, sharpie, and zip lock bags (for labeling soil samples taken back to the classroom)

Considerations – Soil organic matter typically is measured in a lab. The University of Illinois soil color chart provides an estimate of the amount of SOM in mineral soils formed under grass, as many soils are in the Midwest and other natural grassland regions around the world. It can be used for other soils, but is not as accurate. Please read color chart instructions for details and other considerations. Other accepted methods to estimate organic matter such as color charts for other types of soils, lab testing, or tools can be used.

In-field Estimate for Soil Organic Matter (refer to color chart for more guidance)

1. Soil Sampling: Soil organic matter is highly variable. At least 10 small samples are gathered randomly from an area that represents the soil type and management history from the surface 0-8 inch depth and placed in the small plastic bucket and mixed. You may also estimate organic matter at each sample site and average organic matter readings for the area you are assessing. Repeat for each sampling area.

2. Use moist soil. If the sample is dry moisten it.

3. Match the soil with the color that it most closely matches (Figure 3) organic matter color chart (or other method of estimating organic matter content). Record associated organic matter content in Table 3 and complete calculations in interpretations section of this document (suggest averaging several samples).

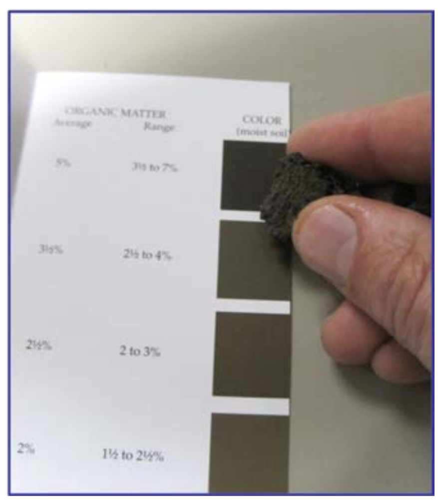

Figure 3. Soil color chart with soil at 3.5% soil organic matter (Kucera 2012).

Interpretations

Record SOM content; estimate organic matter, carbon (C), nitrogen (N), phosphorus (P), and sulfur (S) contained in SOM; and estimate N, P and S mineralized annually in Table 3. Use information in Tables 1 and 2 and follow example calculation to complete Table 3, compare management systems, and answer discussion questions.

Table 1. Ratio of carbon, nitrogen, phosphorus, and sulfur and average mineralization factor in soil organic matter (Doran 2012).

	Carbon	Nitrogen	Phosphorus	Sulfur
Ratio in Soil Organic Matter	100	10	1	0.25-0.50
Carbon:Element Ratio	1:1	10:1	100:1	200-400:1 (avg.=300:1)
Element Percent of Soil Organic Matter	58%	5.8%	0.58%	0.15-0.29 (avg.=0.22)
Annual Mineralization Factor (may need to be adjusted for local conditions)	Mineralization Factor for Soil Organic Matter Nutrients: 1.5% per year under average conditions (.015 factor)			

Table 2. Average bulk density for soil minerals (texture) and organic matter (Rawls 1983).

Class (texture, organic matter)	Average Bulk Density (g/cm^3)
Organic Matter	0.22
Sand	1.56
Loamy Sand	1.54
Sandy Loam	1.50
Loam	1.45
Silt Loam	1.20
Sandy Clay Loam	1.63
Silty Clay	1.55
Clay Loam	1.45
Silty Clay Loam	1.40

Soil Organic Matter Calculations (done using depth in metric units converted to lbs/ac-depth)**:**

Follow example 1 to complete Table 3, in order to estimate total C, N, P and S, and average yearly nutrient (N, P, and S) release from soil organic matter (largely stable and active SOM fractions).

Example 1: Data - Silty Clay Loam texture, 8-inch (20.3 centimeter) sample depth; 2% organic matter estimate from soil color chart; no bulk density (BD) measurement (BD based average values from Table 2).

Sampling depth conversions: Sampling depth (cm) = inches x (2.54cm/in)

8 inch (sampling depth) x 2.54cm/inch = ***20.3 cm sampling depth***

Estimated Bulk Density Calculation (refer to bulk density educator guide for calculating actual bulk density or use estimate from Table 2 in this guide)

Est. Bulk Density (Table 2) = 100 / % organic matter/organic Matter BD) + ((100 - % organic matter)/avg soil BD))

100 / (2/0.22 g/cm3) + ((100 – 2)/1.40 g/cm3) =***1.26 g/cm3***

Soil Organic Matter (SOM) (lbs/ac/depth) = [(Soil Organic Matter % x 10,000 ppm) x (Bulk Density) x (sample depth cm/10) x (0.893 conversion factor)]

SOM lbs/ac: (2% x 10,000ppm) x (1.26) x (20.3cm/10) x (0.893) = ***45,682 lbs SOM/ac-8"***

Soil Organic Carbon (lbs/ac-8") = 45,682 lbs SOM/ac-8" X 0.58 (58 % organic C) **= 26,496 lbs org. C/ac-8"**

Soil Organic Nitrogen (lbs/ac-8") = 45,682 lbs SOM/ac-8" X 0.058 (5.8% org. N) = **2,650 lbs org. N/ac-8"**

Mineralized Org. Nitrogen (lbs N/ac-8"/yr) = 2650 lbs org. N X 0.015 (min. Factor) **= 39.8 lbs N/ac-8"**

Soil Organic Phosphorus (lbs/ac-8") = 45,682 lbs SOM/ac-8" X 0.0058 (.58% 'org' P) = **265 lbs org. P/ac-8"**

Mineralized Org. Phosphorus (lbs/ac-8"/yr) = 265 lbs org. P X 0.015 = **4.0 lbs P/ac-8"**

Soil Organic Sulfur (lbs/ac-8") = 45,682 lbs SOM/ac-8" X 0.0022 (.22% org. S) = **100.5 lbs org. S/ac-8"**

Mineralized Org. Sulfur (lbs/ac-8"/yr) = 100.5 lbs org.P/ac X 0.015 (min. factor) = **1.5 lbs S/ac-8"**

Table 3. Soil organic matter calculations (adjust calculations based on sampling depth).

Site	Sample Depth (cm) convert from inches to cm	SOM (%) from color chart or other source	Bulk Density (g/cm3)	Soil Organic Matter (lbs/ac)	Soil Org. C (lbs/ac)	Soil Org. N (lbs/ac)	Mineralized org. N (lbs/ac/yr) (includes N flush from wetting dry soil)*	Soil Org. P (lbs/ac)	Miner-alized org. P (lbs/ac /yr)	Soil Org. S (lbs/ac)	Miner-alized org. S (lbs/ac/ yr)
Ex 1	20.3cm	2%	1.26	45,682	26,496	2650	39.8*	265	4.0	100.5	1.5

*More accurate estimates of yearly organic N release can be estimated by measuring N released from active and microbial organic matter pools in soil due to re-wetting of dried soils. In example 1, an additional 20-30 lbs/ac of N can be released from microorganisms (N flush) due to soil wetting and drying. This additional N flush can be estimated using the Solvita® Test given in the "Soil Respiration Soil Quality Kit Guide for Educators", or using a "Biological Respiration and Nitrification Test" available at certain soil testing labs.

Do you expect SOM levels to decline, improve, or stay the same and why?

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Does total soil organic matter, and nutrients contained in soil organic matter and nutrients mineralized annually appear too high or too low? Why or why not?

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Glossary

Active Organic Matter – Microorganisms and other organic compounds are used as food by microorganisms. Active soil organic matter decomposes faster than other components of soil organic matter in response to management changes.

Fresh Plant Residues – Refers to plant residue, animal, or other organic substances that have recently been added to the soil and have only begun to show signs of decay. Does not include surface residue cover.

Humus or Stable Organic Matter – Complex organic compounds that remain after many organisms have used and transformed the original organic material leaving a stable form. Humus is not readily decomposed because it is either physically protected inside soil aggregates or chemically too complex to be used by most organisms. Humus is important in binding tiny soil aggregates, and improves water and nutrient holding capacity.

Mineralize – Organic matter decomposition which releases nutrients in a plant available form (e.g., phosphorus, nitrogen, and sulfur).

Small Living Organisms or Soil Microorganisms – Bacteria, fungi, nematodes, protozoa, arthropods, etc.

Soil Organic Matter – Refers to organic component of soil, consisting of three primary parts including small (fresh) plant residues and small living soil organisms, decomposing (active) organic matter, and stable organic matter (humus).