Crops & Soils Magazine - Features

# Why is soil organic matter so important?



doi:10.2134/cs2018.51.0205

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## Abstract

Soil organic matter is a small, but critical component of the soil. This article demonstrates the value of enhancing soil organic matter for increasing the functionality of soils. Earn 1 CEU in Soil & Water Management by reading this article and taking the quiz at www.certifiedcropadviser.org/education/classroom/classes/550.

This article in CNS

Vol. 51 No. 2, p. 4-55

Published: March 22, 2018

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Soil organic matter is a small fraction of the soil. We get excited about changes from 2 to 3%, and yet this component plays such a critical role in soil. Without organic matter in the soil, the functions we need to sustain life would not be possible. Managing our soils to preserve and enhance this organic matter is necessary if we want to increase the functionality of soils.

In a recent analysis of 10 years of observations over a conventional tillage corn–soybean system in the Midwest, Dold et al. (2016) found that there was a loss of nearly 1,000 lb of carbon per acre per year, which would equate to 0.1% per decade of farming. Especially affected is the 6-inch top layer where approximately 660 lb of organic carbon per acre per year have been lost (Dold et al., 2017). We can also visually observe the decrease in soil organic matter from our fields by the changing coloration of topsoil from darker to lighter, and the variations we observe within fields in terms of productivity and water availability are directly related to the soil organic matter content (Hatfield, 2012).

The intent of this article is to demonstrate the value of enhancing soil organic matter. The current emphasis on soil quality can be summarized very simply as a path towards restoring the resilience of soil that begins with restoring the organic matter within the soil. Around the world, there is a large difference in the soil organic carbon content of soils (Fig. 1).

To begin that journey towards understanding the value of soil organic matter, we need to understand that soil organic matter plays a vital role in the soil. For example, soil organic matter has been positively associated with

Increased biological activity

Increased aggregate stability

Enhanced infiltration rates

Decreased soil bulk density

Reduced soil compaction

Enhanced nutrient cycling for all macro- and micronutrients

Improved water storage and reduced nutrient leaching

Enhanced gas exchange between the soil and the atmosphere

Reduced greenhouse gas emissions through a combination of C sequestration and enhanced gas exchange

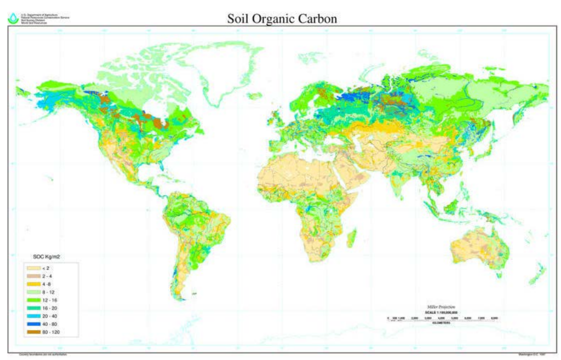


**Fig. 1.**

Worldwide distribution of soil organic carbon in soils (source: USDA-NRCS; see http://bit.ly/2HzXefX).

These changes in soil attributes are noticeable in soils with increased organic matter; however, they are derived from management practices that enhance the soil biology as the first step. Enhancing the soil biology requires four components: food, water, air, and shelter. These are the basic needs for life, and soil biology is no different than any other living organism. Figure 2 is a simple diagram depicting how soil changes when soil biology is enhanced with the stabilization of the soil biology being the first step in changing the soil organic matter content. Changes in soil organic matter manifest in the invisible processes of organic matter decay and nutrient cycling and finally in the visible processes of improved aggregate or soil structure and water availability.

There has been a question about the source of the organic material that is converted into organic matter. In an elegant study, Cambardella and her student used radioisotope-labeled carbon to determine whether the organic material from roots or shoots were the source of soil organic matter (Gale and Cambardella, 2000; Gale et al., 2000a, 2000b). They found that soil organic matter was determined by the root material in the soil. If we extend this finding to how we manage the soil,


**Fig. 2.**

Process of soil aggradation with enhanced soil biological activity (source: from Hatfield et al., 2017).

then the negative effect of tillage on soil organic matter can be seen and could be summarized as tillage and residue removal being the primary factors causing a reduction in soil organic matter content and the primary causes of soil degradation (Hatfield, 2014). The studies by Gale and Cambardella do raise a question about the role of the surface residue if the primary source of active fraction of soil organic matter is from the roots.

## The role of residue

The role of residue on the surface is multi-faceted; however, it serves a vital purpose in stabilizing and protecting the soil microclimate to satisfy two of the critical needs of soil biology for water and shelter. Soil without crop residue cover experiences wide variation in temperature and soil water content. Across the Midwest in the spring, bare soil surface temperatures can exceed 120°F during the middle of the day with soil water contents close to air dry. This type of environment is not conducive to biological activity. A residue-covered soil exhibits maximum temperatures that are in the high 80s, and the presence of the residue layer reduces the soil water evaporation rate so that the area near the soil surface is often moist. During the middle of the summer, you will find crop roots very near the surface under crop residue because of the available soil water and an environment that allows them to actively grow. With no residue on the surface, it is difficult to find plant roots, except at a depth where the soil microclimate becomes more stable with fewer extremes in temperature and moisture.

One of the complaints about residue on the soil surface in the upper Midwest is that it keeps the soil too wet and cold during the spring. Sauer et al. (1996) found that corn residue did reduce the soil water evaporation rate, which decreased the rate of warming; however, the largest impact is on the diurnal variation in temperature more than the mean temperature. Hatfield and Prueger (1996) compared different tillage systems and found that maintaining crop residue in the fall decreased the rate of cooling of the soil, which maintained soil biological activity into the fall and had minimal effect in the spring. Management of soil to create the stable microenvironment requires the presence of crop residue to moderate the temperatures and moisture extremes at the soil surface. Lastly, in addition to the vital role that residue plays in providing shelter and food supply to biota, residue also physically protects the soil surface from raindrop impact. During a rainfall, the kinetic energy of raindrops is transferred into the soil surface, dislodging soil particles and organic material that can be easily swept away when runoff conditions develop (Papanicolaou et al., 2015).

The stabilization or increase of organic matter in the soil is determined by the quality of the residues. Soil organic material is often referred to as either labile or passive where the labile fraction is the most recent and active component of soil organic matter while the passive or recalcitrant fraction is the older component that is more resistant to decomposition (Alvarez and Alvarez, 2000). Whether a soil fraction is susceptible or recalcitrant to mineralization is determined by aggregate size and its chemical and physical properties. In general, macro-aggregated, easy digestible (e.g. non-ligneous), and/or free (i.e., not protected within aggregates) soil organic matter is more prone to mineralization than organic matter associated with or within micro-aggregates and chemically easy digestible material.

Plant material in agriculture deposited by roots and crop residue that may have been moved into the soil by earthworms or manure or compost represents the most active fraction of the soil organic material. This is the food source for the biological community, and this fraction is most readily decomposed. The active fraction is referred to as particulate organic matter (POM) and has become the fraction that is most affected by management practices, e.g., tillage, residue management, crop rotations, and cover crops (Carter, 2002; Franzluebbers et al., 2000). For example, Kantola et al. (2017) found significant changes in POM contents among cropping systems, and POM mainly originated from the incorporation of crop residues. As mentioned before, the POM fraction in the soil leads to the rapid release of nutrients contained in this organic matter but does not necessarily contribute to an increase of soil organic carbon due to its rapid turnover. Yet, even within the POM fraction, there are sub-fractions of different turnover rates, depending on the chemical composition and whether the organic matter is protected within POM aggregates. These POM sub-fractions may contribute in the long run to the more stable fraction of soil organic matter, especially under constant input of plant material and soil protection management practices (Ontl et al., 2015; Liao et al., 2006). Both measurement of POM and stability of aggregates are therefore essential methods to determine soil quality. The measurement of POM has been developed by Cambardella and Elliott (1993), and these methods have become the standard utilized today in research studies.

In recent studies, there has been more attention paid to observations of soil carbon dioxide ($CO_2$) concentrations in the soil as a surrogate for the activity of soil biological systems because of the availability of instrumentation required for these observations. Since soil biological systems represent living organisms, they respire, leading to a rapid increase in $CO_2$ released from the soil.

## Soil aggregate size, stability

Organic material is the glue that binds soil particles together in the form of soil aggregates (Gale et al., 2000b). Therefore, soil aggregates can be a visible sign of biological activity occurring within the soil. It is not only the size of the aggregate, but the stability of the aggregate that becomes important for soil function. This is shown in Fig. 3 where a contrast is made between a soil with poor aggregate stability and one with high aggregate stability. A soil with low biological activity may have aggregates; however, these are not stable and rapidly change when the soil becomes wet during a rainfall event.

One of the current methods used for soil quality is the wet aggregate stability test (Fig. 4) where a soil sample is placed in a water column to evaluate how rapidly the soil aggregates dissolve. For soils with low aggregate stability, the structure of the aggregates fails under the force of water, and the finer fractioned material that was held within the aggregates begins to clog pore spaces, restricting infiltration and causing runoff conditions to quickly develop during a rainfall event (Hatfield et al., 2017). As the depth of runoff increases, larger soil particles and residue can be mobilized by the flow and transported down the hillslope. This is exaggerated when there is no residue cover to absorb the raindrop energy. Soils with high aggregate stability maintain pore space and infiltration rates during a rainfall event because the aggregates don't change. Producers who have improved their soils will often report being able to "handle a 4-inch rain without any runoff while the neighbor's field is moving into the ditch." We can learn a lot about the quality of the soil by merely observing what occurs during rainfall events.

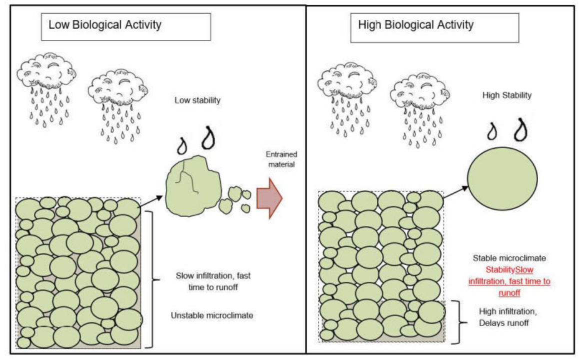


**Fig. 3.**

Depiction of changes in aggregate structure when exposed to rainfall for a soil with low and high biological activity.

These same factors that affect the infiltration of water also affect the exchange of gases between the soil and the atmosphere. There are two critical gases for biological activity, oxygen ($O_2$) and $CO_2$, and stability of the soil aggregates affect the exchange of both gases. One of the benefits of soil organic matter is enhanced infiltration and reduced bulk density, but we rarely consider these changes in the context of gas exchange. When the aggregate structure is reduced, then gas exchange becomes limited and biological systems below the surface become deprived of oxygen.

**Fig. 4.**

Aggregate stability test showing aggregates from (l to r) a no-till system, an intensive tillage system (rototilling 5+ times/year), and a conventional tillage system. Image is a screenshot from a YouTube video from University of Wisconsin Integrated Pest and Crop Management. See https://youtu.be/d1M7EFqqsMM.

## What's it worth?

A question that is often asked is what is organic matter worth in soils? It is difficult to place a value on soil organic matter, but we can show the value of what some of the characteristics of soil mean in terms of agricultural production. An analysis by Hudson (1994) revealed the linear relationship between soil organic matter and soil water-holding capacity with a different curve for each soil type (Fig. 5). The role of increased organic matter is to increase the volume of water a soil can hold, and this relationship is only part of the process. Soil can only store water if it is able to enter into the soil, and the role of the stable aggregates at the surface is a vital part of that process in order to be able to infiltrate as much water as possible. The process of infiltration is a necessary step in being able to store soil water. It is not merely the amount of water the soil can hold and make available that affects plant growth, but the impact of that soil water on crop productivity. High production is derived from crops with high water use efficiency, and enhancing soil water availability is one key to enhanced productivity (Hatfield et al., 2001). An example of this impact is shown in Fig. 6 where the results from Fig. 5 are replotted to show the days of available soil water for a corn crop transpiring at the maximum rate during grain filling. As we increase soil organic matter, there are more days of available soil water with four more days in which the corn crop is not water stressed during grain filling at 4% compared with 2%. The effect of the increased availability of soil water could be extremely significant in years with more variable rainfall.

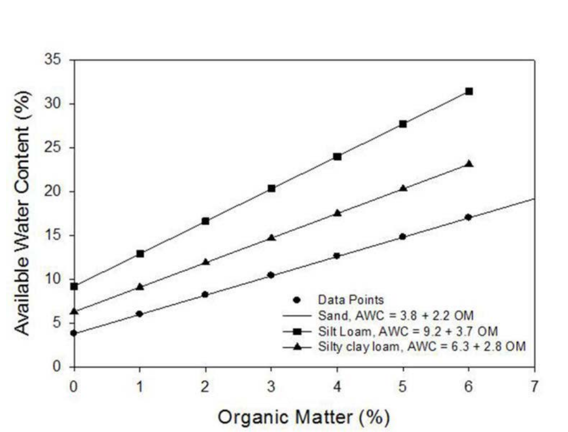


**Fig. 5.**

Relationship between soil organic matter and available water content for three soils (redrawn from Hudson, 1994).

The value of enhanced soil water was observed in the results obtained by Egli and Hatfield (2014a and 2014b) where they found a linear relationship between the average county yield for corn and soybean in Iowa and Kentucky and the quality of the soil. Available soil water was the primary factor affecting the ability of a given soil to produce a yield. These same factors determine yield variation within fields, and enhancing the soil organic matter to increase available soil water will pay dividends in terms of being able to stabilize crop yields.

The positive benefits of soil organic matter encompass a range of soil properties; however, the driving force is soil biological activity and the management of the soil microclimate to provide the functional needs for these living organisms. The effect of the increased biological activity on the stability of the soil aggregate affects all of the other positive benefits in terms of increasing infiltration of water and exchange of soil gases. Managing our soils to increase and maintain soil biological activity is the foundation for enhancing them and increasing their capacity to produce crops.

## Acknowledgments

We want to express a sincere thanks to Missouri Rice and Merchandising Council for providing the funding for this project. We also want to express our heartfelt appreciation to Chad Mikeal for assistance with plot management and harvesting, and to Blake Gray of KOCH Agronomic Services, LLC for providing the fertilizer for this study.

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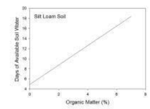


**Fig. 6.**

Relationship between days of available soil water and soil organic matter content for a silt loam soil using the findings from Hudson (1994).

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