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Advanced Soil Organic Matter Management

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Managing Soils

Soil organic matter (SOM) is the foundation for productive soil. It promotes healthy crops, supplies resources for microbes and other soil organisms, and regulates the supply of water, air and nutrients to plants. SOM can deliver over half of the nitrogen and a quarter of the phosphorous crops require, thus strongly influencing fertilizer requirements. Agricultural soils in Michigan and across the Upper Midwest are often sandy and intensively managed. Under these conditions, strategic soil management regimes are needed to prevent depletion of SOM.

Fig. 1. Soil organic matter quality varies depending on plant inputs and management practices.

This bulletin describes the agronomic practices you can use to build SOM and the scientific underpinnings of those practices. We encourage farmers, farm advisors, agency personnel and other stakeholders to use the information presented here to improve their crop and soil management plans to increase SOM. Part of this effort should include on-farm experiments, which are an important step in adapting recommendations to specific regions and cropping systems.

Practices that influence SOM include crop rotation, tillage, residue management, cover crops and targeted use of manure or compost (see Fig. 1). A wide range of management tools exist to reduce soil disturbance and promote living plant cover, both of which conserve SOM and protect against erosion.

Soils with sufficient SOM typically have an increased capacity to hold water and suppress disease, and require less fertilizer and have higher yields than soils depleted of SOM. Further, increasing SOM content can help stabilize atmospheric concentrations of carbon dioxide, a critical greenhouse gas.

SOM is the foundation on which sustainable cropping systems are built. Any effort to improve soil quality and function needs to start with restoring SOM, which is the primary influence on soil's physical, biological and chemical characteristics. SOM serves as the primary habitat and food source for soil organisms. Accordingly, the activity, biomass and diversity of soil biological communities is usually closely associated with SOM concentration. Soil disease suppression, aggregation, and soil chemistry and nutrient supplying capacity are all influenced by SOM concentrations. Crop growth, soil moisture holding capacity and nutrient supply are all regulated in large part by SOM. The bottom line is that, for soils to be productive, SOM must be in sufficient supply.

Unfortunately, SOM is easily lost from farm fields, and many producers in Michigan and the Upper Midwest are faced with having to substitute costly external inputs (fertilizers) for the benefits provided by SOM. These inputs maintain crop productivity in the short term, but do little in the long term to improve soil health or environmental quality. An active management plan is important to build SOM, to create and maintain productive, biologically active soils.

Overall, a good SOM management strategy is to pursue a diverse mixture of residues that include stable materials with a high carbon-to-nitrogen ratio (such as wheat straw) and materials that break down more easily (such as legume cover crop residues). Plant root systems and compost provide slow-to-degrade materials that help build SOM. Complementary to these are residues with vegetative and nutrient-enriched tissues that readily decompose and act as a nutrient supply.

What Is Soil Organic Matter?

Soil organic matter is a biological system that functions as an integrated whole. At the same time, there are components of SOM that can be considered as separate pools. These pools have different histories, characteristics and turnover times. The amount and type of organic matter varies from soil to soil, but generally SOM can be divided up into three pools with different turnover times (see fig. 2). SOM management should focus on strategies that build all three pools. This is the key to simultaneously building SOM and deriving benefits from its decomposition, including nutrient turnover, aggregate formation and water storage.

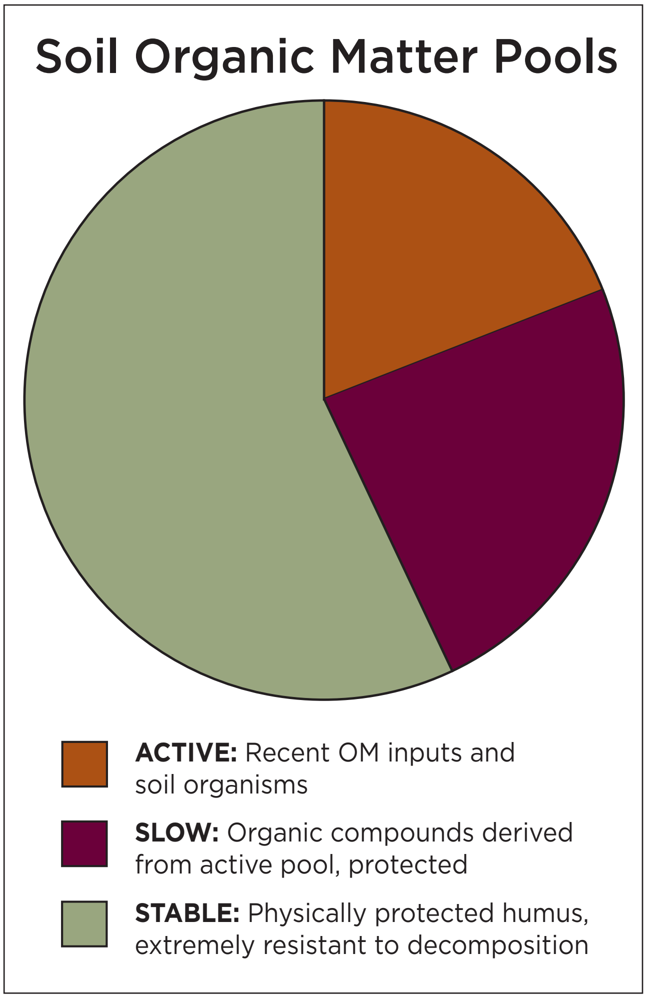

Fig. 2. Typical distribution of soil organic matter between active, slow, and stable pools. Actual proportions will vary with soil type and management practices.

Stable SOM

The stable SOM pool consists of material that is hundreds to thousands of years old. Sometimes this pool is called the passive pool, or humus. It is a highly recalcitrant pool (resistant to decomposition) that influences the cation exchange capacity of the soil, and is important in soil physical processes such as aggregation. The amount of stable SOM is not strongly influenced by recent management practices and tends to increase with increasing clay concentration in the soil. However, management practices such as residue removal, burning, tillage and cover-cropping can have long-term effects on the relative and absolute amounts of stable SOM.

Slow SOM

The slow SOM pool has a turnover time that varies from years to decades. A soil's physical condition and nutrient buffering capacity are both strongly influenced by this slow turnover pool of organic matter. Different from the stable SOM pool, the slow pool is also a source of nutrients including nitrogen and phosphorous. It includes decomposed materials, residues and microbial products that are protected through physical (for example, interior of soil aggregates) and biochemical processes.

Active SOM

The active SOM pool has a turnover time of months to years, and it includes constituents such as soil microorganisms that are involved in even faster turnover times. It is primarily composed of recent plant residues that are in the early stages of decomposition and of soil organisms. This active SOM pool is very important for nutrient release, and helps develop a soil's slow SOM pool.

Managing for high-quality residues that are enriched in nitrogen (N), such as legume cover crops, will help ensure a supply of nutrient release from this active SOM pool. Long-term SOM management, however, should strike a balance between these high-quality residues and those that are chemically complex and thus decompose more slowly. This balance can be achieved through providing the soil with a diversity of plant residues and organic amendments such as compost and manure. Table 1 presents information on tissue quality and properties associated with widely available sources of organic amendments.

Managing Soil Organic Matter

Two general approaches to building soil organic matter exist:

- Slow down decomposition rates (for example, by reducing tillage intensity).
- Enhance carbon inputs from organic materials (such as by using cover crops or compost amendments).

All of the strategies designed to increase SOM fall into at least one of these categories, but ideally management plans should include both approaches.

Building the Stable SOM Pool

The key to building stable soil organic matter is time. Producers must follow practices designed to increase SOM for years to transfer significant amounts of C (carbon) from plant litter and the active and slow pools into the stable pool. Building the slow SOM pool through appropriate management practices will gradually increase the stable organic matter pool.

Building the Slow SOM Pool

Adding organic materials is crucial to building the slow pool. This can be achieved through leaving crop and cover crop residues in place or by applying manure amendments. Crop residues include inputs from roots, which are crucial to enhancing the slow and stable organic matter pools. Legumes generally have large taproot systems with tissues that are slow to degrade and help build SOM. Rotation with a legume hay crop or pasture is highly effective at improving SOM. Alfalfa production enhanced soil C by 60 percent in a long-term cropping system trial in southwest Michigan, compared to a conventionally tilled corn-soybean-wheat rotation (Grandy & Robertson, 2007). No-till management also enhanced soil C in the topsoil by about 40 percent.

Table 1 shows that there are tradeoffs associated with different kinds of organic matter inputs. Some materials supply large amounts of carbon and have the right qualities to build the stable and slow organic matter pools, and other materials supply nutrients and are high-quality inputs that help build the active SOM pool. The recommended management practice is to promote a mixture of the two types of materials by combining the amendment material types shown in Table 1.

Building the Active SOM Pool

High-quality residues for building the active pool are generally immature tissues with soluble, available N-enriched compounds (for example, proteins), as well as soluble carbon compounds (such as sugars). The C:N ratio is used as a measure of N-enrichment and availability. A C:N ratio below 25 promotes rapid decomposition and mineralization of N. Residues with a C:N ratio greater than 25 may require additional soil N to break down but will persist longer in the soil and contribute more to SOM pools. For example, immobilization of N often occurs after dairy manure or compost is applied, as these materials are usually low in N, which is associated with a wide C:N ratio greater than 25 (Table 1). However, this is a temporary development, and it helps build the slow SOM pool. Over a span varying from months to years, much of the N that has been temporarily immobilized will be released.

Table 1. Properties of organic residues, including manure from different livestock species, and legume cover crops such as red clover or hairy vetch. Manure composition varies depending on the species and on the materials used to feed and bed the livestock.

Residue Quality	Poultry Manure	Slurry Manure (Swine or Beef)	Dairy Manure	Wheat straw*	Legume roots and leaves**
N content	2–4%	1–3%	1–4%	<1%	2–5%
C content	19–28 %	14–23%	16–45%	45%	45%
C:N ratio	5–14	4–25	11–45	40 or higher	25 or lower
pH	Neutral to Alkaline	Acidic	Neutral	Neutral	Neutral
Quality: for active SOM (nutrient supply)	High	Medium	Low-Medium	Low	High
Quality: for stable SOM (build C)	Low	Low	Medium-High	High	Low-Medium

* Stover from other small grains such as rye or barley has similar properties.

** Legumes grown in rotation as forage or cover crops provide inputs from leaves which are high in nitrogen and root tissues, which have moderate nitrogen levels and are relatively slow to decompose.

Managing a combination of high-quality and low-quality residues with fertilizer can maximize yield potential in many crops (Snapp, Nyiraneza, Otto, & Kirk, 2003). Manure can vary in quality and often promotes a diverse community of soil organisms and active organic matter.

An Integrated Approach to SOM Management

Efforts to manage SOM to improve crop productivity and environmental quality need to focus on increasing the concentration of C in all three pools. This is the best way to achieve the short-term objectives of providing nutrients through SOM turnover and the long-term objectives of increasing nutrient and water holding capacity. One way to achieve this is through adding a diversity of inputs, including crop residues with varying chemical compositions and C:N ratios as well as compost and manure. Reducing the number of tillage operations or the intensity of tillage can also increase soil organic matter. Decomposition is accelerated by tillage, which brings organic materials into contact with organisms and generally improves the environment for biological activity. Reduced tillage and no-till practices reduce the amount of soil disturbance, and leave a surface cover of residues. This protects against the erosive forces of wind and water, conserving soil. In general, research has shown that SOM will increase in the topsoil with conservation tillage. However, an important finding from long-term experiments is that reduced tillage is most effective at enhancing SOM if it is combined with rotations or cover crops that include deep-rooted and high-residue-producing plants such as alfalfa (Franzluebbers, 2010).

Both of these practices – diversifying residue inputs and reducing tillage intensity – must be practiced long-term to build soil organic matter in all three pools. Short-term improvements in management of several years or less may have some effect on the active pool C, but will have little if any effect on the slow and stable pools. There is no way around this simple fact: Efforts to build total soil organic matter, as well as the slow and active organic matter pools, must be maintained in order to see significant improvements in soil productivity and environmental quality.

Managing SOM in the Future

Crop residue market opportunities are under active consideration by some farmers. Removal of residues with a wide C:N ratio – for example, through selling corn stover residues – will generally promote N mineralization from the active SOM pool. However, removal of residues could endanger soil quality (Doll & Snapp, 2009). One win-win solution is to sell some residues but apply compost or grow a cover crop to replace the residues and conserve the soil. Manure and compost additions are effective ways to build soil organic matter even with complete removal of corn stover (Thelen, Fronning, Kravchenko, Min, & Robertson, 2010). Winter cover crops such as cereal rye provide substantial amounts of residues (1000 lbs. to 4000 lbs. of biomass per acre), and can be planted after a soybean or corn crop is harvested (Rector, Harrigan, Mutch, & Snapp, 2009).

Compost and slurry manures are two sources of organic amendments that have recently become widely available. Dairy compost in particular is a carbon- and nutrient-enriched amendment that provides both short- and long-term soil quality benefits. In a field crop experiment, annual application of 2 tons of dairy compost increased SOM by 50 percent over a decade (kbs.msu.edu/people/faculty/snapp).

As shown in Table 1, manure that is stored as slurry is generally low in carbon, and moderately enriched in nutrients. Slurries can be expensive to transport due to their high water content and require careful management to protect the environment. The combination of manure application and planting a cover crop is recommended to provide a beneficial mixture of residue qualities and maximum soil cover. Cover crop seed can be mixed directly with manure using a no-till planter for a highly effective means of building SOM (Harrigan, Mutch, & Snapp, 2006).

Conclusions

Soil organic matter consists of different pools, ranging from a short-term, active SOM pool to a long-term, stable SOM pool. There is growing evidence that a mixed quality of residues is effective at enhancing SOM pools through supporting a diverse soil food web. However, it is difficult to predict SOM responses for specific soil types and crop rotations. Soil organic matter responses occur over a long timeframe, often of a decade or more. It is important for farmers to check – by testing on an economically modest scale – any soil quality promotion claim for an organic amendment, manure type or residue management practice.

The principles of SOM building are well known to reduce soil tillage and enhance organic inputs. Research has recently reinforced the value of root system residues, and of combining manure or compost with cover crop and forage rotations. To learn more, see the reference list that follows and the New Ag Network articles about research findings related to the long-term field crop trials at the Kellogg Biological Station in southwest Michigan. The articles are online at ipm.msu.edu/.

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