

WHY SOIL ORGANIC MATTER MATTERS

HIGHLIGHTS

- Organic matter is the cornerstone for healthy, fertile soils.
- Increases in soil organic matter lead to higher concentrations of plant available phosphorus and sulfur concentration.
- In 1 acre of land, every 1% of soil organic matter can store up to 1,000 pounds of nitrogen, which can be made available to plants through microbial activity at a rate of 2%-3.5% a year (about 20-35 pounds of plant-available N).
- The same 1% of soil organic matter can retain up to 20,000 gallons of plant-available water per acre.
- Fresh organic matter is the main feed source for soil organisms. These organisms are responsible for the decomposition of organic inputs, making nutrients available to the plants as well as improving soil structure and quality.
- The activity of organisms in the soil causes loss of organic matter as they respire and release carbon dioxide. Therefore, it is essential to continuously add organic matter to the soil.
- There are several ways to increase organic matter in the soil, such as cover crops, no-till farming and manure application.
- The depletion of organic matter in the soil will result in greater need for irrigation and fertilizers in an attempt to maintain crop yields.

IMPORTANCE

Soil organic matter includes a variety of organic, or carbon-based, substances such as living organisms in the soil and their exudates, residues of plants and the remains of animals once present in the soil. Although it is typically in very small amounts in the soil, organic matter influences all properties in the soil. It can improve soil chemical, physical and biological properties, ultimately increasing crop yields. However, the continuous activity of microorganisms in the soil naturally leads to organic matter loss, as they respire and release carbon dioxide. Therefore, it is essential to continuously add organic matter to the soil.

Beyond agricultural benefits, organic matter plays a crucial role in carbon sequestration. On average, carbon composes about 50% of the soil organic matter. Plants are the primary source of soil organic matter, in which they sequester carbon from the atmosphere and use that carbon to build their tissues over the photosynthesis process. Animals also provide organic matter to the soil, but they are considered secondary because their contribution to the soil organic matter relies on the manure addition, not a direct process. Remarkably, there are three times more carbon in the soil than in the whole world's vegetation.



Figure 1. Cover crops contribute significantly to soil organic matter by adding both aboveground plant residues and belowground roots. Photo by Jacob Adkison

There are several management practices to increase organic matter in the soil including cover crops (Figure 1), no-till farming (Figure 2) and manure application.

EFFECTS ON SOIL CHEMICAL PROPERTIES

Improvement of nutrient status: Soil organic matter can provide much of the nitrogen, phosphorus, sulfur and micronutrients that plants need. Organic compounds can enhance phosphorus availability in the soil through several mechanisms, for example, by forming more soluble organophosphate complexes, replacing phosphorus retention sites with organic anions and increasing the mineralization of organic phosphorus into plant-available forms. Sulfur status in the soil will also be positively impacted by higher organic matter content, as it helps retain sulfur in forms that minimize leaching yet remain available for plant uptake. Nitrogen is the main plant nutrient in organic matter. Every 1% of soil organic matter in an acre contains about 1,000 pounds of nitrogen. This includes nitrogen forms that are not available to the plants without microbial activity (about 95%). However, nitrogen can become available due to the mineralization of organic matter; considering a 2%-3.5% mineralization rate a year, it results in 20-35 pounds of available nitrogen to plants per acre per year (Figure 3). Additionally, several free-living bacteria can fix nitrogen in the soil. Since soil with a higher content of organic matter usually present a greater microbial activity, it is expected that biological nitrogen fixation will be enhanced by organic matter in the soil.

Increase in cation exchange capacity (CEC): A large portion of the soil's CEC is provided by organic matter. Soil organic matter can hold positively charged elements (cations), which consequently reduces leaching. The reaction between organic matter CEC and the cations are weak, therefore, they are still available for plant uptake. Examples of positively charged nutrients are nitrogen (as ammonium $[\text{NH}_4^+]$), potassium (K^+), calcium (Ca^{2+}), magnesium (Mg^{2+}), zinc (Zn^{2+}) and manganese (Mn^{2+}).

Increase in anion exchange capacity: Despite soil organic matter being predominantly negatively charged, it can also hold to negatively charged elements (anions), reducing leaching while keeping them available to plants. This is very important because not all plant nutrients are positively charged. In addition to that, soils normally have very limited anion exchange capacity, and in consequence, limited ability to retain negatively charged nutrients. Examples of negatively charged nutrients are nitrogen (as nitrate $[\text{NO}_3^-]$) and sulfur (as sulfate $[\text{SO}_4^{2-}]$).

Slow release of nutrients: While most nutrients present in soil organic matter cannot be accessed by plants, as soil organisms start decomposing it, the organic

nutrient forms are broken into simpler inorganic forms that can be absorbed by plants. This process is called mineralization, which supplies most of the nitrogen, phosphorus, sulfur and micronutrients required by plants.

Protection of nutrients in available forms: Some nutrients are often present in unavailable forms in some soils (e.g., iron, zinc and manganese), but due to chelation they remain in forms that can be absorbed by plant roots. In chelates, nutrients are bound to more than one part of its organic molecule. Chelates are byproducts that result from the decomposition of organic matter or from root exudates.

Reduction of nutrient leaching: Due to the presence of chelates, along with cation and anion exchange capacity in soil organic matter, nutrients are less likely to leach from this portion of the soil. This is especially important to enhance fertilizer use efficiency and prevent the contamination of nearby water bodies (eutrophication).



No-till system

Conventional system

Figure 2. No-till farming contributes significantly to soil organic matter preservation by reducing soil erosion and runoff. Photo by Saulo Castro

EFFECTS ON SOIL PHYSICAL PROPERTIES

Formation and stabilization of soil aggregates: Soil aggregates are primarily formed by certain components of the organic matter in the soil. Plant residues and manure are feed sources for earthworms, insects and microorganisms, which mix the mineral soil and the organic matter. The byproduct of these organisms helps to bind soil particles together, improving aggregate stability.

Improvement of soil aeration and water flow: Larger soil organisms, such as earthworms and insects, create channels in the soil, named soil biopores, which enhance both aeration and water flow. Earthworms not only construct these tunnels, they also maintain their structure. They produce mucus to keep their skin properly hydrated,

and part of that mucus is left behind on the walls of the tunnels, increasing their structure strength. In addition to that, old root channels can remain open for a period of time after root decomposition, further improving soil porosity.

Improvement of water-holding capacity: Organic matter has a very high water-holding capacity compared to mineral soil. It also indirectly influences the amount of water available to plants by improving soil structure and total pore space. A 1% increase in soil organic matter can allow a single acre to retain up to 20,000 gallons of additional plant-available water (Figure 3). Conversely, depletion of soil organic matter can drastically reduce the soil's water holding capacity, leading to increased runoff and erosion.

Reduction of erosion and runoff: Organic matter helps reduce erosion and runoff by improving soil structure and physically covering the soil surface (for example, plant residues). That organic matter covering the soil can reduce the strength of a raindrop falling on the soil and its ability to detach soil particles. It can also slow down water flow and increase chances of infiltration. This reduction in erosion and runoff can significantly increase crop yields, since the topsoil — the most fertile layer of the soil — is preserved.

Increase in soil temperature: Organic matter accumulation leads to the darkening of the topsoil. This can be beneficial during the beginning of the growing season, in which a warmer soil can expedite seed germination, seedling development and soil microbial

activity. Organic matter can also work as buffer for soil temperature changes, maintaining a more suitable temperature for crop establishment and microbial activity.

EFFECTS ON SOIL BIOLOGICAL PROPERTIES

Increase in microbial activity: Microbial activity is essential for breaking down organic matter in the soil, releasing nutrients (mineralization) and producing carbon dioxide (CO₂). Moreover, microbial metabolism is responsible for the production of some organic compounds that are very stable. Some of these organic compounds can persist in the soil for more than 10 years — or more than 100 years — before they are decomposed and CO₂ is released. This resistance to breakdown allows organic matter to accumulate in the soil.

Increase in microbial diversity: Microbial diversity is likely more important than increased microbial activity. Fresh organic matter is the main source of food for microorganisms. When it is plentiful, it will stimulate the growth of different microorganisms. These different microorganisms in the soil can increase the availability of different nutrients to plants. These diverse organisms perform a range of functions. Some fix atmospheric nitrogen, while others can break down minerals and increase phosphorus availability to plants.

Increase in macro and mesofauna population: The increase in population of earthworms and other organisms can have a positive impact on several chemical and physical properties of the soil by improving soil aeration, facilitating water infiltration and retention.

Plant pathogen suppression: Increasing organic matter can enhance microbial activity and diversity, leading to the proliferation of beneficial organisms that act as natural antagonists to plant pathogens. This can help reduce disease incidence.

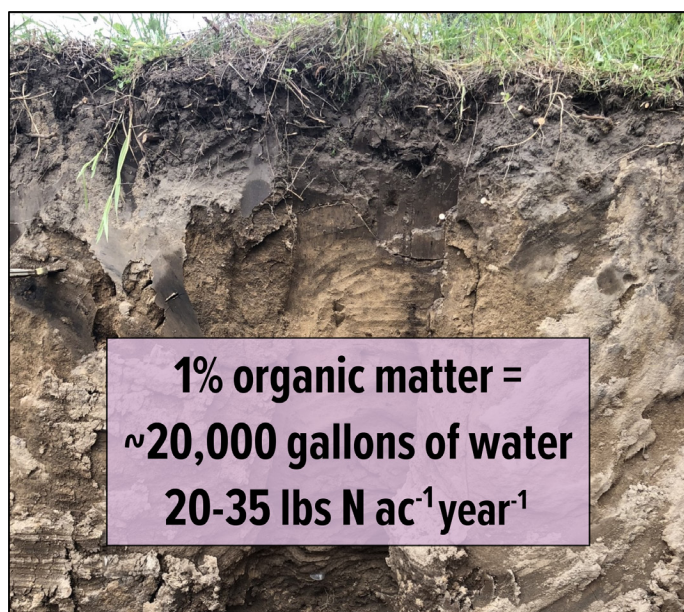


Figure 3. In a single acre, every 1% of soil organic matter can store about 20,000 gallons of plant-available water and release approximately 20-35 pounds of plant-available nitrogen per year. Photo by Leandro Vieira

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P4007 (online) 8/25

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