

Soil Organic Matter and its Benefits

Composition:

Soil organic matter is a very important part of the composition of a healthy soil. It is the decomposition product of different types of organic materials. Materials that go through the decomposition process to form soil organic matter include: crop and plant residues, tree litter, animal waste, animals and different types of soil organisms, their by-products and to a lesser extent human waste (figure 1).



Figure 1. Recently applied livestock manure to improve soil organic matter level.

All living cells are carbon based but only a few organisms are able to transform carbon dioxide into organic carbon that can be used to build cells. Soil organic matter originates from the photosynthetic process in which plants produce organic compounds (sugar) by utilizing the energy of sunlight in the presence of chlorophyll. Sugar is then produced by combining carbon dioxide from the atmosphere with soil water and oxygen to produce sugar, water and oxygen (Wikipedia). Other organisms then have access to and can utilize the organic carbon to build their own cells.

Organic carbon is derived from inorganic carbon specifically carbon dioxide (CO₂) obtained from air that is transformed through the process of photosynthesis.

PHOTOSYNTHESIS



Sugar is used by plants and other organisms to produce energy through the process of respiration, leaving behind carbon dioxide and water as by-products.

RESPIRATION



Note: Photosynthesis and respiration processes are basic to the cycling of carbon and oxygen (figure 2).

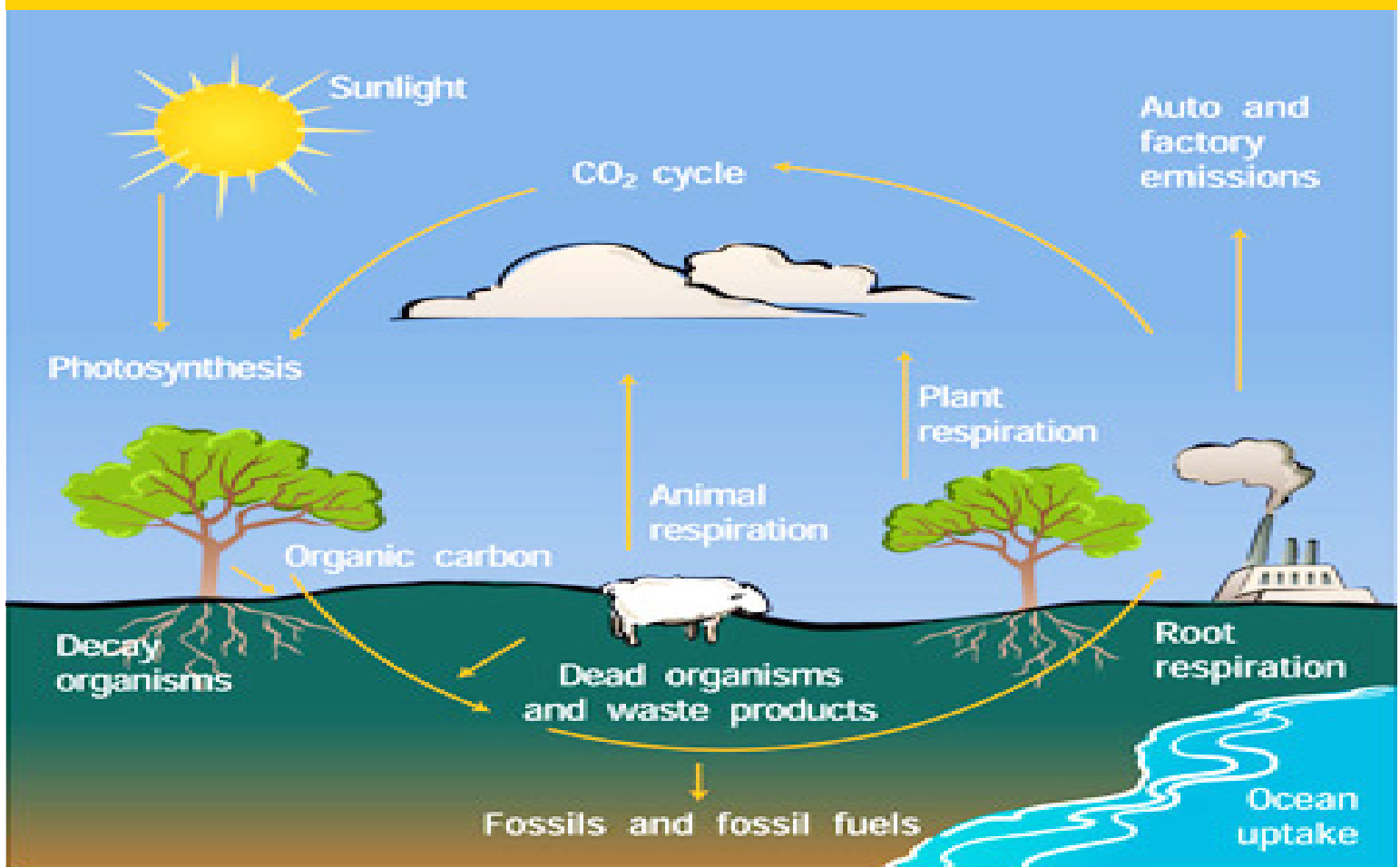


Figure 2. Photosynthesis and respiration processes (figure courtesy of Wikispaces' APBio-Werle site).

The continuous formation and breakdown of organic carbon compounds that serve as energy sources for microorganisms leads to the formation of soil organic matter (Sylvia et al. 2005).

Properties:

Soil organic matter is heterogeneous or non-uniform in nature and does not have any defined physical or chemical structure. It can be present in soils under various stages of decomposition (figure 3) from mineral associated partially decomposed plant material to fully decomposed humus (Sylvia et al., 2005).



Figure 3. Recently added organic material going through the decomposition process.

Recently added materials like plant roots and residues are considered to be part of the most active (labile) fraction of organic soil carbon. Approximately 10 to 20% of plant material will be incorporated into soil organic matter (Sylvia et al., 2005). This active fraction is mainly responsible for serving as the food source of soil microorganisms. As all life on earth is dependent upon the functions of microorganisms. Thus, organic matter decomposition and transformation is also dependent upon the activity of soil microorganisms.

Stable soil organic matter sequesters (stores) carbon originally derived from the atmosphere and reduces loss of organic carbon to decomposition, a source of atmospheric carbon dioxide. Therefore, increasing soil organic matter levels can also contribute to the reduction of global warming by reducing compounds that destroy the ozone layer.

Levels of soil organic matter are generally higher in the cooler and humid regions of the world versus the warm and arid regions due to the higher decomposition rates and longer decomposition periods under warmer conditions (favorable for soil microorganisms). Decomposition rates of organic matter will also vary with soil textural classes. Studies have shown that organic matter associated with the sand-sized fraction is more susceptible to decomposition thus leading to high turnover versus silt or clay fractions that can provide greater physical protection relative to soils containing high sand contents (The Importance of Soil Organic Matter in Cropping Systems of Northern Great Plains, Overstreet and DeJong-Huges, University of Minnesota Extension, 2009).

Decomposition Process:

A wide range of soil organisms exist and what they consume varies. Some feed only on plants, other living organisms or both, and some known as detritivores eat dead and decaying plant or animal matter that may include excrements. Each group of organisms plays a different role. Larger soil organisms such as earthworms, mites and beetles (figure 4) shred organic material creating greater surface area and reduce the size of organic material which in turn provides access to soil microorganisms that play a primary role in the decomposition of organic materials and the formation of soil organic matter (Fortuna, 2012).



Figure 4. An earthworm actively functioning in the soil.

Plants are considered producers since they produce their own food through photosynthesis, an autotrophic process. Consumers like nematodes usually consume living material that contains carbon such as plants roots, microorganisms and other nematodes. The microorganisms that consume, decompose and utilize organic carbon are heterotrophs. They recycle organic carbon utilizing it as an energy source. Heterotrophs consist mainly of bacteria and fungi that break down and decompose organic matter while feeding on it releasing essential nutrients: nitrogen, phosphorous, potassium, sulfur and others that are made available to plants and other organisms (Fortuna, 2012). Microorganisms also release enzymes that increase the rate of decay increasing the rate at which plant and animal derived organic material is transformed. A group of special enzymes known as extra cellular enzymes produced mainly by fungi are excreted outside of fungal cells. Extra cellular enzymes transform large organic molecules into smaller molecules that can be absorbed by plant roots as well as microorganisms (Sylvia et al., 2005).

The carbon to nitrogen ratio (C:N ratio) plays an important role in determining how quickly organic matter will decompose (Sylvia et al., 2005).

It is the ratio of the carbon versus nitrogen

contained in a material. All organic materials have a C:N ratio because they contain carbon and nitrogen. As organisms decompose organic matter, they use carbon as a source of energy and nitrogen to produce protein. On average microorganisms require 25 to 30 parts of carbon for every part of nitrogen they consume. Therefore, high C:N ratios above 30:1 will result in slower decomposition rates whereas low C:N ratios below 20:1 will result in nitrogen losses.

C:N ratio is also an indication of whether decomposition of residues will result in a net gain in plant available nitrogen or if free nitrogen will be tied up in the end products of decomposition. A C:N ratio below 25:1 usually implies that decomposition will release nitrogen for plant uptake and a ratio above 30:1 will usually result in a reduction of free nitrogen.

Functions:

Though small in proportion to the entire soil mass by weight, organic matter is linked to important functions in the soils directly or indirectly and is critical to maximizing biological activity within the soil (figure 5). Humic materials (humus) along with clay particles provide cation exchange sites in soils that hold the positively charged plant nutrients improving the soils ability to reduce nutrient losses to leaching. Although the relative proportion of the soil organic matter fraction is small compared to the clay fraction on a dry weight basis, humus provides a greater number of exchange sites, many times greater than the clay portion of the soils. Microorganism supported by the rich food substrate of soil organic matter stabilize soil particles through encouragement of aggregation, which results in better water holding capacity in sandy soils and improved soil drainage in clay soils by promoting larger sized pores.



Figure 5. A recently added aggregate of livestock manure (left) versus a heavy soil aggregate of poor structure on the right.

Improved soil structure and drainage will also decrease the erosion potential of the precious top soil by reducing the runoff.

Higher organic matter levels also tend to favor soil temperatures that promote improved plant root growth, healthy microbial populations and moderate pH ranges.

Soil microorganisms decompose organic material to obtain energy which leads to the formation of soil organic matter. Microbial process, population size, diversity and health are dependent upon maintaining healthy levels of soil organic matter. The sequestration of soil carbon that results from increasing soil organic matter levels can also help in the reduction of greenhouse gases released to the atmosphere.

Practices That Can Increase Soil Organic Matter Levels:

(The Importance of Soil Organic Matter in Cropping Systems of the Northern Great Plains, Overstreet and DeJong-Huges, University of Minnesota Extension, 2009)

- ⇒ Crop rotations by planting;
 - Cover crops to provide soil cover to reduce evaporation, erosion and runoff.
 - Perennial grasses to add above-the-ground as well as below-the-ground biomass.
 - Legumes for green manure purposes.
 - Planting crops/plants that produce greater biomass.
- ⇒ Incorporation of straw/crop residues (figure 6).
- ⇒ Reduced tillage to minimize soil carbon losses and to slow down organic matter decomposition processes.
- ⇒ Application of fertilizers on cover crops and legumes to produce more biomass.
- ⇒ Application of manure, plant material or other carbon-rich waste.
- ⇒ Using forage by grazing versus harvesting.



Figure 6. Plant residues ready to be incorporated into the soil.

Summary:

Soils of Northern Great Plains have some of the highest organic matter levels of all mineral soils in the United States ranging between 4 to 7% (The Importance of Soil Organic Matter in Cropping Systems of the Northern Great Plains, Overstreet and DeJong-Huges, University of Minnesota Extension, 2009). Soils of this region are relatively young (11000 to 14000 years old) and have only been exposed to the process of weathering after the recession of glaciers and drying of glacial lakes, such as Lake Agassiz (present day Red River Valley) (Geography of North Dakota, How Stuff Works, 2012). As a result, they are rich in organic matter and plant nutrients relative to older more weathered soils such as those of the southern Appalachian region. An additional reason for high soil organic matter levels in the Northern Great Plains is the dominance of prairie grasses until 150 years ago, a great source of organic matter. Such grasses contribute 1.4 tons of aboveground and 4.0 tons of underground biomass/acre (The Importance of Soil Organic Matter in Cropping Systems of Northern Great Plains, University of Minnesota Extension, 2009).

Being relatively young and rich in organic matter, soils of Northern Great Plains still require close monitoring as continuous cropping, poor management practices and natural factors (erosion, runoff) can adversely affect the soil organic matter levels.

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