Stroud Water Research Center

Pennsylvania Soil Health Coalition

Soil Carbon: Powering Cropping Systems

Understanding the Role of Carbon in the Soil Ecosystem and How Management Decisions Can Influence It

In Brief

Soil carbon (C) plays a vital role in plant growth, soil water retention, nutrient cycling, and carbon sequestration. Soil carbon exists in two forms — inorganic and organic. The inorganic amounts are determined by the soil parent material, with limestone-derived soils having the highest levels. The organic amount is highly dependent on climate conditions and management.

Soil organic matter (SOM) is comprised of approximately 50-58% soil organic carbon (SOC). Hydrogen, oxygen, nitrogen, phosphorous, and other nutrients make up the remaining amount. SOC is usually concentrated in the top six inches of soil. Soils in cool, northern climates tend to have higher organic matter levels because decomposition from soil microbial activity is slower.

Cover cropping and no-till planting are two practices that increase soil organic carbon.

Research Highlights

- Studies have shown (Reicosky, 1997) that 13.8 times more carbon dioxide is lost from the soil after a full-tillage event compared to no-till. Most of this carbon loss happens in the first five hours after tillage.
- Estimates are that 2.5 to 6 times more "liquid" carbon is exuded from the roots than the amount of carbon incorporated into root biomass. (Johnen and Sauerbeck, 1977; Molina et al., 2001).

Carbon Cycling

A large portion of the carbon in plant residues left on the surface is respired as carbon dioxide (CO_2) back into the air during decomposition. Carbon in the root systems is more likely to contribute to increasing SOM levels. Much of the liquid carbon that leaks out of plant roots as exudates serves as food for the soil microbes and is therefore cycled through the soil food web during the growing season. The respired portion of the carbon returned to the air as CO_2.

Photosynthesizing plants recapture this CO_2 released by the soil and cycle it back into plant growth, root systems, and new root exudates.

Three Forms of SOM

Soil Organic Matter (SOM) is the fraction of the soil composed of anything that once lived. Organic matter is made up of different components that can be grouped into three major types:

1. Dead plant tissues and living microbial biomass (<5 years old).
2. Active soil organic matter referred to as detritus (5–50 years old).
3. Stable soil organic matter, referred to as humus (50+ years old).

The first two types of organic matter contribute to soil fertility because the breakdown of these fractions results in the release of plant nutrients such as nitrogen (N), phosphorus, potassium, and micronutrients.

The humus fraction has less influence on soil fertility because it is the final product of decomposition (hence the term *stable organic matter*). However, it is still important for soil fertility management because it contributes to soil structure, water holding capacity, and cation exchange capacity. This is also the fraction that darkens the soil's color.

SOC in the top six inches is actively cycling because this is where most soil microbes and plant roots are concentrated.

Long-term carbon sequestration happens when SOC is accumulated deeper than six inches, and this requires deep-rooted plants.

Photos: Lisa Blazure

Management: What You Can Do

- Minimize soil disturbance. Tillage introduces oxygen deeper into the soil profile and stimulates bacterial growth. Increased bacteria populations start eating the SOC.
- Plant cover crops. Living plants continuously grow root systems, a large contributor to SOM. Living roots also pump carbon into the soil through root exudates. If there is enough carbon in this form, the microbes won't consume the more stable forms of carbon.
- Add organic inputs such as manure, compost, and biochar.
- Avoid monoculture legume crops if possible. These crops may alter the soil C:N ratio, resulting in a loss of SOC and aggregate stability.
- Learn more at **pasoilhealth.org**.

Regenerating Soils

In many agricultural systems, SOM levels are only about 50% of their historical values. By regenerating soils with the practices above, there is the potential to create high-functioning soils with good soil structure to infiltrate water, room for deeper plant rooting, diversified microbial communities, and better nutrient cycling. These features build resiliency into the food production system and reduce impacts to the local environment.

Carbon as a Commodity

Carbon market programs are based on the stock SOC, that is, the tons of carbon found in a specified volume of soil. To determine the carbon stock of a soil, the measured SOC concentration is combined with the soil's bulk density and the thickness of the soil that was sampled. Carbon stocks are commonly reported in metric tons per acre. Computer models are often used to predict how management practices will change SOC concentrations and will calculate the metric tons of carbon held in the soil. Farmers can be paid for this sequestered carbon.

"To be a successful farmer one must first know the nature of the soil."
— Xenophon, "Oeconomicus," 400 B.C.


Inputs such as manure, compost, and biochar will also increase soil organic carbon levels.

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