Mosaic AgriSight®
TRUSTED CROP NUTRITION EXPERTISE℠

ISSUE 21: 2022

Carbon Storage and the Benefits to Agricultural Soils

Carbon (C), especially carbon dioxide (CO_2), is a topic that is constantly being discussed for its role in the environment. Agriculture finds itself a part of this conversation for some key reasons. As production agriculture became more mechanized, emissions from equipment with internal combustion engines and field tillage have contributed to increases in atmospheric CO_2. In recent years, land used for growing crops as well as range and pastures for livestock are being considered as a potential place to store CO_2 from the atmosphere. Soil can store carbon in many forms, with the most prevalent being organic matter (58% carbon) which is generally found in higher amounts towards the soil surface. A soil's ability to store (sequester) carbon is driven by many factors and complex interactions. Whether the goal is to store carbon for payment, improve soil health, or build organic matter, the same principles and practices apply.

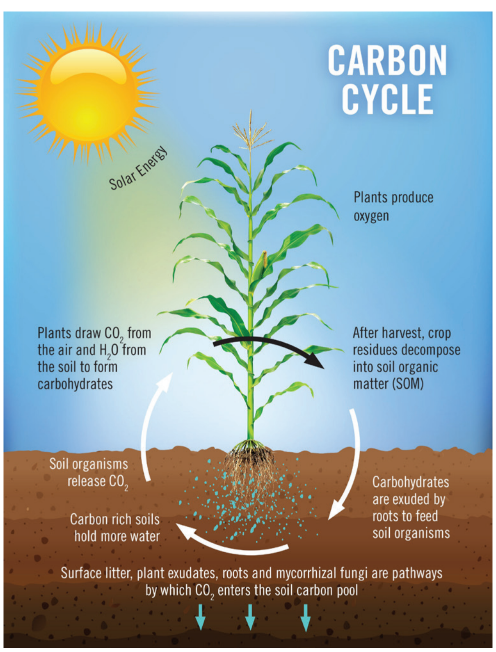

Figure 1: The Carbon Cycle in Agriculture

Understanding the Carbon Cycle:

Plants and sunlight are the main ingredients required to turn carbon into life's building blocks. Actively growing plants harvest sunlight, consume CO_2 from the air, and uptake water and nutrients from the soil (Figure 1) to produce carbohydrates through the process of photosynthesis. This energy source (i.e., carbohydrates) is used to drive growth and development of all parts of the plant, including roots, vegetative, and reproductive components. Plants also allocate some of these carbohydrates to be released into the rhizosphere (area around plant roots) which assists with chemical and biological processes to make nutrients more available for plant uptake.

Every part of a plant, both above- and below-ground contains carbon. It is important to consider and account for the components of the crop that get harvested and removed from the field vs those that are left behind. It is common that the remaining stalks, leaves, and roots that comprise

- Carbon-rich soil is more biologically active, provides more crop nutrients, is more resilient to weathering factors, holds more water, and better resists erosion.
- Soils primarily store carbon as organic matter, which is composed of 58% carbon.
- Corn produces an average of 7.6 pounds of organic matter for each bushel of grain produced.
- Approximately 20% of carbon that is captured by plants is converted to soil organic matter.

plant residue contain more carbon than the fruit, grain, lint or other product that is harvested[1]. It is the consumption of the plant residues (living or dead) by animals, insects, and macro- or microorganisms which can cause carbon to either be released as CO_2 into the air through the process of cellular respiration or converted to an even more stable form of carbon that is stored in the soil.

Soil texture is the single most important factor in determining a soil's carbon holding capacity. Temperature, rainfall, historical management, erosion, tillage, and crop rotation all have an impact on how carbon has cycled within a field over time and determines the current carbon pool for that field. Figure 2 illustrates three different soil types, and the size of the container represents the total carbon that each soil can hold. The amount of green liquid in each container represents the current pool of carbon with the same farming practices implemented for several decades, and the illustration shows that the ability to resist carbon loss in clay soil may be better than in sandy soil. Inversely, the ability to build carbon in clay soil is greater than in sandy soil. Implementing identical farming practices to promote carbon storage going forward will have similar, but not equal effects due to differing soil factors.

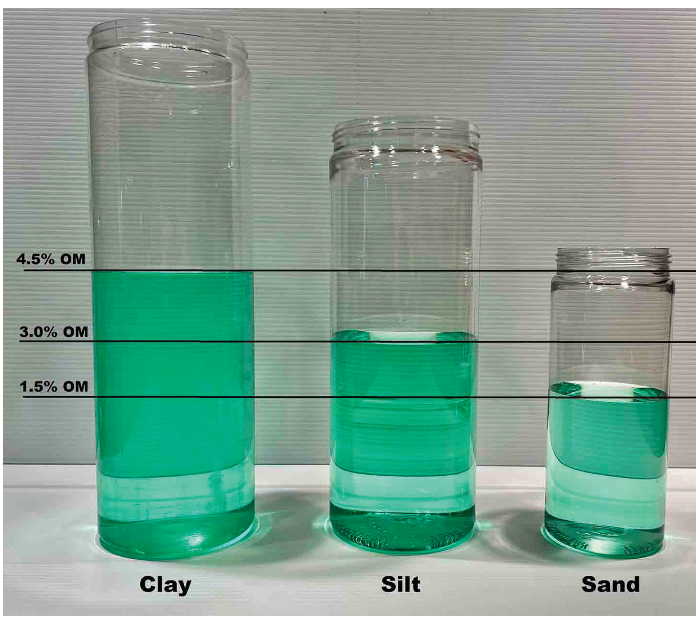

Figure 2: Illustration of relative carbon holding capacity of three soil types.

Carbon Conversion to Organic Matter:

The conversion of carbon to soil organic matter (SOM) requires a complex mix of microbes, bacteria, fungi, insects, and animals that contribute to digesting plant residues and carbohydrates. The exact mix of the microbial population is controlled by environmental factors such as temperature, moisture, oxygen, and soil pH. Regardless of the specific mix of soil biology that are involved in carbon cycling, the process is not 100% efficient. As microorganisms, especially bacteria, consume carbon and other nutrients, as much as 80% of the total carbon is cycled to forms other than organic matter, such as carbon dioxide which is respired back to the atmosphere during the digestion process[2].

Over the past twenty-five years, the concept of capturing and storing carbon by crops and soils to generate a commercial commodity has been presented as a financial opportunity for agriculture producers a multiple times. Each iteration has gained some traction in the marketplace, but few programs have found long-term success. Fortunately for agriculture producers, the principles and practices have been roughly the same with each iteration of working with Carbon Registries or Carbon Markets. Farms and livestock operations are contracted to utilize the soil in each field to capture carbon and are paid for the retention of that carbon. To qualify for a carbon sequestration program on agricultural fields, growers must implement additional practices to meet at least one of two desired outcomes:

1. Improve the carbon storage potential of the soil. To store more carbon within the soil, a grower typically needs to either increase the number of days per year that something is growing in the fields or increase the diversity of plant species that are growing. Having plants growing during portions of the year when a cash crop is not producing new vegetation adds photosynthesis, which provides the rhizosphere with a food source (carbohydrates) that it would not have otherwise. Adding a new species to a crop rotation or to a grazing or cover crop mix changes the types of microbial life which are being fed.
2. Decrease the amount of carbon loss from soils. Carbon is lost from soils when soil is exposed to a sudden supply of oxygen, such as what happens when tillage equipment disturbs or turns over soils. The microbial community springs to life because of the newfound oxygen, leading to a significant increase in microbiology species and population, especially bacteria. This rapid increase of the bacterial community results in a large amount of CO_2 being released into the atmosphere, creates a quick flush of nutrient availability, and produces some organic matter. This process of "oxygenating" the soil occurs with every tillage operation and leads to a long-term loss of accumulated carbon.

Growing Carbon into Organic Matter:

Using data provided in Table 1, corn produces an average of 7.6 pounds of organic matter for each bushel of grain produced. A corn yield of 200 bushels per acre would contribute 1,500 pounds of SOM, or just slightly less than 0.08% SOM annually (Table 2). Increased production (vegetative + grain) and adding a green cover crop each year can increase the amount of carbon converted to SOM annually. For example, adding a cereal rye cover crop that is terminated at 12-15 inches in height (4,000 pounds/ac of dry matter) produces an additional 560 pounds of SOM per

Table 1: OM Production in Corn Calculation[1]

1 bu/ac = 56 lbs @ 15% Moisture	47.6 lbs @ 0% moisture
1:1 stover to dry grain (academic standard)	47.6 grain + 47.6 stover = 95.2 lbs
Root Mass = 20% of plant mass	95.2 lbs X 20% = 19.04 lbs of roots
35% root mass is in top 6" –Furrow Slice	19.04 lbs X 35% = 6.66 lbs of roots
Stover + Furrow Roots = Total Furrow Residue	47.6 + 6.66 = 54.26 lbs/bu
14% = conversion of dry residue to SOM	54.26 X 14% = 7.6 lbs SOM per bu
1% OM = 20,000 lbs	7.6 / 20,000 = 0.00038% OM/bu

year. It is important to note that after carbon is sequestered into organic matter, SOM is still a food source for different soil microbial communities and can mineralize into plant available nutrients. Depending on the crop rotation and amount of carbon cycled each year, it is possible to see as much as 80% of the newly formed organic matter consumed in the following 5 years[3,4]. However, implementation of sustainable cropping practices that sequester carbon can maintain or build SOM over time. Carbon-rich soil is more biologically active, provides more crop nutrients, is more resilient to weathering factors, holds more water, and better resists erosion. For a more complete understanding of the direct benefits of soil organic matter, refer to **AgriSight Issue 19 Five Benefits of Soil Organic Matter**.

Table 2: Corn Yield Soil Organic Matter Creation
(Estimated SOM creation based on 7.6 lbs/bu and average production practices)

Corn Yield bu/ac	Estimated SOM Creation Lbs/Ac/Yr (% SOM)
100	760 (0.038)
200	1,520 (0.076)
300	2,280 (0.114)

Benefits of Carbon Accumulation:

Today, the reality is that direct payments from conservation programs or carbon capture companies seldom completely offset the actual costs of participation in such programs.

Farmers or ranchers should be looking at the culmination of benefits resulting from carbon capture in addition to direct payments for carbon storage to assess the value to a field or the farm. Additional benefits from the cycling and availability of crop nutrients, improvements in soil structure that increase water holding capacity and resilience to environmental factors that degrade or remove topsoil, and the increase in biological activity that helps cycle residue more quickly all need to be considered when assessing the value of investing in management practices to increase carbon capture. Being mindful of how yearly practices influence soil trends is an investment in future generations and their opportunities to operate on the same land.

Additional practices such as improving nutrient use efficiency (NUE) may soon add more opportunities for growers to qualify for carbon capturing payments. Addressing nutrient deficiencies with advanced crop nutrition programs can create more productive and sustainable cropping systems, capable of more efficient carbon capture. Incorporating fertilizer products like MicroEssentials® with Enhanced Efficiency Fertilizer designation can add yield and sequester more carbon.

Building carbon within soils is a dynamic process that can be influenced by raising higher yields and mitigating losses. Many factors including weather, soil type, and cropping cycle can influence the rate and success of implementing farming practice changes.

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MC 1384 062022