Science Societies

Growing carbon for sustainable and resilient soils

By Kelly Murray Young, Allison Thomson

May 4, 2020

Sustainability Programming for Ag Retailers and CCAs (SPARC)

A COLLABORATIVE INITIATIVE BROUGHT TO YOU BY

This article is brought to you by the SPARC Initiative created in partnership between the American Society for Agronomy, the Agricultural Retailers Association, Environmental Defense Fund, and Field to Market: The Alliance for Sustainable Agriculture to empower trusted advisers to deliver services that drive continuous improvement in the productivity, profitability, and environmental outcomes of farmers' operations. Learn more about the

SPARC Initiative and access additional resources, including the six-module series on sustainability, at **www.fieldtomarket.org/SPARC**.

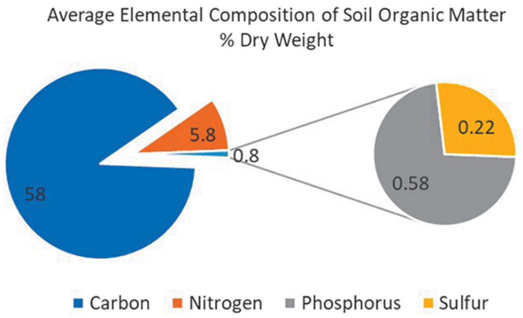

Figure 1, *Elemental composition of soil organic matter.*

Soil organic matter and the carbon (SOC) and other nutrients within it (Figure 1) make soils more productive, promoting higher crop yields and supporting a greater amount and diversity of soil biota. Soil organic carbon also makes soils more resilient to moisture stress because it acts like a sponge to absorb excess water, thereby reducing runoff and erosion in high-intensity rainfall events. By holding water in the soil for longer, SOC provides a reservoir of soil moisture for when rainfall is low and evapotranspiration is high. Unfortunately, farmland soils in the U.S. have lost organic matter and the carbon within it because of disturbance from intensive plowing over many years before widespread adoption of conservation tillage practices. Slowing, stopping, and reversing SOC loss will support soils to become more productive and resilient.

Certified Crop Adviser taking a soil sample. Source: USDA-NRCS.

How quickly and how much SOC increases depends on many factors including the soil type, parent material, land use history, management changes, and weather. And for all soils, there is an upper limit to how much carbon can be stored that would be reached after several decades of management for sequestration. That upper limit may be the same as, higher, or lower than the historical carbon (from before the plow), depending on changes in weather patterns and what management systems are feasible.

Active scientific research continues to explore many questions that remain unanswered about soil carbon, including:

- How much organic matter and carbon can be regained in a particular soil? And what is the rate of storage that is possible under specific crop rotation and management

practices?
- How long will it stay in the soil, and how deep will it be stored? Does that depth make a difference in how long the carbon can stay stored?
- What do changes in organic matter and carbon mean for the nitrogen cycle—losses to air or water and implications for soil fertility and fertilizer management?

Although scientists have been working on these questions for decades, clear guidance for farmers remains elusive because:

1. Soils are diverse. Even within a single farm field, there can be soils with very different characteristics, including carbon levels and potential for gain, and;
2. Soils have complex chemical, biological, and physical attributes that can lead to different impacts of the same management practice applied to different soils.

Carbon Markets

The potential for agriculture to store carbon in the soil to help combat climate change is also a growing conversation among many farmers and organizations across the agriculture value chain. For example, a number of initiatives are under way to create markets for farmers to sell carbon credits. Groups are working to develop protocols that would define how to measure the soil carbon gain and quantify it accurately enough, so that it can be bought and sold as a “carbon credit” in a market. The primary challenge these efforts are working to solve is how to develop measurements and metrics that meet the level of accuracy required for a market while also being cost effective for the farmer to adopt. If the carbon credit payments are sufficient to incentivize farmers to adjust their practices, then soil carbon storage (also called carbon sequestration) can provide an important climate mitigation bridge by absorbing excess carbon dioxide from the atmosphere over the coming decades, buying society time to mitigate greenhouse gas emissions and adapt to weather changes.

To establish robust agricultural carbon markets, there must be practical and reliable methods for assessing the amount of carbon added to agricultural soils as a result of agronomic practices, such as reducing tillage or adding cover crops to the rotation.

Assessing Soil Organic Carbon

The most accurate method of determining changes in SOC is by direct measurement. Most CCAs have likely spent considerable time collecting soil samples from agricultural fields with a bucket and shovel or a soil probe. Obtaining soil samples from agricultural fields that accurately represent the entire field can be tricky. Confidence in test results increases with the number of samples spread out across the field, but different soil-sampling and analysis techniques can give highly variable results. Gross and Harrison (**2018**) found that core, clod, and excavation soil-sampling methods produce very different bulk density results and that the commonly used core method consistently led to underestimated SOC levels at soil depths greater than 20 cm. A review by Davis et.al (**2018**) of 41 published SOC studies on U.S. corn and Brazilian sugarcane found a lack of consistency in sampling and laboratory analysis methods used in field research that reported SOC values.

Farmer pulling up a cover crop to show its roots. Photo courtesy of

Edwin Remsberg and USDA-SARE.

Direct measurement of SOC can be expensive. Laboratory SOC analysis may cost $7 to $10 for each sample, depending on the lab and number of samples submitted. The number of samples required to obtain an accurate estimate of SOC of a given field depends on the size and the uniformity of the soil in the field. According to the USDA-NRCS (**2002**), to obtain an accurate measure of soil carbon for a large production field with uniform soil texture, one composite sample is needed per 20 ac, or one composite sample per 5 ac in fields with variable texture or hilly topography. Therefore, the cost of laboratory analysis alone ranges anywhere from $70 to $800, depending on cost per sample and field uniformity. However, there is more to the cost of direct soil testing than the laboratory analysis. For each composite soil sample, 15 to 20 core samples need to be collected and combined. Using the USDA-NRCS guidelines to adequately sample a 400-ac farm, it would take anywhere from 150 to 1,600 individual core samples to collect the recommended 10 to 80 composite samples, depending on the uniformity and topography of the fields. Labor costs to collect so many samples are likely to make most farmers reconsider implementing a full soil-testing protocol in large fields or in fields with non-uniform soil texture.

Due to these high costs, there is considerable interest in SOC testing methods that do not require taking field samples and subsequent laboratory analysis. Izaurralde et al. (**2013**) evaluated three in situ methods: laser-induced breakdown spectroscopy, diffused reflectance mid-infrared Fourier transform spectroscopy, and inelastic neutron scattering. Although these techniques yielded measurements comparable to the industry standard method of dry combustion, significant work is needed to calibrate the instruments. Furthermore, this equipment can be difficult to transport and may require substantial troubleshooting in the field.

Since direct measurement of SOC is so challenging, simulation models provide insights for farmers working to understand how their practices impact carbon. Using algorithms developed by soil and computational scientists, it is possible to explore the impacts on SOC from different crop rotations, residue management, tillage, and other agronomic practices and field operations. Field to Market: The Alliance for Sustainable Agriculture offers the Fieldprint Platform, a pioneering assessment framework that empowers brands, retailers, suppliers, and farmers at every stage in their sustainability journey to measure the environmental impacts of commodity crop production and identify opportunities for continuous improvement. The Soil Carbon metric in the Fieldprint Platform is measured using the USDA-NRCS Soil Conditioning Index (SCI). The SCI returns a value between –1 and +1 for each field. A positive value indicates increasing SOC, a neutral value (between –0.05 and +0.05) indicates maintaining SOC at current levels, and a negative value indicates SOC is declining. The magnitude of the index, either positive or negative, reflects confidence in the direction but does not indicate the actual amount of SOC that is lost or sequestered. Scores are unitless, relative, and crop specific. Growers and their trusted advisers can confidentially access this tool for free at **www.calculator.fieldtomarket.org**.

How to Preserve and Build Carbon Stores in Agricultural Soils

Despite the challenges of definitively measuring SOC, it is valuable to encourage good agronomic practices that are known to preserve or build soil carbon and boost farm productivity and resiliency to variable weather patterns and management challenges. Increasing carbon stores in agricultural soil depends on three things:

1. Keeping soil covered.
2. Maintaining living roots.
3. Reducing soil disturbance.

Keeping Soil Covered

Soil exposed to the elements is more vulnerable to erosion than that protected by vegetative or other cover. When soil is picked up and carried away by wind or flowing water, it carries the carbon contained within it. Soil in cultivated and non-cultivated areas on the farm should be under continuous coverage to protect against erosion. The following are practices that have been proven to improve soil cover and reduce or prevent soil erosion:

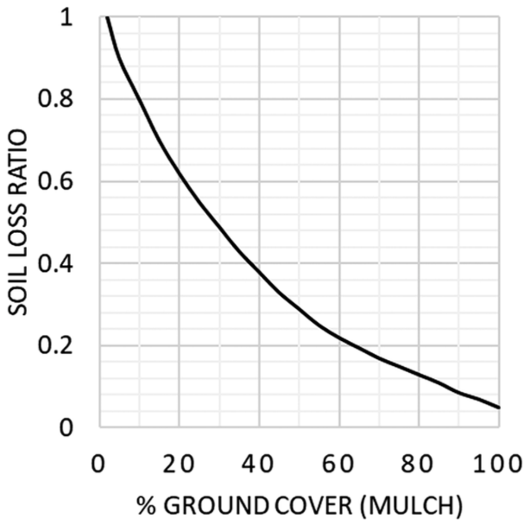

***Figure 2**, The effect of mulch ground cover on soil erosion.*

- **Stabilizing slopes with vegetative barriers**: Hilly areas are particularly prone to erosion, so installing vegetative barriers composed of perennial grasses with numerous, stiff, upright stems can be a useful strategy for capturing soil that is moving downslope. Vegetative barriers slow moving water and allow sediment and crop protectants carried in the water to be trapped and removed, thereby also protecting downstream water quality.
- **Managing crop residues**: Residues from previous crops, when left on the soil surface, can significantly reduce soil erosion and simultaneously add soil organic carbon. Conservation tillage is any tillage system that leaves at least 30% of the soil covered by the previous crop's residues at planting time. If 30% of the soil surface is covered in crop residues, McCarthy et al. (1993) estimate that soil erosion can be reduced by 50% compared with bare, fallow soil (Figure 2). It should be noted that on long or steep slopes, crop residues may be prone to detaching from the soil surface and floating away during flooding.

Maintaining Living Roots

Hilly areas are particularly prone to erosion, so installing vegetative barriers can be a useful strategy for capturing soil that is moving downslope. Source: Jeff Vanuga/USDA-NRCS.

Living cover provides additional support for soil biota by having active roots in the ground all year. In addition, continuously living roots preserve and build SOC in a number of ways. Roots help prevent soil erosion by physically holding the soil in place. Actively growing roots exude a variety of compounds, such as carbon-rich mucilage into the soil. Plants may allocate as much as 40% of the carbon assimilated by photosynthesis to root exudates (Lynch & Whipps, **1990**; Badri & Vivanco, **2009**). Diversifying and lengthening crop rotations to maintain living roots in the soil year-round can directly increase SOC.

Reducing Soil Disturbance

Preparing the soil for planting can be a primary source of soil erosion. Plowing, disking, and other land preparation activities that are designed to create a “clean,” even seed bed significantly disturb the soil. Soil disturbance negatively impacts SOC by accelerating erosion and microbial decomposition of soil organic matter.

Tillage incorporates crop residues into the soil profile, rather than leaving them on the

Practicing conservation tillage and adding organic matter (like manure shown here) can help protect and build soil organic carbon. Photo by Will Parson/Chesapeake Bay Program.

soil surface where the residues function as a barrier to the erosive forces of wind and water. Tillage also reduces soil aggregate size, which has numerous effects on soil function. Smaller aggregates and the organic matter contained within are more easily picked up and carried away by wind or water erosion.

Summary of Practices that Preserve and Build Soil Carbon

There is no one way to protect and build SOC that is practical and effective in every cropping system in every region, but the following practices can be effective in keeping soil covered, maintaining continuously living roots, and reducing soil disturbance:

- **Conservation tillage**: Reduce the frequency and intensity of tillage operations and leave at least 30% of the previous crop's residues on the field.
- **Cover crops**: If a farming operation is already growing cover crops, consider “planting green,” or planting cash crops directly into an actively growing cover crop.
- **Added organic matter**: Manure, compost, and other organically based fertilizers can supply both nutrients and carbon to the soil.

As the farmer's trusted adviser, CCAs play a key role in encouraging and providing technical guidance on locally appropriate practices that are known to protect and build carbon in agricultural soils. As interest in carbon sequestration and the potential for carbon markets continues to rise in the U.S., growers will look to you for help in both building and quantifying SOC.

References

Badri, D. V., & Vivanco, J. M. (2009). Regulation and function of root exudates. *Plant, Cell & Environment*, **32**, 666-681. **https://doi.org/10.1111/j.1365-3040.2009.01926.x**

Davis, M.R., Alves, B. J., Karlen, D.L., Kline, K.L., Galdos, M., & Abulebdeh, D. (2018). Review of soil organic carbon measurement protocols: A U.S. and Brazil comparison and recommendation. *Sustainability* **10**, 53. **https://doi.org/10.3390/su10010053**

Gross, C.D., & Harrison, R.B. (2018). Quantifying and Comparing soil carbon stocks: underestimation with the core sampling method. *Soil Science Society of America Journal*, **82**, 949-959. **https://doi.org/10.2136/sssaj2018.01.0015**

Izaurralde, R.C., Rice, C.W., Wielopolski, L., Ebinger, M.H., Reeves, J.B., Thomson, A.M., … McCarty, G.W. (2013). Evaluation of three field-based methods for quantifying soil carbon. *PLoS ONE* **8**(1), e55560. **https://doi.org/10.1371/journal.pone.0055560**

Lynch, J.M., & Whipps, J.M. (1990). Substrate flow in the rhizosphere. *Plant and Soil* **129**, 1-10. **https://doi.org/10.1007/BF00011685**

McCarthy, J.R., Pfost, D.L., & Currence, H.D. (1993). *Conservation tillage and residue management to reduce soil erosion*. **https://extension2.missouri.edu/g1650**

USDA-NRCS. (2002). *Fact sheet MN-NUTR3: Soil sampling*. Retrieved from **https://bit.ly/2S62lLB**

USDA-NRCS. Undated. Soil health for educators: Soil organic matter. Retrieved from **https://bit.ly/3eNU4pw**

More sustainability

Back to issue

Back to home
