Measuring Soil Organic Carbon:
A CRUCIAL IOWA RESOURCE

KEY THEMES

Soil organic carbon is closely related to soil organic matter, but the two are measured differently.

Soil organic carbon is linked to many aspects of soil health such as nutrient exchange, soil water holding capacity, and it provides great value on the farm.

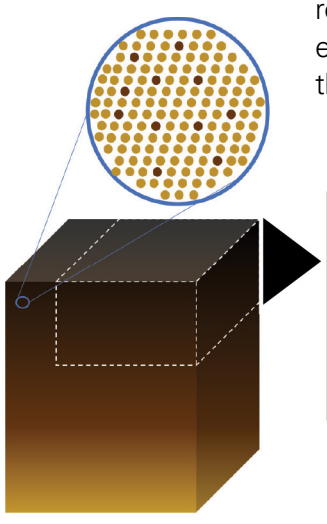
Carbon markets are focused on changes in soil organic carbon stock that result from the application of new agricultural management practices.

The stock of soil organic carbon in a field is based on organic carbon concentration, depth of sampling, area of the field, and adjustments for other soil characteristics.

WHAT IS THE DIFFERENCE BETWEEN ORGANIC MATTER AND ORGANIC CARBON?

Soil Organic Matter (SOM) is the fraction of the soil composed of anything that once lived. It includes plant and animal remains in various states of decomposition, cells and tissues of soil organisms, and substances from plant roots and soil microbes.

Soil Organic Carbon (SOC) is the fraction of soil organic matter that is carbon. Crop residues contribute to SOC but they are not SOC in their undecomposed form. Roughly half of soil organic matter is SOC. Third party carbon programs are buying carbon credits from farmers implementing improved soil management practices and selling it to companies interested in reducing greenhouse gas emissions associated with their supply chains.



Quantifying carbon 'stock' in a field accounts for:
- **SOC**
- **measurement area**
- **measurement depth**
- **bulk density**

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HOW MUCH SOIL CARBON DO I HAVE?

Carbon market programs are based on the 'stock' of SOC, that is, the tons of carbon found in a specified volume of soil, not just the carbon concentration.

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 layer that was sampled. [An additional correction to the calculation is required if the soil contains a significant fraction of coarse fragments (particles that are > 2 mm in diameter).] Carbon stocks are commonly reported in metric tons per acre or per hectare (with the depth of sampling specified).

Soil organic carbon is usually concentrated near the soil surface. Measurements collected for the top six inches of soil cannot be extrapolated to greater depths. In some soils (like that in the accompanying photo), the difference in SOC with depth is dramatic. In other soils, it is more gradual.

In general, the more SOM a soil has, the darker its color. But SOC cannot be determined visually, it needs to be measured in the lab or via indirect methods. For example, these two soils are clearly different in terms of soil aggregates, color, texture, and amount of roots, but have SOC levels that are not statistically different due to the variability of SOC.

Bulk density is a crucial part the SOC stock calculation. Carbon market programs need to measure or estimate this value for farm fields. It is the mass of oven-dry soil per unit volume. Typical values in the surface horizon of Iowa cropland range from 1.2 to 1.4 g/cm^3 (75 to 87 lb/ft^3) but values can vary with the intensity of tillage, compaction by farm equipment, crop roots, and the season of sampling. Few farms or agricultural cooperatives have experience measuring bulk density.

Soil profile with accumulation of SOC in topsoil.

Image: Lee Burras, Department of Agronomy–Iowa State University

Two soil cores from adjacent locations on the same soil type but with with different cropping histories.

Images: Marshall McDaniel,Department of Agronomy–Iowa State University

IS IT HARD TO MEASURE CHANGES IN SOIL ORGANIC CARBON?

SOC concentrations vary considerably across a crop field. Changes in SOC due to management changes are too small to measure annually. The period required to detect SOC changes in most Iowa soils is likely to be a decade or more. Carbon market programs commonly use a combination of models, remote sensing, and aggregation of many farms to reduce actual soil sampling per field, to reduce program costs, and to improve long-term predictions.

UNIT CONVERSIONS

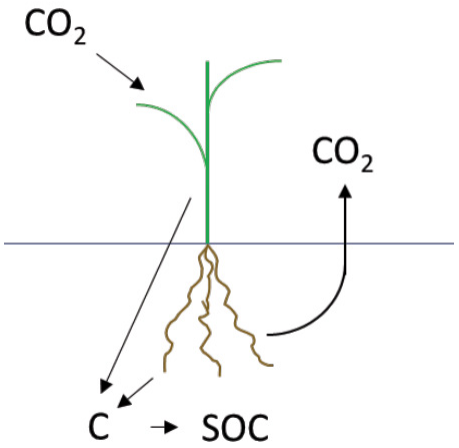
Carbon markets trade metric tons of carbon dioxide equivalent (CO_2e) rather than SOC. The net change in removal of CO_2 from the atmosphere via photosynthesis to form SOC vs. estimated change emissions or losses of CO_2 and other greenhouse gases is the basis of the value. Converting SOC to CO_2e is straightforward. For example, 1 metric ton SOC x 3.67 tons CO_2 per ton carbon = 3.67 metric tons CO_2e. Increasing the SOC stock by 1 ton would remove 3.67 tons of CO_2 from the atmosphere.

DOES THE 'ORGANIC' PART OF SOC MATTER?

The surface horizons of some Iowa soils also contain carbon that is not organic but is present as carbonate salts (particles of solid limestone). This inorganic form of carbon is not part of SOM or SOC, so measurements of SOC must also account for any inorganic carbon in the soil.

Traditional Soil Fertility Soil Testing vs. Soil Testing for Carbon Market Programs

Considerations	Soil Fertility Sampling	Carbon Program Sampling
Where to sample, how many samples	Flexible, zone, or grid sampling	Very specific protocol
Basis of organic matter/ soil carbon measurement	Typically soil organic matter is measured, but SOC is not	Wide range of approaches, but typically a mixture of soil sampling and models
Who samples	Farmer, co-op, independent agronomist	Sampling completed by carbon market program or 3rd-party verifier
What is measured in the lab	Organic matter, typically by loss on ignition (LOI) method	SOC analysis, typically by dry combustion: very high temperature
Cost per sample	$	$$



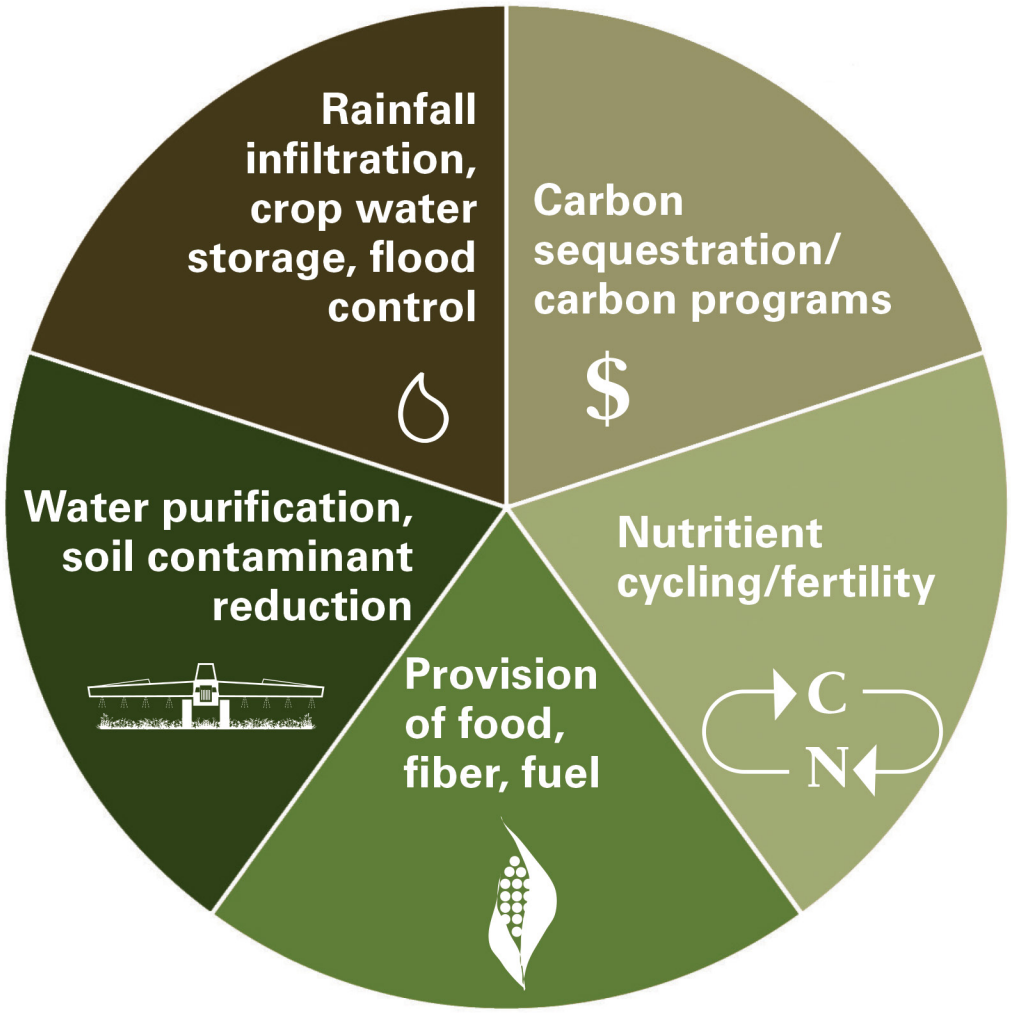
Carbon cycle.

Example Soil Organic Carbon Data

	Thickness of sampled horizon, inches	SOM	SOC	g soil cm^{-3}	Stock of organic carbon, metric tons per acre
Site 1	6 inches	6.0%	3.5%	1.20	25.2
Site 2	12 inches	3.4%	2.0%	1.35	32.4

ROLES OF SOIL ORGANIC CARBON

Soil organic carbon has a wide range of crucial roles in agriculture. It impacts crop productivity, soil health, the movement of water, and removal of contaminants. Changes in SOC potentially have other co-benefits with market value.



"Soil carbon is a crucial part of Iowa's agricultural infrastructure."

DANIEL J. ROBISON, ENDOWED DEAN'S CHAIR, COLLEGE OF AGRICULTURE AND LIFE SCIENCES, IOWA STATE UNIVERSITY

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