When Soil Carbon Rises, What Does It Actually Mean?

An increase in soil organic matter is encouraging. Demonstrating carbon sequestration is another matter.

Raul Cano, Ph.D. | September 22, 2026

During Climate Week, we hear a great deal about returning carbon to the soil. It is an appealing idea, and there is solid biological evidence behind it.

Plants take carbon dioxide from the atmosphere through photosynthesis. They use that carbon to build leaves, stems, roots, and seeds. Some enters the soil through dead roots and plant residues. Some is released directly by living roots in compounds that feed nearby organisms.

Once carbon enters the soil, bacteria, fungi, and other organisms begin to process it. Some returns to the atmosphere through respiration. Some remains in living cells or as microbial remains. Some becomes associated with minerals or is enclosed within soil aggregates, where it may persist much longer.

Soil can store carbon. The harder question is how we determine how much has actually been stored. A laboratory report showing an increase in organic matter or organic carbon is encouraging. It may indicate that more plant material is entering the soil, that microbial activity has changed, or that the soil is beginning to recover from disturbance.

It does not necessarily tell us how much additional carbon is present in the field. It certainly does not, on its own, prove that carbon dioxide has been removed from the atmosphere and stored long term. That requires a closer look at what we are measuring.

Organic matter, organic carbon, and carbon stock

These terms are sometimes used as if they were interchangeable. They are not!

Soil organic matter includes partially decomposed plant material, microbial cells and remains, compounds produced during decomposition, and other biological material. It contains carbon, nitrogen, phosphorus, sulfur, hydrogen, oxygen, and other elements.

Soil organic carbon is the carbon component of that material. A soil carbon stock estimates the mass of carbon contained within a specified area and soil depth. It may be reported as tons of carbon per acre or metric tons per hectare.

To calculate that stock, the percentage of carbon is not enough. We also need to know how much soil is represented. That requires measurements such as bulk density, sampling depth, and the proportion of the sample occupied by rocks or other coarse material.

Consider two soils that both contain 2 percent organic carbon. One is loose and porous, while the other is dense and compacted. A cubic foot of the dense soil contains more soil mass than the same volume of the porous soil. Even though their carbon percentages are identical, the amount of carbon within that volume will not be the same.

If a soil test shows carbon rising from 2 percent to 2.5 percent, we have learned something important about the sample. We still cannot translate that change into tons of stored carbon without knowing more about the soil from which it came.

Where the sample comes from matters

Most soil carbon is found near the surface, where plant residues accumulate and biological activity is highest. Carbon also reaches deeper layers through roots, dissolved compounds, and the movement of organisms and water.

A management practice may increase carbon in the upper few inches without increasing it deeper in the profile. Tillage may move carbon from one part of the profile to another. Erosion may remove surface soil and alter the composition of what remains.

For these reasons, samples taken at different depths cannot be compared as if they represent the same soil. Even when the stated depth is the same, soil is naturally variable. A sample from one side of a field may differ from one taken a few yards away. Season, crop stage, recent fertilizer applications, moisture, and the location of old crop rows can all influence the result.

Reliable monitoring therefore depends on returning to documented locations, sampling at the same depths, and collecting samples at comparable points in the cropping cycle. In many cases, researchers divide the soil profile into several depth intervals rather than combining all samples into one.

This may sound overly exacting. But soil carbon often changes slowly, while natural variation within a field can be substantial. Without a consistent method, variation can look like progress—or hide progress that is actually occurring.

Percentage is not the same as quantity

There is another reason carbon percentages require care.

Management practices that improve soil aggregation may reduce bulk density by creating more pore space. This is generally beneficial for roots, water movement, and gas exchange. However, it also means that a fixed depth of soil may contain less soil mass than before.

The percentage of carbon could rise even as the total amount of carbon within the field changes little. Researchers sometimes account for this by comparing an equivalent mass of soil rather than relying only on a fixed depth.

Erosion creates a different problem. If mineral soil is lost while a carbon-rich layer remains, the remaining sample's carbon concentration may increase even though the field has not gained carbon.

A concentration tells us what proportion of a sample is carbon. A stock tells us how much carbon is present in a defined body of soil. When discussing climate, we ultimately need to know the stock.



Carbon enters soil through plants, roots, residues, and microbial activity, but it does not all remain there. Some becomes part of the soil's organic matter, while some returns to the atmosphere through respiration. Illustration generated with AI under the author's direction and approved by the author.

Soil carbon is always moving

Soil is alive, and living systems do not hold still.

Roots feed microorganisms. Microorganisms transform plant material. Other organisms consume both. Carbon moves through this community repeatedly, sometimes very quickly and sometimes over many years.

A portion becomes carbon dioxide as plants and soil organisms respire. A portion remains in microbial cells or in the residues those cells leave behind. Some compounds bind to mineral surfaces. Others become physically protected inside soil aggregates.

This helps explain why we must interpret microbial activity carefully. A soil with high respiration may be losing carbon, building organic matter, or doing both at the same time. Respiration tells us that organisms are active. It does not tell us the final carbon balance.

To understand that balance, we need measurements over time.

A single soil sample is a photograph of a moving process. Sequestration is the story told by many photographs taken consistently.

How long will it remain?

The word sequestration also implies that the carbon will remain in the soil for a meaningful period.

Cover crops, diverse rotations, retained crop residues, compost, manure, reduced disturbance, and productive root systems can increase carbon inputs or slow carbon losses. Their effects vary with climate, soil texture, water, temperature, previous land use, and management.

Carbon may accumulate rapidly at first and then slow as the soil approaches a new balance. If the management practice is discontinued, some of the gain may be lost.
The Food and Agriculture Organization describes soil organic carbon sequestration as a slow and reversible process. That does not diminish its value. It reminds us that keeping carbon in soil requires continued stewardship.

We must also look beyond the boundary of one field. If organic material added to one field was removed from another, the receiving field may gain carbon while the larger system gains little. A practice that increases soil carbon but also increases nitrous oxide or methane may have a smaller climate benefit than the carbon measurement alone suggests.

These questions do not make soil carbon unimportant. They help us understand its real contribution.

What would convince me?

If I were evaluating a claim that an agricultural practice had increased soil carbon, I would want to know how the baseline was established and whether there was a reasonable comparison plot.

I would ask whether samples were collected from documented locations, at the same depths, and at comparable times. I would want measurements of bulk density and carbon concentration, with corrections for stones and other coarse material.

I would also want enough samples to account for field variability and enough time to determine whether the change persisted.

Not every soil study needs to meet the requirements of a carbon-credit program. A study designed to evaluate aggregation, microbial activity, nutrient cycling, or root growth can provide valuable information without proving carbon sequestration.

The problem arises when a measurement intended to answer one question is used to make a much larger claim.

Why this matters to our work

My work with Ancient Organics Bioscience is one reason I want to get this right. We are studying biologically informed approaches intended to improve soil function and agricultural performance.

Changes in organic matter, organic carbon, respiration, aggregation, nutrient availability, and crop performance can help us determine what is happening in a treated soil. Each measurement contributes a different part of the picture.

Encouraging results should lead to better experiments. If early findings suggest that a biological treatment might contribute to carbon storage, the appropriate response is to design trials that can test that possibility: establish a baseline, include suitable comparisons, measure bulk density, return to the field over time, and report what the results can and cannot show.

Farmers deserve that care. They need to know whether an approach works under the conditions of their own land. Organizations investing in climate solutions need measurements they can trust. The public should be able to distinguish between a promising soil response and a verified climate outcome.

Soil carbon deserves a place in the climate conversation. Rebuilding depleted soils may also improve water movement, aggregation, nutrient cycling, root growth, and crops' ability to withstand difficult weather.

Those benefits matter whether or not a field is ever enrolled in a carbon market.
But when we say that carbon has been sequestered, we should be prepared to say how much, at what depth, compared with what baseline, and for how long.

That is how a promising observation becomes credible evidence.
In the next post, I will turn to something farmers can see and feel more directly: how soil structure affects water, roots, and resilience during drought and heavy rain.

—Raul

Disclosure: I have a professional and financial interest in Ancient Organics Bioscience. I include this information so readers can consider it when evaluating my perspective.

Sources

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