New Protocol Recommendations For Measuring Soil Organic Carbon Sequestration

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Increased levels of greenhouse gases, particularly carbon dioxide (CO_2), have been associated with the burning of fossil fuels, deforestation, cultivation of grasslands, drainage of the land, and land use changes. Concerns about long-term shifts in climate patterns have led scientists to measure soil organic carbon (SOC) in agricultural landscapes and to develop methods to evaluate how changes in tillage practices affect atmospheric carbon sequestration. University of Illinois professor of soil science Kenneth Olson has used data collected over a 20-year period at Dixon Springs, Ill., to develop a new protocol for more accurately measuring the carbon removed from the atmosphere and subsequently sequestered in the soil as SOC.

"Many experiments comparing no-till to conventional tillage on similar soils have shown no-till to have higher levels of soil organic carbon," Olson said. "So we know in general that no-till is often better than conventional tillage at building or retaining more of the organic matter in the soil, which is important to crop productivity. However, this does not mean that no-till is necessarily sequestering atmospheric carbon. It is often just losing carbon at a lower rate than conventional tillage." This unexpected discovery was the result of Olson's use of a pre-treatment SOC measurement method that compares change in soil organic carbon over time on the same plots using the same tillage methods. "This protocol does not assume that soil carbon pools are at steady state (remain the same over time), but measures SOC at the beginning of an experiment, at intervals during, and at the end of the experiment," Olson said.

"Comparison studies with one treatment as the baseline (usually conventional tillage) or control and other tillage such as no-till as the experimental treatment should not be used to determine SOC sequestration if soil samples are only collected and tested once during or at the end of the study," Olson said. The comparison method assumes the conventional tillage baseline to be at a steady state and having the same amount of SOC at the beginning and at the end of the long-term study, and this may not be true. No-till as the experiment treatment needs to be compared to itself on the same soils over time to determine if SOC sequestration has really occurred.

Olson compared two decades of data from previously eroded Grantsburg soils on 6 percent slopes to a 30-inch depth with low SOC content in an attempt to quantify the amount and rates of SOC sequestration, storage, retention, or loss as a result of a conversion from conventional tillage to a no-till system. Olson used both the comparison and the pre-treatment SOC measurement methods on the same plot area. His analysis revealed conventional tillage and no-till plot areas had less carbon (C) at the end of the study than at the beginning using the pre-treatment SOC method. According to the comparison method, no-till sequestered 4.1 tons of C per acre for a 17 percent gain during the 20 years of the study. However, the pre-treatment SOC method showed that the no-till plots actually lost 3.1 tons of C per acre, a 13 percent loss in 20 years. Thus, no SOC sequestration had actually occurred during the Dixon Springs study.

There were three major reasons why the comparison study approach was the wrong method for measuring C sequestration on the Dixon Springs plot area. First, the conventional tillage plots were not at steady state and actually lost 30 percent of the C in 20 years due to erosion and SOC-rich sediment being transported off the plots. Second, when the no-till and conventional tillage plots were sampled only once, it was not possible to determine the rate of change over time. Last, the effect of tillage equipment breaking down the soil aggregates increased the carbon available to microbial decomposition and the release of C to the atmosphere as CO_2.

"Field experiments must be designed to more carefully measure, monitor, and assess internal and external inputs," Olson said. "The amount of SOC loss from soil storage during the time of the experiment needs to be subtracted from SOC gains to determine the change in net SOC storage. Further, soil laboratory and field methods for quantifying SOC concentration must be refined to reduce under- and over-estimation bias."

Olson also recommends that the definition of SOC sequestration include a reference to the land unit. "Soil organic carbon sequestration is currently defined as the process of transferring CO_2 from the atmosphere into the soil through plants, plant residues, and other organic solids

that are stored or retained as part of the soil organic matter (humus). The retention time of sequestered carbon in the soil (terrestrial pool) can range from short-term (not immediately released back to the atmosphere) to long-term (millennia) storage," Olson said. The SOC sequestration process should increase net SOC storage during and at the end of a study to above the previous pre-treatment baseline levels and result in a net reduction in the atmospheric CO_2 levels. I believe that the phrase 'of a land unit' needs to be added to the definition to add clarity and to exclude the loading or adding of organic C derived naturally or artificially from external sources," Olson suggested.

Olson concluded by saying that carbon not directly from the atmosphere and from outside the land unit should not be counted as sequestered SOC. The definition of SOC sequestration as defined with borders would mean any C already in storage and transported or redistributed to the plot area or field would have to be accounted for and does not qualify as sequestered SOC.

"Any manure from outside the plot area or SOC-rich sediments transported and deposited from adjacent upland are just redistributed or transported C and not really sequestered SOC," Olson said. "That C was already in storage and may in fact be released back to the atmosphere if applied to the plot. For example, decomposing manure loaded on a land unit increases the return of CO_2 to the atmosphere and does not result in a depletion of atmospheric CO_2, which is the real goal. Because we often lack the ability to directly measure the total change in the atmospheric CO_2 as a result of C loading on a plot or field, we indirectly estimate it by measuring the change in amount of SOC being stored in the land unit.

"These proposed protocols are necessary to move the science forward and to attempt to address future predicted climate trends," Olson said. "The amount of SOC sequestered as a result of alternative agricultural systems such as no-till and its effects on net SOC storage changes in the soil over time and the SOC released to the water and atmospheric pools need to be measured or calculated."

Olson said that any future Cap and Trade program will require SOC sequestration protocols to be established. The method of measurement is critical if SOC sequestration is to be verified. "If landowners are to truly sequester SOC, they must be able to prove that net carbon gains have occurred over time in their fields and that the increased SOC remains permanently stored in their soil," Olson said.

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