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Soil Carbon Sequestration—Fundamentals

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What Is Soil Carbon Sequestration?

Soil carbon sequestration is the process of transferring carbon dioxide from the atmosphere into the soil through crop residues and other organic solids, and in a form that is not immediately reemitted. This transfer or "sequestering" of carbon helps off-set emissions from fossil fuel combustion and other carbon-emitting activities while enhancing soil quality and long-term agronomic productivity. Soil carbon sequestration can be accomplished by management systems that add high amounts of biomass to the soil, cause minimal soil disturbance, conserve soil and water, improve soil structure, and enhance soil fauna activity. Continuous no-till crop production is a prime example.

The Global Warming Debate

There is a growing concern that increasing levels of carbon dioxide in the atmosphere will change the climate, making Earth warmer and increasing the frequency of extreme weather events. Most climate models predict that if global warming occurs, it will not produce globally uniform effects. Most places in higher latitudes will become warmer, but some will actually cool down (for example, Northwestern Europe). Global precipitation will increase due to increased evaporation from the oceans, but some areas will receive substantially less rainfall than today. It is expected that temperatures will rise more near the poles and less in tropical regions. Nights and winters are expected to warm more than daytime and summer temperatures. Thus in general, warming will tend to occur at the lower ends of current temperature ranges.

This has led some to argue that global warming will be generally beneficial to mankind, potentially opening new areas in the upper temperate zones to agricultural enterprises that are not practical today due to the cold climate. Also, increased concentrations of carbon dioxide would have a fertilizing effect on some crops and vegetation, stimulating growth.

For Ohio, most climate models predict substantially warmer winters and slightly hotter summers. Some indicate that summers would also be drier. Thus, agriculture would be faced with a longer and drier growing season. The soil organic matter content may decline, increasing risks of soil compaction and erosion, and decreasing plant available water capacity. Adaptations might include the introduction of crops (such as cotton or sorghum) that won't grow in our current climate. Reducing the number and severity of winter storms might benefit farmers, but the increasing likelihood of summer droughts would present a real challenge. In contrast with rising sea levels, the level of the Great Lakes, including Lake Erie, could drop by 7 to 8 feet, primarily because of reduced rainfall and increased use of irrigation.

Carbon and Soil Organic Matter

Carbon is a key ingredient in soil organic matter (57% by weight). Plants produce organic compounds by using sunlight energy and combining carbon dioxide from the atmosphere with water from the soil. Soil organic matter is created by the cycling of these organic compounds in plants, animals, and microorganisms into the soil. Well-decomposed organic matter forms humus, a dark brown, porous, spongy material that provides a carbon and energy source for soil microbes and plants. When soils are tilled, organic matter previously protected from microbial action is decomposed rapidly because of changes in water, air, and temperature conditions, and the breakdown of soil aggregates accelerates erosion. A soil with high organic matter is more productive than the same soil where much of the organic matter has been "burned" through tillage and poor management practices and transported by surface runoff and erosion. However, organic matter can be restored to about 60 to 70% of natural levels with best farming practices.

Plowing and Erosion

Organic matter has been lost from our cropland mainly through plowing, which makes soil more likely to erode. Water erosion, the major issue in Ohio, and wind erosion, as exemplified by the Dust Bowl in the Plains, are the major culprits worldwide.

USDA research shows that carbon dioxide gas is lost directly from tilled soil in proportion to the volume of soil loosened. Subsoiling 14 inches deep can lose more carbon than plowing 8 inches deep; strip-till loses even less, and pure no-till planting loses the least and may even increase sequestered carbon under favorable conditions. These losses are unrelated to residue cover.

Minimizing erosion is an important step to reversing the loss and building soil quality, which usually requires leaving residue on the surface or planting a cover crop. It is extremely difficult (and maybe impossible) to build up organic matter with annual chisel or moldboard plowing. It might be possible to find a system with livestock manure, cover crops, and high yielding crops that could manage to increase organic matter with plowing every few years. With the use of herbicides and modern agricultural machinery, plowing is unnecessary on most soils.

We know from historic agricultural research plots at the University of Illinois and University of Missouri that a century of plowing can reduce soil organic matter levels to half of their natural amounts. Since the OSU–OARDC tillage plots at Wooster were established in 1962, continuous no-till nearly doubled the organic matter in the top 2 inches, while plowing has reduced it by a third.

Policy Development

Governments around the world are reacting to the perceived global warming threat with policies that may affect each of us. These policies may include large reductions in fossil fuel usage, which emits large amounts of carbon dioxide into the atmosphere. For agriculture, what is needed are ways to minimize carbon loss and maximize retention of carbon in the soil.

Carbon Management and Sequestration Center

The Carbon Management and Sequestration Center is located at The Ohio State University under the direction of Dr. Rattan Lal. The multi-disciplinary center is focused on carbon sequestration in soil, vegetation, and wetlands, and in biofuel offsets.

The Center is:

- Developing a national database on current and potential rates of terrestrial carbon sequestration for diverse land uses and soil/vegetation/wetland management options;
- Determining carbon sink capacity for major soils, vegetational zones, and ecoregions of the United States;
- Establishing relationship between soil carbon and soil quality in relation to total biomass and economic productivity;
- Standardizing new and innovative methods of carbon determination in vegetation and soil;
- Assessing comparative economics of carbon sequestration through different processes;
- Assessing feasibility of biofuels as fossil fuel offsets;
- Providing training opportunities for scientists and land managers; and
- Supporting carbon trading by assessing the rate of sequestration, and the societal value of carbon.

Conclusion

Adding organic matter to farmland is good for soil quality and crop yields, both short-term and long-term. Continuous no-till is an efficient way of doing this. Cover crops and manure also help raise carbon levels. If you want to sequester carbon to reduce global warming (and possibly receive a small annual payment) think of it as a bonus for being a good farmer. Soil carbon sequestration is a natural, cost-effective, and environmentally-friendly process. Once sequestered, carbon remains in the soil as long as restorative land use, continuous no-till, and other Best Management Practices are followed. It is a win-win option. While mitigating climate change by off-setting fossil fuel emissions, it also improves quality of soil and water resources, enhances agronomic productivity, and buys us time to identify and implement viable alternatives to fossil fuel.

Resources

Carbon Management and Sequestration Center (**http://cmasc.osu.edu**).

"Climate Change: Science, Policy, and Economics," Ohio State University Extension Fact Sheet AE-3-98.

"Global Climate Change," Ohio State University Extension Fact Sheet CDFS-186-96.

Science, Vol. 304, June 11, 2004, pp. 1623–1627.

Soil Quality Information Sheet, USDA Natural Resources Conservation Service, April 1996.

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