CARBON SEQUESTRATION IN SOILS

Over the past 150 years, the amount of carbon in the atmosphere has increased by 30%. Most scientists believe there is a direct relationship between increased levels of carbon dioxide in the atmosphere and rising global temperatures. One proposed method to reduce atmospheric carbon dioxide is to increase the global storage of carbon in soils. An added benefit to this solution is the potential for simultaneous enhancement in agricultural production. But what exactly is carbon sequestration, and what is its role in the global carbon cycle? How can we manage soils to capitalize on their ability to store carbon? And what are the costs and tradeoffs of these activities?

Ecological Society of America

What is Carbon Sequestration?

Carbon is found in all living organisms and is the major building block for life on Earth. Carbon exists in many forms, predominately as plant biomass, soil organic matter, and as the gas carbon dioxide (CO_2) in the atmosphere and dissolved in seawater. **Carbon sequestration** is the long-term storage of carbon in oceans, soils, vegetation (especially forests), and geologic formations. Although oceans store most of the Earth's carbon, soils contain approximately 75% of the carbon pool on land — three times more than the amount stored in living plants and animals. Therefore, soils play a major role in maintaining a balanced global carbon cycle.

How is Carbon Sequestered in Soils?

Through the process of photosynthesis, plants assimilate carbon and return some of it to the atmosphere through respiration. The carbon that remains as plant tissue is then consumed by animals or added to the soil as litter when plants die and decompose. The primary way that carbon is stored in the soil is as ***soil organic matter (SOM).*** SOM is a complex mixture of carbon compounds, consisting of decomposing plant and animal tissue, microbes (protozoa, nematodes, fungi, and bacteria), and carbon associated with soil minerals. Carbon can remain stored in soils for millennia, or be quickly released back into the atmosphere. Climatic conditions, natural vegetation, soil texture, and drainage all affect the amount and length of time carbon is stored.

Benefits and Potential Costs of Management Techniques to Enhance Carbon Sequestration in Soils

In agricultural systems, the amount and length of time carbon is stored is determined predominately by how the soil resource is managed. A variety of agricultural practices that can enhance carbon storage have been proposed. The benefits of these various practices as well as their potential hidden costs must be considered when management decisions are made. Though not discussed here, there may also be direct or indirect monetary costs and benefits to farmers to implement these techniques.

Benefits of Soil Sequestration of Carbon

Removing CO_2 from the atmosphere is only one significant benefit of enhanced carbon storage in soils. Improved soil and water quality, decreased nutrient loss, reduced soil erosion, increased water conservation, and greater crop production may result from increasing the amount of carbon stored in agricultural soils. Management techniques, which are successful in providing a net carbon sink in soils, include the following:

- ***Conservation tillage*** minimizes or eliminates manipulation of the soil for crop production. It includes the practice of mulch tillage, which leaves crop residues on the soil surface. These procedures generally reduce soil erosion, improve water use efficiency, and increase carbon concentrations in the topsoil. Conservation tillage can also reduce the amount of fossil fuel consumed by farm operations. It has been estimated to have the potential to sequester a significant amount of CO_2.

No-till planting on terraces in Montgomery County, Iowa.

- ***Cover cropping*** is the use of crops such as clover and small grains for protection and soil improvement between periods of regular crop production. Cover crops improve carbon sequestration by enhancing soil structure, and adding organic matter to the soil.

- ***Crop rotation*** is a sequence of crops grown in regularly recurring succession on the same area of land. It mimics the diversity of natural ecosystems more closely than intensive mono-cropping practices. Varying the type of crops grown can increase the level of soil organic matter. However, effectiveness of crop rotating depends on the type of crops and crop rotation times.

Strategies to Reduce CO_2

High levels of fossil fuel combustion and deforestation have transformed large pools of fossil carbon (coal and oil) into atmospheric carbon dioxide. Strategies aimed at reducing CO_2 in the atmosphere include soil carbon sequestration, tree planting, and ocean sequestration of carbon. Other technological strategies to reduce carbon inputs include developing energy efficient fuels, and efforts to develop and implement non-carbon energy sources. All of these efforts combined can reduce CO_2 concentrations in the atmosphere and help to alleviate global warming.

Potential Costs of Soil Sequestration of Carbon

Some agricultural practices that have been proposed as methods for sequestering carbon have hidden costs including the following:

Nitrogen fertilizer can increase soil organic matter because nitrogen is often limited in agroecosystems. However, the CO_2 released from fossil fuel combustion during the production, transport and application of nitrogen fertilizer can reduce the net amount of carbon sequestered. Nitrogen from fertilization can also run off agricultural lands into nearby waterways where it may have serious ecological consequences.

Growing plants on semiarid lands has been suggested as a way to increase carbon storage in soils. However, the fossil fuel costs of irrigating these lands may exceed any net gain in carbon sequestration. Additionally, in many semi-arid regions surface and groundwater contain high concentrations of dissolved calcium, and bicarbonate ions. As these are deposited in the soil, they release CO_2 into the atmosphere.

Management for carbon sequestration affects other gases that influence climate such as atmospheric concentrations of nitrous oxide and methane. Changes in these gases must also be factored into management strategies for carbon storage.

The Role of Forests in Reducing Atmospheric Carbon

As forests grow, they store carbon in woody tissues and soil organic matter. The net rate of carbon uptake is greatest when forests are young, and slows with time. Old forests can sequester carbon for a long time but provide essentially no net uptake. When forests are cut, the carbon they contain may be quickly returned to the atmosphere if the woody tissue is burned or converted to products, such as paper, that are short-lived. If the wood is used for construction or furniture, then those products retain carbon during their lifetimes and act as carbon sinks. A post harvest approach that reduces waste and puts most of the wood into long-lived products is an effective strategy to help reduce global atmospheric carbon. However, the net sink for carbon in long-lived wood products is still relatively small, so forest cutting ultimately acts to reduce the storage of carbon on land.

What are scientists doing to understand soil carbon sequestration?

There is still much to learn about carbon sequestration. Current research is addressing issues that include the following:

- Impacts of land use and land management on soil carbon sequestration and ways to increase the storage time of carbon in the soil.
- The underlying mechanisms controlling soil structure and the storage of carbon. These include various chemical, physical, biological, mineralogical, and ecological processes.
- The relationships between biodiversity, atmospheric CO_2 levels, and increased nitrogen deposition in carbon storage.

Where Can I Get Additional Information?

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Soil Science Society of America, 677 South Segoe Road, Madison, WI 53711. 608-273-8095. http://www.soils.org.

U.S. Department of Energy, Office of Fossil Energy, 1000 Independence Avenue, SW Washington, DC 20585. 202-586-6503. fewebmaster@hq.doe.gov; http://www.fossil.energy.gov/coal_power/sequestration/.

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