GREAT LAKES BIOENERGY RESEARCH CENTER

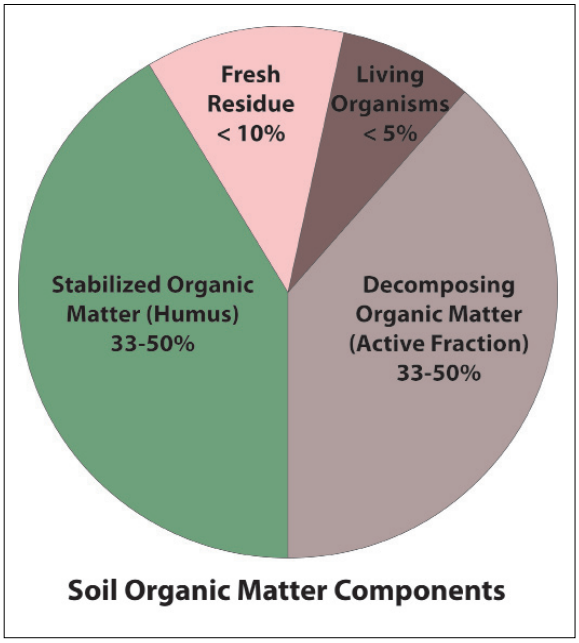
What is carbon sequestration?

Carbon is found in all living organisms and is the major building block for life on earth. In the environment, carbon exists in many forms – predominately as plant biomass, soil organic matter, geologic deposits 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. High levels of fossil fuel combustion and deforestation have transformed large pools of carbon from fossils (oil and coal deposits) and forests into atmospheric carbon dioxide.

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. Soils therefore play a major role in maintaining a balanced global carbon cycle. Since most scientists believe that there is a direct relationship between increased levels of CO_2 in the atmosphere and rising global temperatures, interest in soil carbon sequestration is attracting the attention of researchers, policy makers, farmers, and the general public.

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 humus – carbon associated with soil minerals. Carbon can remain stored in soils for millennia, or be quickly released back into the atmosphere through respiration by soil microbes. Climatic conditions, natural vegetation, soil texture, drainage, and human land use all affect the amount and length of time carbon is stored in soil.



Soil Organic Matter Components

Adapted from the US Department of Agriculture

This material adapted from the Ecological Society of America, Ecoed.net, "Carbon Sequestration"

Agricultural Practices that Increase Soil Carbon Sequestration

In agricultural systems, the amount and length of time carbon is stored in the soil is largely determined by how the soil resource is managed. A variety of agricultural practices that can enhance carbon storage have been proposed. The benefits of these 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 costs and benefits to farmers implementing these techniques. 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 that sequester carbon in soils include:

- **Conservation tillage** - minimizes or eliminates plowing of soil for crop production through practices such as no-till (no plow) farming or mulch tillage. These procedures generally reduce soil erosion, improve water use efficiency, and increase carbon concentrations in the topsoil, leading to a significant increase in soil CO_2 sequestration. Conservation tillage can also lower the amount of fossil fuel consumed since it reduces the operation of farm machinery.

Mulch left on the soil to reduce erosion
Photo courtesy of University of Nebraska-Lincoln Extension.

- **Cover cropping** - uses 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.

Alfalfa, a cover crop
Photo courtesy of National Renewable Energy Laboratory

- **Crop rotation** - sequences of crops grown in regularly recurring succession on the same area of land. It mimics the diversity of natural ecosystems more closely than intensive monocropping practices. Varying the type of crops grown can increase the level of soil organic matter. Effectiveness of crop rotating varies by region, crop type, and crop rotation timing.

Hidden Costs of Some Proposed Agricultural Methods

Some agricultural practices proposed as methods for sequestering carbon may have hidden costs:

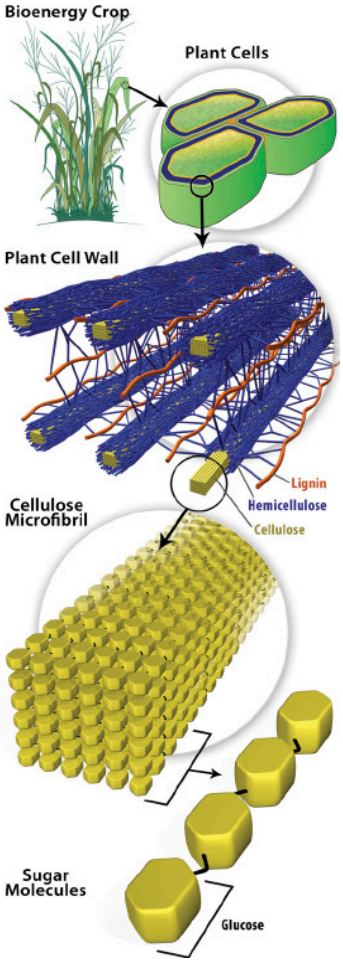
- **Increased use of nitrogen fertilizer** may temporarily increase soil organic matter because nitrogen is often limited in agroecosystems. The CO_2 released from fossil fuel combustion during the production, transport and application of nitrogen fertilizer, however, can reduce the net amount of carbon sequestered. Nitrogen from fertilization can also run off from agricultural lands into nearby waterways where it may have serious ecological consequences by stimulating excessive algal growth.
- **Growing plants on semiarid lands** has been suggested as a way to increase carbon storage in soils. The fossil fuel costs of supplying irrigation for these lands, however, 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 CO2 into the atmosphere.

Other Strategies to Reduce CO_2 Emissions

Additional strategies aimed at reducing CO_2 in the atmosphere include tree planting and ocean sequestration of carbon. As forests grow, for example, they store carbon in woody tissue 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.

Technological strategies to reduce carbon inputs include developing non-carbon energy sources and energy-efficient fuels such as biofuels. The production of "second generation" biofuels from cellulose, for example, has the potential to decrease greenhouse gas emissions relative to gasoline or corn ethanol. Cellulosic ethanol is produced from crop residues (e.g., stalks, hulls), forestry residues (e.g., forest thinning, wood byproducts), energy crops (e.g., switchgrass), and sorted municipal wastes.

All of the above efforts combined may reduce CO_2 concentrations in the atmosphere and help alleviate the impacts of climate change.



Courtesy of US Department of Energy

There is still much to learn about carbon sequestration. Current scientific research is examining:

- The full impacts of land use and land management on soil carbon sequestration and ways to increase the storage time of carbon in soil.
- The relationship between underlying mechanisms controlling soil structure and the storage of carbon. These include various chemical, physical, biological, mineralogical, and ecological processes.

Photo courtesy of National Renewable Energy Laboratory

Where can I get more information?

- Ecological Society of America, 1707 H Street, NW, Suite 400, Washington, DC 20006. (202) 833-8773. Esahq@esa.org; http://esa.sdsc.edu
- Soil Science Society of America, 677 South Segoe Road, Madison, WI 53711. (608) 273-8095. headquarters@Soils.org; http://www.soils.org
- Great Lakes Bioenergy Research Center, 1550 Linden Drive, Madison, WI 53705. http://www.greatlakesbioenergy.org/education/
- U.S. Department of Energy. http://www.fe.doe.gov/
- Carbon Sequestration in Soils. 1999. Science. William H. Schlesinger. 25 June, vol. 284.