Carbon Sequestration in Agriculture and Forestry

Frequent Questions

1. What is terrestrial carbon sequestration?

Terrestrial carbon sequestration is the process through which carbon dioxide (CO_2) from the atmosphere is absorbed by trees, plants and crops through photosynthesis, and stored as carbon in biomass (tree trunks, branches, foliage and roots) and soils. The term "sinks" is also used to refer to forests, croplands, and grazing lands, and their ability to sequester carbon. Agriculture and forestry activities can also release CO_2 to the atmosphere. Therefore, a carbon sink occurs when carbon sequestration is greater than carbon releases over some time period.

2. Why are agricultural and forestry sequestration activities important?

Forests and soils have a large influence on atmospheric levels of carbon dioxide (CO_2)—the most important global warming gas emitted by human activities. Tropical deforestation is responsible for about 20% of the world's annual CO_2 emissions (IPCC Special Report on LULUCF (2000) EXIT Disclaimer). On a global scale, however, these emissions are more than offset by the uptake of atmospheric CO_2 by forests and agriculture. Therefore, agricultural and forestry activities can both contribute to the accumulation of greenhouse gases in our atmosphere, as well as be used to help prevent climate change, by avoiding further emissions and by sequestering additional carbon. Sequestration activities can be carried out immediately, appear to present relatively cost-effective emission reduction opportunities, and may generate environmental co-benefits. At the same time, it is important to recognize that carbon sequestered in trees and soils can be released back to the atmosphere, and that there is a finite amount of carbon that can ultimately be sequestered.

3. How much carbon can agricultural and forestry practices sequester?

Carbon sequestration rates vary by tree species, soil type, regional climate, topography and management practice. In the U.S., fairly well-established values for carbon sequestration rates are available for most tree species. Soil carbon sequestration rates vary by soil type and cropping practice and are less well documented but information and research in this area is growing rapidly.

Pine plantations in the Southeast can accumulate almost 100 metric tons of carbon per acre after 90 years, or roughly one metric ton of carbon per acre per year (Birdsey 1996). Changes in forest management (e.g., lengthening the harvest-regeneration cycle) generally result in less carbon sequestration on a per acre basis. Changes in cropping practices, such as from conventional to conservation tillage, have been shown to sequester about 0.1 – 0.3 metric tons of carbon per acre per year (Lal et al. 1999; West and Post 2002). However, a more comprehensive picture of the climate effects of these practices needs to also consider possible nitrous oxide (N_2O) and methane (CH_4) emissions. (See also FAQ #6)

Carbon accumulation in forests and soils eventually reaches a saturation point, beyond which additional sequestration is no longer possible. This happens, for example, when trees reach maturity, or when the organic matter in soils builds back up to original levels before losses occurred. Even after saturation, the trees or agricultural practices would need to be sustained to maintain the accumulated carbon and prevent subsequent losses of carbon back to the atmosphere.

For more information on carbon sequestration and saturation rates for individual practices, visit the Practices section of this Web site. Full references cited in this answer are provided below.

4. How well can carbon sequestration be measured?

Several methods can be used to measure the carbon and—more importantly for the atmosphere—the changes in carbon in above-ground and below-ground biomass, soils, and wood products. Statistical sampling, computer modeling and remote sensing can be used to estimate carbon sequestration and emission sources at the global, national and local scales. Current forest carbon estimates are generally more accurate and easier to generate than soil estimates. Estimating changes in soil carbon over time is generally more challenging due to the high degree of variability of soil organic matter—even within small geographic scales like a corn field—and because changes in soil carbon may be small compared to the total amount of soil carbon. More information on these carbon accounting methodologies can be found in the Land-Use Change and Forestry chapter of the Inventory of U.S. Greenhouse Gas Emissions and Sinks, and in the IPCC (2000) Special Report on Land Use, Land-Use Change, and Forestry section on methods.
EXIT Disclaimer

5. How much carbon sequestration occurs in the U.S.?

The U.S. landscape acts as a net carbon sink—it sequesters more carbon than it emits. Two types of analyses confirm this: 1) atmospheric, or top-down, methods that look at changes in CO_2 concentrations; and 2) land-based, or bottom-up, methods that incorporate on-the-ground inventories or plot measurements.

For Inventory of U.S. Greenhouse Gas Emissions and Sinks, please go to the current and archived inventory pages. More information on U.S. carbon sequestration estimates and historical trends can be found under the National Analysis section of this Web site.

6. Do sequestration practices affect greenhouse gases other than CO_2?

Yes. Methane (CH_4) and nitrous oxide (N_2O) are potent greenhouse gases that are also important to consider for forests, croplands and grazing lands. Practices that maintain and sequester carbon can have both positive and negative effects on CH_4 and N_2O emissions. The relationship among practices that affect CO_2, CH_4, and N_2O can be especially complex in cropping and grazing systems. For example, if nitrogen-based fertilizers are applied to crops to increase yields, this would likely enhance soil carbon but the benefit could be partially or completely offset by increased emissions of N_2O. The practice of rotational grazing can be beneficial across all three major gases: soil carbon can be maintained and enhanced; livestock CH_4 emissions should decline due to improved forage quality; and N_2O emissions can be avoided by eliminating the need for fertilizer applications on the pasture. These complex interactions among gases mean that it is important to consider not only carbon but all the greenhouse gas effects for certain sequestration practices.

For more information on levels of CH_4 and N_2O emissions from U.S. agriculture, visit the National Analysis section of this Web site.

7. What are the other environmental effects of sequestration practices?

Practices that aim to reduce carbon losses and increase sequestration generally enhance the quality of soil, water, air and wildlife habitat. Tree planting that restores fuller forest cover may not only sequester carbon but could improve habitat suitability for wildlife. Preserving threatened tropical forests may avoid losses in both carbon and biodiversity, absent any leakage effects. And reducing soil erosion through tree planting or soil conservation measures can sequester carbon and improve water quality by reducing nutrient runoff. In certain cases, there may be tradeoffs between carbon objectives and environmental quality. Replacing diverse ecosystems with single-species timber plantations may generate greater carbon accumulation, but could result in less biodiversity, at least at the scale of the plantation.

8. How could carbon sequestration be affected by climate change?

According to a National Academy of Sciences 2001 report, "Greenhouse gases are accumulating in the Earth's atmosphere as a result of human activities, causing surface air temperatures and subsurface ocean temperatures to rise." In addition to temperature, human-induced climate change may also affect growing seasons, precipitation and the frequency and severity of extreme weather events, such as fire. These changes can influence forests, farming and the health of ecosystems, and thus carbon sequestration. Some argue that rising CO_2 levels will enhance sequestration above normal rates due to a fertilization effect. However, the concurrent changes in temperature and precipitation, along with local nutrient availability and harmful air pollutants, complicate this view. Furthermore, recent studies of pine forests fumigated with elevated CO_2 levels have shown that this fertilization effect may only be short-lived (Schlesinger and Lichter 2001; Oren et al. 2001). Current projections of business-as-usual U.S. sequestration rates under various climate change scenarios show both increases and decreases in carbon storage depending on various assumptions. To date, few analyses of the potential for additional sequestration over time have considered the future effects of climate change.

9. How do sequestration activities compare with greenhouse gas reductions in other sectors?

In terms of its global warming impact, one unit of CO_2 released from a car's tailpipe has the same effect as one unit of CO_2 released from a burning forest. Likewise, CO_2 removed from the atmosphere through tree planting can have the same benefit as avoiding an equivalent amount of CO_2 released from a power plant. However, the climate benefits of sequestration practices can be partially or completely reversed because terrestrial carbon can be released back to the atmosphere through decay or disturbances. Trees that sequester carbon are subject to natural disturbances and harvests, which could suddenly or gradually release the carbon back to the atmosphere. And if carbon sequestration practices in agriculture, such as reduced tillage, are abandoned or interrupted, most or all of the accumulated carbon can be quickly released. Some sequestration practices, like tree planting and improved soil management, also reach a point where additional carbon accumulation is no longer possible. For example, mature forests will not sequester additional carbon after the trees have fully grown. At this point, however, the mature trees or practices still need to be sustained to maintain the level of accumulated carbon. Addressing the issues of reversibility (or permanence) and carbon saturation is important if sequestration benefits are to be compared to other greenhouse gas reductions.

http://www.epa.gov/sequestration/faq.html
Last updated on 22 June 2010

References in this FAQ section where links are not available:

Birdsey, R.A. (1996) Regional Estimates of Timber Volume and Forest Carbon for Fully Stocked Timberland, Average Management After Final Clearcut Harvest. In Forests and Global Change: Volume 2, Forest Management Opportunities for Mitigating Carbon Emissions, eds. R.N. Sampson and D. Hair, American Forests, Washington, DC.

Lal, R. et al. (1999) The Potential of U.S. Cropland to Sequester Carbon and Mitigate the Greenhouse Effect. Lewis Publishers.

McCarl, B. and U. Schneider (2001) Greenhouse Gas Mitigation in U.S. Agriculture and Forestry. Science, 294:2481-2482.

Oren, R. et al. (2001) Soil fertility limits carbon sequestration by forest ecosystems in a CO_2-enriched atmosphere. Nature, 411:469-472.

Schlesinger, W. and J. Lichter (2001) Limited carbon storage in soil litter of experimental forest plots under increased atmospheric CO_2. Nature, 411:466-469.

West, T.O. and W.M. Post (2002) Soil Carbon Sequestration by Tillage and Crop Rotation: A Global Data Analysis. Soil Science Society of America Journal. Available at DOE CDIAC site.