IGCC POLICY BRIEF

October 1999 ISSN 1089-8352 Number 12-4

Climate Change Science

Part IV of VI: Soil Carbon Sinks

Susan Trumbore

Future stabilization of atmospheric carbon dioxide concentrations cannot be achieved by land management alone. It requires reduction of emissions from fossil fuel burning. *Full recommendations, page 4.*

Summary: Decomposition of organic matter makes soils an important source of source of greenhouse gasses—carbon dioxide, nitrous oxide, and methane—to the atmosphere. Human land modification and agriculture has led to a global net loss of soil carbon, and dramatically increased nitrous oxide and methane emissions. Better management practices can increase soil carbon storage, but to be significant these must cover large areas over a long period of time—and changes can be difficult to measure. Further, there are inherent limits to how much atmospheric carbon can be removed or stored by forests or soils. Stabilizing future atmospheric carbon dioxide concentrations cannot be achieved without reducing fossil fuel emissions.❖

This brief is the product of the *Climate Change–Science Policy Interface* panel to the UNFCC COP-4 meetings held in Buenos Aires, Argentina 12–13 November 1998, and the 10–11 May 1999 *Global Climate Change: Recent Science Developments* briefing to the U.S. Congress, held at the invitation of U.S. Senator Diane Feinstein. Both events were co-sponsored by IGCC and the Scripps Institution of Oceanography. We wish to thank the University of California Office of the President Office of Research for generous support of this work.

Geochemical tracers can be used to study the exchange of important greenhouse gases like carbon dioxide, methane and nitrous oxide between the land biosphere and the atmosphere. Emissions from soils are major sources of these three trace gases to the atmosphere, and are expected to change in response to future changes in land use and climate. Past human land modification and agriculture has led to a global net loss of soil carbon, and dramatically increased nitrous oxide and methane emissions.

The Missing Sink

Nearly 8 billion tons of carbon dioxide are added to the atmosphere each year by fossil fuel burning and tropical deforestation. We can account for the fate of most of this human-produced greenhouse gas. Roughly forty-one per cent accumulates in the atmosphere; twenty-nine per cent is taken up by the oceans. Of the remaining thirty percent, seven percent is accounted for by the re-growth of forests cut in the last century. A process that has yet to be identified is responsible for removal of the final twenty-three percent of carbon dioxide emissions from the atmosphere.

This unattributed carbon uptake is often referred to as "the missing sink". Several independent pieces of evidence indicate that most of this sink is on land and in the northern hemisphere, and a number of likely processes have been identified, including fertilization of land plants by carbon dioxide and nitrogen derived from human activities. So far, however, the exact process or combination of processes responsible for sequestering a fifth of annual human global carbon dioxide emissions has not been determined with certainty.

Growing Concentrations

While there is much current scientific controversy surrounding the exact location of and processes contributing to the unidentified carbon sink, two clear statements can be made.

First, whatever the process is, or how it is distributed in space, it is not sufficient to offset current human emissions. Carbon dioxide concentrations continue to grow in the atmosphere every year despite uptake on land and in the oceans. Doubling the land sink would still not offset emissions and atmospheric carbon dioxide concentrations would continue to increase.

Second, as fossil fuel emissions continue to rise, we expect the proportion of total carbon emissions taken up by these processes to decrease in the future. All of the processes thought to take up carbon and store it on land should saturate over time, as decomposition of larger stores of dead organic matter catches up with increased removal of CO_2 by more productive land plants.

One of the largest uncertainties in predicting the future storage potential for carbon on land is knowing how long carbon remains in plants and soils before being returned to the atmosphere through respiration and decomposition. Tracking the penetration of radiocarbon, created in the 1960's during atmospheric nuclear weapons testing, into plant and soil carbon pools can help determine the time scale of exchange of carbon between plants, soils, and the atmosphere. These rates are vital to developing an understanding of how carbon accumulates and is lost from soils, and to determining the capacity of soils for storing ("sequestering") carbon. My research using radiocarbon for this effort spans boreal, temperate and tropical ecosystems.

For greenhouse gases other than carbon dioxide, stable isotopes provide useful tracers to indicate how soil physical and microbial processes control the emission and consumption of nitrous oxide and methane in soils. This fundamental information on the processes controlling trace gas fluxes is needed to develop predictive models of how emissions will respond to future changes in land use or climate.

Known Best Practices

Including soils in carbon sequestration projects remains controversial. What is known is that human land-use *can* affect carbon dioxide in the atmosphere. For example, approximately one-fifth of the total carbon dioxide emissions to the atmosphere each year are released from forests and soils during tropical deforestation. Preserving existing forests would reduce carbon dioxide emissions directly. Land management practices that remove carbon dioxide from the atmosphere have also been identified, including (but not limited to) promoting tree growth through aforestation and reforestation, and increasing soil carbon through conservation tillage agriculture.

However, for better land management practices to significantly increase soil carbon storage, they must cover large areas over a long period of time—and changes can be difficult to measure. In addition, the total of all greenhouse gas emissions must be included, not just the carbon storage. For example, increasing plant productivity with nitrogen fertilizers will store carbon in soils, but this will be offset by increases in nitrous oxide emissions.

Inherent Limits

Further, as with the unattributed carbon sink, there are inherent limits to how much carbon can be removed from the atmosphere by any of these processes All of the processes identified as likely contributors to storing carbon on land, once it has been taken up, also have inherent limits to how long sequestered carbon can remain sequestered in forest or soils once there. For example, the rate of carbon sequestration in re-growing forests slows as forests mature. And plant growth stimulated by higher carbon dioxide concentrations or nitrogen inputs will ultimately be limited by other factors, such as water or micronutrient availability.

Not by Management Alone

While we can account for most of the carbon dioxide we emit into the atmosphere

THE IGCC CLIMATE CHANGE PROGRAM is a University of California system-wide initiative that brings leading climate scientists directly in touch with key national and international policy-makers. Bringing objective, timely scientific expertise directly to bear in ongoing negotiations, IGCC sent a delegation of eminent climate change scientists to the November, 1998 (fourth) meeting of the Conference of the Parties (COP-4) of the United Nations Framework Convention on Climate Change (UNFCCC), held in Buenos Aires, Argentina. Through three panel presentations on abrupt climate change, carbon sinks, and the science–policy interface, UC scientists advised UN national delegations, intergovernmental organizations, industry representatives, environmental agencies, and international media about current, relevant implications of recent research.

IGCC was the only academic organization with a substantial presence at the conference, where there were otherwise few scientists. According to Michael Molitor, IGCC Climate Change Program Coordinator, "Our fundamental understanding of the climate system is evolving rapidly. There are some basic scientific assumptions that underlie the Kyoto protocol negotiating process that need to be reexamined in light of recent advances." The importance of these latest discoveries was not lost on UN delegates. Thereafter, on 10–11 May 1999, IGCC Climate Change Program held briefings for policymakers in the nation's capitol. IGCC's delegation comprised:

Sandra BROWN, Winrock International
Richard CARSON, IGCC
Michael MOLITOR, IGCC
Stephan RAHMSTORF, Potsdam Institute for Climate Impact Research
Jayant SATHAYE, Lawrence Berkeley National Laboratory
Stephen SCHNEIDER, Stanford University
Jeff SEVERINGHAUS, Scripps Institution of Oceanography, UCSD
Lisa SHAFFER, Scripps Institution of Oceanography, UCSD
Robert SHELTON, UC Office of the President
Richard SOMERVILLE, Scripps Institution of Oceanography, UCSD
Mark THIEMENS, UCSD Center for Environmental Research and Training
Susan TRUMBORE, UC Irvine
Ray WEISS, Scripps Institution of Oceanography, UCSD

each year, the exact mechanism responsible for removing approximately one-fifth of the emissions and sequestering them on land in the northern hemisphere remains unknown.

All of the processes that have been proposed for this unattributed carbon sink have inherent limits in terms of the total amount of carbon that can be stored and how long carbon will remain sequestered. The same limits apply to management of land to take up carbon.

Ultimately, compared to the predictions of fossil fuel release over the next decades, land management to sequester carbon dioxide would provide small, though not insignificant, ameliorating effects. But because our ability to sequester carbon on land is limited, future stabilization of atmospheric carbon dioxide concentrations cannot be achieved by land management alone. It requires reduction of emissions from fossil fuel burning. ❖

Susan Trumbore is associate professor of geochemistry at the UC Irvine Department of Earth System Science. She is the lead author on *IPCC Special Report on Land Use Change and Forestry*. She received her Ph.D. in Geology and Geochemistry from the Lamont-Doherty Earth Observatory of Columbia University.

This is the fourth of a five-part series titled Climate Change Science. *See also* PB 12-1: Bridging Science to Policy *by Richard Carson;* PB 12-2: Predicting 21st Century Climate *by Richard C.J. Somerville;* PB 12-3: Critical Omissions for Critical Emissions *by Mark Thiemens*; PB 12-5: Abrupt Climate Change *by Jeff Severinghaus; and* PB 12-6: Practical Implementation *by Michael Molitor.*

To obtain additional copies of this or other briefs, contact the Publications Clerk or view at: http://www-igcc.ucsd.edu/ or gopher-igcc.edu.

For more information on IGCC and its programs contact: Monique Kovacs, International Affairs Program Coordinator, (202) 296-8183, <mkovacs@ucsd.edu>; or Ronald Bee, IGCC Development and External Affairs Officer, (858) 534-6429, <rbee@ucsd.edu>.

How to reduce atmospheric carbon dioxide:

1. **Reduce fossil fuel emissions.**
2. **Find the mechanism that removes emissions and sequesters them on land in the northern hemisphere. Maybe it can be enhanced.**
3. **Manage land to store carbon, prevent carbon emission, and reduce nitrous oxide and methane emissions through forest preservation, reforestation, and management of agricultural soils.**
4. **Plan for the long term. Know that there are inherent limits to the total amount of carbon that can be stored on land, and to how long that carbon will remain stored.**

University of California

Institute on Global Conflict and Cooperation
Robinson Building Complex, 9500 Gilman Drive
La Jolla, CA 92093-0518 USA
phone: (858) 534-3352 fax: (858) 534-7655
ph13@sdcc.ucsd.edu • http://www-igcc.ucsd.edu/

UCI

Department of Earth System Science
220 Rowland Hall
Irvine, CA 92697-3100 USA
phone (949) 824-8794 fax (949) 824-3874
setrumbo@uci.edu • http://www.ess.uci.edu