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Carbon Accounting: Measuring the Contribution of Forests to Solving the Climate Change Problem

Global climate change is a hotly debated topic worldwide. It has many facets—environmental, societal, economic, and political—at many levels, from international, national, and regional to community and personal. And it raises serious concerns about the future of the world and humanity. Increased burning of fossil fuels (coal, oil, and gas) since the Industrial Revolution has resulted in increased levels of carbon dioxide (CO_2) in the atmosphere. Because of this, more of the sun's heat reflected by the earth can no longer escape from the atmosphere into space but is bounced back, giving rise to the increased atmospheric temperatures of the greenhouse effect. This climate warming is now especially evident in the polar region and boreal forests, with melting glaciers and the permafrost, which could bring about sea-level rising and methane release. Insect outbreaks and wildfires are also on the rise from warmer temperatures, longer growing seasons, and droughts.

For any effort to slow the rise in atmospheric carbon to succeed, techniques for accurately measuring carbon in forests and forest lands are a necessity.

Richard Birdsey, program manager, Forest Service, Northern Global Change Research

The world's forests are major players—both as problems and solutions—in the climate change problem: On the one hand, deforestation, insect outbreaks, and forest fires are sources of CO_2. On the other hand, healthy forests can be major carbon sinks that remove CO_2 from the atmosphere and sequester it (that is, store it) as long-term C stocks in trees, soils, and wood products. This happens because plants use photosynthesis to remove C from the air and ultimately produce not only cellular food (glucose) and energy but also, in trees, the building blocks of wood, cellulose and lignin. Plants also respire, which releases CO_2 to the atmosphere. However, in healthy trees, photosynthesis takes up more CO_2 than is released by respiration; thus trees get bigger and store more carbon as they get older.

Knowing where carbon is stored in ecosystems and in what quantities is vital to our understanding of the global climate change problem and to all efforts to ameliorate atmospheric carbon levels. Scientists of all nationalities and specializations are working on the many aspects of understanding the basics of CO_2 sources, cycling, and sequestration. Many scientists, foresters, and land managers believe that currently available reforestation and silvicultural practices can be used to increase sequestration of CO_2 in forest carbon sinks.

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Indeed, "carbon credits," which are defined to be equivalent to a unit of reduced emissions of fossil fuel, are now being traded on the Chicago Climate Exchange. For any effort (whether private, governmental, or commercial) to slow the rise in atmospheric carbon to succeed, techniques for accurately measuring carbon in forests and forest lands are a necessity.

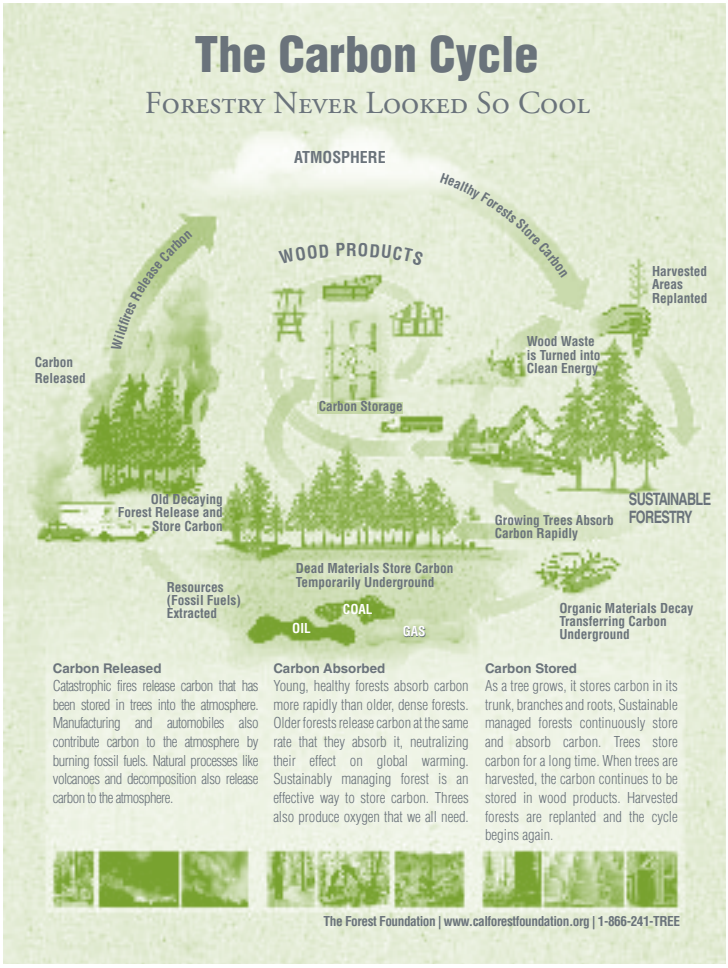
NORTHERN RESEARCH STATION CARBON ACCOUNTING RESEARCH

Since 1991, the **Northern Global Change Program** (NGCP) at the U.S. Forest Service Northern Research Station (NRS), led by program manager Dr. Richard A. Birdsey, has supported many NRS scientists and their university partners studying the impacts of climate change and the carbon cycles of forests. This work has led to pioneering methods for estimating forest carbon and developed the essential accounting rules and guidelines for making forest carbon a commodity that can be traded for emissions reductions. In the NRS **Forest Inventory and Analysis** (FIA) unit, **the Forest Carbon Accounting and Research Team** has been formed to conduct the annual national inventory of forest greenhouse gases and carbon stored in forests. The team currently comprises three full-time members—Dr. Linda S. Heath (team leader), Dr. James E. Smith, and Michael C. Nichols (Durham, NH)—plus eight contributing FIA scientists. They are Elizabeth LaPoint (Durham, NH), William H. McWilliams (Newtown Square, PA), and Dr. Mark H. Hansen, Patrick D. Miles, Dr. Charles H. "Hobie" Perry, Ronald J. Piva, Barry T. "Ty" Wilson, and Dr. Christopher W. Woodall (St. Paul, MN). Other members are anticipated and welcomed!

An important aspect of the team's work is focused on using and enhancing FIA data for carbon accounting and reporting. FIA data collection nearly provides a comprehensive carbon survey. The inventories are now being taken on an annual basis in 48 of 50 states, and field crews are collecting data closely related to nearly every reported carbon stock, including live and standing dead trees, downed woody material, forest floor, and soil. Related research by the FIA **National Inventory and Monitoring Applications Center** (NIMAC) will help with project-level carbon estimation.

CARBON ESTIMATION AND CURRENT TOOLS

Accurate estimates of carbon in forests are crucial for forest carbon management; carbon credit trading; national reporting of greenhouse gas inventories to the United Nations Framework Convention for Climate Change; calculating estimates for the Montreal Process criteria; indicating sustainable forest



management; and registering forest-related activities for the national 1605(b) Voluntary Reporting of Greenhouse Gases Program and other greenhouse gas registries for states and regions. Drs. Heath, Smith, and Coeli Hoover (Durham, NH), David J. Nowak (Syracuse, NY), and Birdsey (Newtown Square, PA) have contributed to developing a software "toolbox" full of basic calculation methods to help quantify forest carbon for planning, accounting, or reporting. The following six tools can help landowners and managers to register their forest carbon sequestration activities and receive payment. The **Chicago Climate Exchange** has an active program now to fund carbon sequestration from afforestation. Participants must follow their rules and may need to contact an "aggregator" such as the **Delta Institute** or **AgraGate Climate Credits.** (Listing these examples is for information purposes only. The USDA Forest Service is not endorsing these or any other such programs.) Funding from individuals may also be available. Currently, most activity in the U.S. involves registries such as the developing Climate Registry or DOE's voluntary reporting. These tools can all be accessed at www.nrs.fs.fed.us/carbon/tools/

- ***Measurement guidelines for forest carbon* (GTR-NRS-18)**. These guidelines are a reference for

professionals designing forest carbon inventory and monitoring systems to support reporting to greenhouse gas registries by public and private organizations. Landowners, industrial forestry companies, and managers of utility company lands in the United States that are interested in implementing forestry activities and projects designed to generate carbon credits can thus register carbon dioxide reductions using the U.S. Department of Energy 1605(b) Voluntary Reporting Registry and then trade carbon credits as offsets. ***If you want to design a carbon accounting system, read this book.***

- **Stand Level Carbon Management and Reporting With the Forest Vegetation Simulator.** Carbon reporting has been fully integrated into the Forest Service's Forest Vegetation Simulator (FVS), thus allowing users to produce carbon reports along with traditional FVS output. Carbon pools tracked include the following categories: live tree biomass (above-and belowground), dead tree biomass (above-and belowground), down dead wood, forest floor, and herbs and shrubs. ***If you want to examine carbon impacts of management alternatives for forest stands, this is the tool.***

- **Forest Carbon Calculation Tool.** The Carbon Calculation Tool (CCT) 2007 uses publicly available forest inventory data collected by FIA to generate state-level annualized estimates of carbon stocks on forestland based on FORCARB2 estimators. Survey summaries can be used to produce state-level and national tables with annualized carbon stocks and flux (or net stock change) beginning with the year 1990. When completed, a web-based tool will replace CCT. ***This is the tool if you want state, regional, or national estimates of GHG carbon sinks.***

- **Carbon OnLine Estimator (COLE).** This web-based tool for forest carbon analysis generates carbon estimates based on FIA data for any part of the continental United States as large as a county, with uncertainty values decreasing for larger areas. Reports provide carbon "growth and yield" curves for strategic evaluation of potential mitigation strategies. In 2004, COLE was named the official 1605b web-tool by the U.S. Departments of Agriculture and Energy, and a new model version (COLE-EZ) was designed for reporting estimates in the format for reporting to the DOE national registry. COLE was developed in partnership Dr. Paul Van Deusen from the National Council for Air and Stream Improvement, Inc. ***You can customize 1605b carbon accumulation curves with this tool.***

- ***Standard Tables of Forest Ecosystem and Harvested Wood Carbon* (GTR-NE-343).** This report, available in electronic format, contains forest ecosystem carbon-yield tables, representing stand-level merchantable volume and carbon pools as a function of stand age, available for 51 forest types within 10 regions of the United States, both for afforestation and reforestation. Because carbon sequestered in harvested wood remains until the wood disintegrates, methods to calculate carbon in forest products are also included. The estimates and methods are consistent with guidelines for the updated U.S. Voluntary Reporting of Greenhouse Gases Program. ***If you want to estimate carbon in harvested wood products, or use average carbon accumulation curves for planning or registries, this tool may be just what you want!***

- **i-Tree Software.** The i-Tree software tools were developed by NRS scientist Dr. David J. Nowak (Syracuse, NY) and colleagues to help users identify, understand, and manage urban tree populations. Better awareness of the benefits and services provided by the urban forest resource leads to increased attention to tree stewardship and investment in maintenance. Well-placed urban and residential trees can reduce energy use for heating and cooling buildings and reduce the urban heat-island effect. Carbon is one of the variables estimated using i-Tree models, which includes the UFORE (Urban Forest Effects) model. ***This is the model for the urban forest.***

Basic Carbon Facts for the United States: In 2006, gross greenhouse gas emissions in the U.S. were equivalent to 7,202 million metric tons of CO_2 equivalents. In that same year, a net of 745 million metric tons of CO_2 equivalents were removed from the atmosphere and stored in forests and forest products in the 48 conterminous states. This offsets about 10 percent of gross U.S. CO_2 emissions from all sources. An additional 204 million metric tons of CO_2 equivalents were stored by forests and then harvested from forests and burned for energy as a substitute for burning fossil fuels, resulting in a net change of zero to the atmosphere.

DEVELOPING NEW APPROACHES TO MONITORING FOREST CARBON

Knowledge of how management practices and natural disturbances affect carbon pools over time can be improved by integrating forest carbon measurements at experimental forests with the monitoring data available from FIA and remote sensing. NRS has a network of experimental forests, some of which have "flux towers" (see page 5 top) for accurate monitoring of forest/atmosphere CO_2 exchange, along with very accurate measurements of carbon stocks and soil CO_2 fluxes, and special remote-sensing data sets. NRS researcher Dr. Yude Pan is leading an effort to integrate these diverse sources of information by using statistical analysis combined with ecosystem models. At the Silas Little Experimental Forest, the sampling design involves a dense cluster of FIA-type plots located around each flux tower. These plots are used to "ground truth" the ecosystem models for Atlantic Coastal Plain forests, thus allowing researchers to provide accurate estimates of carbon changes for specific land management areas such as the New Jersey Pinelands. From the scientific perspective, these experimental forest sites are among the few places on earth where the regional carbon budget can be "closed," that is, all major exchanges of carbon between the land, atmosphere, and ocean can be accounted for.

This research builds upon a foundation of work begun in 2001 by the U.S. Forest Service to implement a system for forest carbon monitoring and observation on the Forest Service's network of experimental forests. Intensive carbon research sites represent a variety of managed and unmanaged forest conditions in different physiographic regions. At each site, NRS scientific teams are monitoring the effects of management decisions and natural disturbances on the most important carbon pools and separating these effects from natural factors such as climate variability. The NRS flux towers are located at Howland Research Forest, Maine (Dr. David Hollinger, team leader), Bartlett Experimental Forest, New Hampshire (Dr. Hollinger), Silas Little Experimental Forest, New Jersey (Dr. Kenneth Clark), Marcell Experimental Forest, Minnesota (Dr. Randall Kolka), and Baltimore Long-Term Ecological Research Site, Maryland (Dr. John Hom).

Biographies

Dr. Richard A. Birdsey (left) manages the Northern Global Change Research Program and is a specialist in quantitative methods for large-scale forest inventories. He has published estimates of historical and prospective U.S. forest carbon stocks and identified options for increasing the role of U.S. and global forests as carbon sinks. He is a lead author of the Intergovernmental Panel on Climate Change (IPCC) special report on land use, land use change, and forestry. He received his MS and PhD in forestry from the State University of New York, College of Environmental Science and Forestry; he joined the Forest Service in 1979 and is located at Newtown Square, PA.

Dr. Linda S. Heath (center) is now team leader for Forest Carbon Accounting and Research in the NRS Forest Inventory Analysis unit. She is a lead author in two activities of the National Greenhouse Gas Inventories Programme of the IPCC. Heath received her BS in forestry and MS in forest management from the University of Illinois at Urbana-Champaign and her PhD in quantitative resources management from the University of Washington, Seattle. She is located in Durham, NH, and joined the Forest Service in 1988.

Dr. David J. Nowak (right) received his BS and MS degrees from the State University of New York, College of Environmental Science and Forestry, and his PhD from the University of California, Berkeley. He is a contributing author to the IPCC in relation to urban forest carbon storage and sequestration. He is a project leader with the USDA Forest Service Northern Research Station in Syracuse, NY, investigating urban forest structure, health, and change, and its effect on air quality and greenhouse gases.

Measuring Forest/Atmosphere Carbon Exchange in Real Time—The exchange of carbon dioxide (CO_2) between land and the atmosphere is one of the most important indicators of ecosystem productivity. It is presently measured at more than 30 sites in North America. Many of these sites are part of the AmeriFlux Network, which is an integral part of the North American Carbon Program, a multi-agency effort to measure and understand the sources and sinks of CO_2, methane (CH_4), and carbon monoxide (CO) in North America and adjacent ocean regions. Monthly, seasonal, and yearly data from these sites are summed to provide accurate measures specific to one ecosystem type or condition. Increasingly, multiple flux towers are located in contrasting conditions to increase understanding of the effects of different forest treatments (e.g., timber harvest), gradients of vegetation composition, and tree and stand age on carbon exchange. Data from the flux sites have been applied in ecology, weather forecasting, and climate studies, especially for sites with several years of data to quantify inter-annual flux variations.

One of the eddy flux towers at Silas Little Experimental Forest in the New Jersey Pine Barrens. Measurements of energy, water vapor and net CO_2 exchange started in April 2004. Annual net CO_2 exchange (NEEyr) measured at this site ranges between 187 and –293 g of carbon per m^2 per year, with the largest carbon loss value corresponding with complete defoliation by the gypsy moth in 2007.

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Our research themes are (1) Managing Forests with Disturbance, (2) Urban Natural Resources Stewardship, (3) Sustaining Forests, (4) Providing Clean Air and Water, and (5) Natural Resources Inventory and Monitoring.

There are 157 NRS scientists working at 20 field offices, 22 experimental forests, and universities located across 20 states, from Maine to Maryland, Missouri to Minnesota.

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