USDA Forest Service
U.S. DEPARTMENT OF AGRICULTURE

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Forest Carbon Estimation and Monitoring

Carbon dioxide (CO_2) is the most pervasive greenhouse gas (GHG) driving rising global temperatures. Forests play a critical role in moderating CO_2 and reducing the impact of climate change. Trees naturally absorb CO_2 through the process of photosynthesis and store it as carbon. That carbon gets locked in the trunks, roots, and leaves of trees and is deposited in surrounding soils for long periods of time. The amount of carbon stored and released from forests over time (referred to as "carbon flux") is impacted by forest health and conditions, management practices, disturbances such as fire, and wood harvesting and use. Tracking these dynamic processes over vast landscapes is complex, but crucially important for understanding and harnessing the power of forests to curb the national GHG footprint.

Estimating Forest Carbon Stocks and Changes of U.S. Forests

The Forest Service Forest Inventory and Analysis (FIA) program is legislated by Congress to conduct the Nation's forest census. FIA works with States and many other partners to collect data from over 325,000 field sampling areas, or plots, across 50 States, U.S. Territories, and current and former protectorates. These data are used to produce annual and 5-year reports on the status and trends of our forests. FIA is the primary source of data on U.S. terrestrial carbon stocks and flux.

Links to State Reports and Data

- Northern Region
- Southern Region
- Rocky Mountain Region
- Pacific Region

The FIA's statistically designed inventory tracks status and trends in forest area and location; the species, size, and health of trees; total tree growth, mortality, and harvest; wood production and use rates; and forest land ownership. While it was not specifically designed to track carbon, forests are basically composed of carbon. The measurements and samples collected via FIA surveys include those needed to estimate the size of forest carbon pools (figure 1) and can therefore be translated and reported in terms of carbon. FIA surveys are continuously repeated, allowing scientists to also estimate forest change over time by combining those data with information about changes in land cover and disturbances, often provided through additional observations supported by partner contributions or remote sensing technology. Generally, FIA data produce total carbon stock estimates and forest carbon per acre annually at the State level. The data allow for meaningful estimates at the national level or for substate areas such as national forests, large counties, and other specific ownerships.

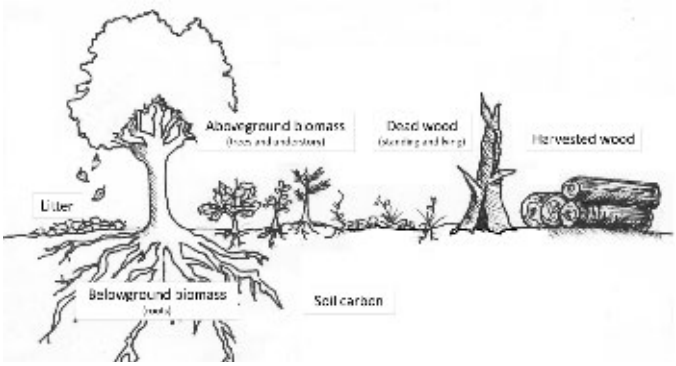

Figure 1. Forest carbon pools.

Harvested Wood Products

When trees are harvested and converted into wood products, their carbon may continue to be stored over long time periods. Accounting for carbon removed from a forest through harvest or restoration or fuel treatment activities is therefore important for understanding the total carbon change or flux. FIA Timber Products Output (TPO) surveys track timber harvest and mill-based economies of U.S. regions. These provide the basic data needed for models that quantify carbon stored in harvested wood.

National and International Greenhouse Gas Reporting

Beyond forest and wood carbon dynamics, changes in land use and land cover, such as from fire, can result in emissions from other GHGs, including methane (CH_4) and nitrous oxide (N_2O). The FIA program is responsible for compiling estimates of GHG emissions and removals from forest land, harvested wood products, urban trees, and woodlands in the United States each year as a component of the National Inventory Report that is submitted to the United Nations Framework Convention on Climate Change (UNFCCC). FIA data also directly inform forest sustainability reporting under the Montreal Process, carbon assessments across national forests and grasslands, the U.S. Global Change Research Program's Second State of the Carbon Cycle Report, and beyond.

Emissions and Removals Categories Estimated by Forest Service Scientists for National Accounting

- Forest land remaining forest land
- Non-CO2 emissions from fire
- N2O emissions from forest soils
- Non-CO2 emissions from drained organic soils
- Forest land converted to non-forest land
- Nonforest land converted to forest land
- Harvested wood products
- Woodlands remaining woodlands
- Urban trees in settlements

The congressionally mandated Resources Planning Act (RPA) Assessment is published every 10 years. It offers long-term (50 year) projections of the status of key natural resources across the United States, in a nationally consistent framework, with regional-level outputs. Much of the input information for the RPA and model development relies on FIA data. This includes the carbon estimates and projections developed for the RPA Assessment. The RPA is used for a range of purposes such as policy making, biennial reporting to the UNFCCC, climate action reporting, and to inform management activities, including State forest action plans, national forest management plans, and regional assessments. The next RPA Assessment is anticipated to be published in summer 2022.

Continuing Research and Data Improvements

How often plots are remeasured can significantly impact the accuracy of forest carbon flux estimates, especially in dynamic ecosystems affected by frequent disturbance or management activities. FIA continuously enhances inventory comprehensiveness and accuracy by increasing the number of plots and survey frequency when possible. FIA conducts a full remeasurement of all plots at variable intervals across the country, depending on funding and the level of importance placed on FIA data by State partners. The baseline standard is a 7-year cycle in the Eastern States, and a 10-year cycle in the West. In some cases, States contribute funding to complete a 5-year remeasurement cycle that can more adequately capture changes in forest volume and carbon. A detailed summary of current partnerships and financial flows is published in the FIA Annual Business Report.

FIA is also applying remote sensing to improve accuracy and cost-effectively collect data in remote areas. For example, in vast and remote landscapes of interior Alaska, logistical challenges make plot establishment and field inventory expensive and challenging. These ecosystems store vast quantities of soil and vegetation carbon and are potentially more vulnerable to climate change as temperature is projected to increase more significantly in boreal and arctic regions. FIA is partnering with the National Aeronautics and Space Administration (NASA) to enhance inventory coverage by supplementing data from the limited number of plots (one plot every 30,000 acres) by using cutting-edge, airborne-based technology. Aircraft equipped with a Goddard Light Detection and Ranging (LiDAR), Hyperspectral and Thermal (G-LiHT) imager system is providing fine-scale, (less than 1 meter) multispectral observations that are used to produce model-assisted estimates of forest biomass, volume, and carbon.

About Forest Service Research and Development: The Research and Development (R&D) arm of the Forest Service works at the forefront of science to improve the health and use of our Nation's forests and grasslands. Research has been part of the Forest Service mission since the agency's inception in 1905. The organization consists of 7 research stations and 81 experimental forests and ranges. Forest Service R&D partners with other Federal agencies, States, Tribes, nongovernmental organizations, universities, and the private sector. Today, more than 400 Forest Service scientists work in a range of biological, physical, and social science fields to promote sustainable management of the Nation's diverse forests and rangelands.