Carbon Storage in Forests

Carbon storage in forest biomass (biological material) is an essential attribute of stable forest ecosystems and a key link in the global carbon cycle. After carbon dioxide is converted into organic matter by photosynthesis, carbon is stored in forests for a period of time in a variety of forms before it is ultimately returned to the atmosphere through respiration and decomposition or disturbance. A substantial pool of carbon is stored in woody biomass (roots, trunks, and branches). Another portion eventually ends up as organic matter in forest floor litter and in soils.

Changes in the amount of carbon stored in forests can result from a variety of anthropogenic and natural influences. For example, carbon is removed or emitted from forests when trees are harvested, when forest land is cleared for other uses such as agriculture or development, or as a result of disturbances such as wildfire, insects, and disease. Net storage of carbon can result from natural reforestation of land that had previously been cleared for agriculture; long after these patches of land have re-grown enough to be classified as "forest," the forest continues to store carbon as it matures. Net carbon storage can also result from active planting of trees and management practices that lead to an increased rate of growth—and ultimately an increase in biomass (U.S. EPA, 2018).

The amount of carbon stored in forests is important for several reasons. A net change in forest biomass can indicate whether forest ecosystems are stable, growing, or declining. Carbon storage is closely related to other vital ecological processes such as primary productivity. Because carbon dioxide is the primary greenhouse gas emitted by human activities, changes in forest carbon can help to mitigate climate change—or they can exacerbate the problem. Forests remove carbon dioxide from the atmosphere, and when they store more carbon than they lose in a given year, they serve as a net carbon *sink* and offset a portion of society's greenhouse gas emissions (see the U.S. Greenhouse Gas Emissions indicator). Conversely, when forests emit more carbon than they store, they serve as a net carbon *source* and ultimately lead to an increase in carbon dioxide added to the atmosphere.

This indicator tracks the amount of carbon stored in forest biomass each year from 1990 to 2016, based on data collected and analyzed by the U.S. Department of Agriculture (USDA) Forest Service. These data cover the contiguous 48 states and southern Alaska. Through its annual Forest Inventory and Analysis (FIA) survey, the Forest Service visits hundreds of forest sites throughout the country and records the number and type of trees within a sample plot, as well as trunk size, height, and other parameters. Forest Service scientists then estimate the volume of biomass and the corresponding amount of carbon using statistical models that show the relationship between trunk size and the weight of branches, leaves, roots, and forest floor litter. These data are extrapolated nationwide using estimates of forest land area based on aerial photographs and satellite imagery.

This indicator divides forest biomass into five components:

- **Aboveground biomass** includes all living biomass above the soil including stems, stumps, branches, bark, seeds, and foliage. This category includes live understory.
- **Belowground biomass** includes all living biomass of coarse living roots thicker than 2 millimeters in diameter.
- **Dead wood** includes all non-living woody biomass either standing, lying on the ground (but not including litter), or in the soil.
- **Forest floor litter** includes the litter, fumic, and humic layers, and all non-living biomass with a diameter less than 7.5 centimeters, lying on the ground.
- **Soil organic carbon** includes all organic material in soil to a depth of 1 meter but excluding the coarse roots of the belowground pools.

What the Data Show

The total amount of carbon stored in U.S. forests increased by 8.5 percent between 1990 and 2016, with every year during this period experiencing a net increase (Exhibit 1). Thus, since at least 1990, U.S. forests have served as a net sink rather than a net source of carbon. In 2016, the most recent year for which emissions data are available, carbon storage in forest ecosystems offset approximately 9 percent of the nation's greenhouse gas emissions (U.S. EPA, 2018).

Of the five forest components shown in Exhibit 1, soil carbon accounts for the largest reservoir of carbon (56.4 percent

of total forest carbon as of 2016), followed by aboveground biomass (27.7 percent). Aboveground biomass accounted for slightly more than half (55.1 percent) of the net gain between 1990 and 2016, as the total amount of carbon stored in aboveground biomass increased by 18.6 percent during this time. The amount of belowground biomass also increased by 19.1 percent, but this component represents a much smaller share of the total carbon pool than aboveground biomass.

Evidence suggests that the net storage of carbon in U.S. forests reflects a combination of management activities, current land-use changes, and ongoing impacts of previous land-use changes. Although the Land Cover indicator shows that acreage of forest cover (areas with 25 to 100 percent tree cover) decreased in the contiguous 48 states between 2001 and 2011, the Forest Extent and Type indicator shows that the amount of forest land (areas with 10 percent or more coverage by forest) has been increasing over a longer timeframe. Between 1907 and 2012, the Forest Extent and Type indicator shows that the United States gained about 25 million acres of forest land. Much of this increase reflects the reforestation of land that had previously been cleared for agriculture (U.S. EPA, 2018).

Limitations

- This indicator underestimates the true amount of carbon sequestered by forests because it does not count the carbon in harvested wood products. For some types of products, such as lumber used in construction, many decades or even centuries may pass before the wood decays and carbon is released to the atmosphere. Wood products disposed of at a solid waste disposal site might not release carbon until many years or decades later, or they might store carbon almost permanently. For more information and estimates of the amount of carbon sequestered in harvested wood products, see U.S. EPA (2018).
- Data from most of Alaska and Hawaii are insufficient for inclusion in this indicator.
- Carbon pools are not measured directly, but are estimated based on inventory-to-carbon coefficients developed with information from field studies. These coefficients have been carefully developed and reviewed, but—like any estimation factors—they contribute some degree of uncertainty to the results.

Data Sources

This indicator is based on data collected by the USDA Forest Service. The national totals in Exhibit 1 came directly from the 2018 edition of EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks* (U.S. EPA, 2018). The underlying physical measurements used as inputs in the carbon storage models can be obtained from the FIA database (USDA Forest Service, 2018) (https://www.fia.fs.fed.us/tools-data/default.asp). As estimates continue to be improved over time, subsequent EPA inventories and Forest Service county-level datasets may reflect revised carbon storage totals.

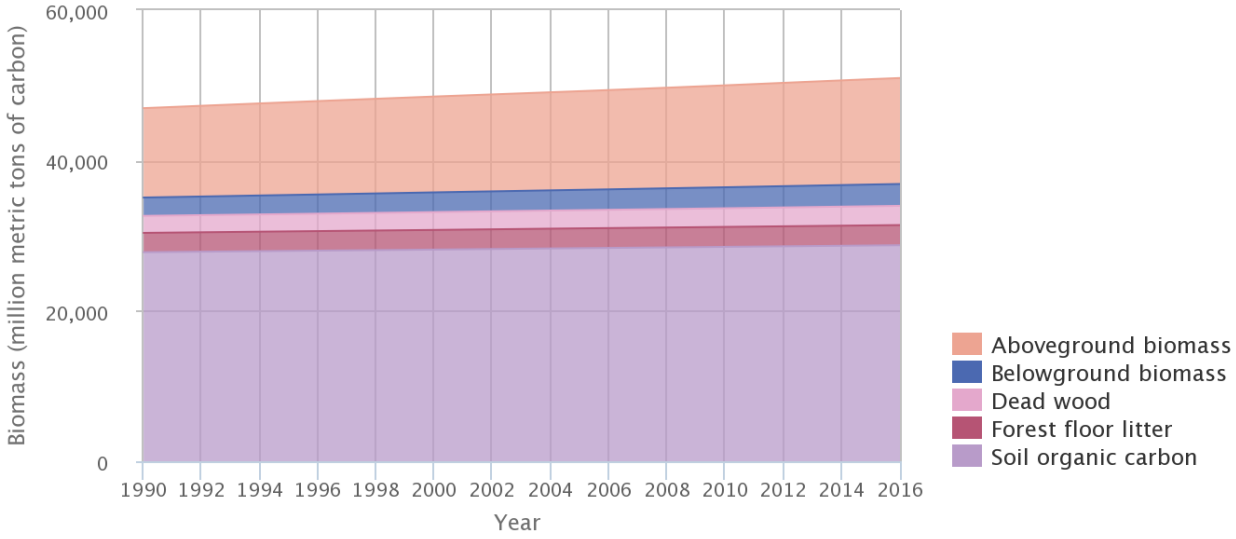
References

USDA Forest Service. 2018. Forest Inventory and Analysis national program: Data and tools. Accessed March 2017.

https://www.fia.fs.fed.us/tools-data/default.asp.

U.S. EPA (United States Environmental Protection Agency). 2018. Inventory of U.S. greenhouse gas emissions and sinks: 1990–2016. EPA
430-R-18-003. https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2016.

Exhibit 1. Total forest biomass in the U.S., by forest component, 1990–2016



Coverage: Contiguous 48 states and southern Alaska.

See text for definitions of categories.

Information on the statistical significance of the trends in this exhibit is not presented here. For more information about uncertainty, variability, and statistical analysis, view the technical documentation for this indicator.

Data source: U.S. EPA, 2018