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Data report

Criterion 5, Indicator 27. Contribution of forest ecosystems to the total global carbon budget, including absorption and release of carbon (standing biomass, coarse woody debris, peat and soil carbon).

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I. Analysis

A. Indication interpretation

1. Rationale from the Technical Advisory Committee (TAC)

This indicator assesses the change in total forest ecosystem carbon stocks, as calculated in Indicator 26 (relative to the total carbon budget of the Earth).

Interpretation from the Technical Advisory Committee (TAC) for the Montreal Process, as recorded in the Roundtable Report: This information establishes the significance of information generated through Indicator 26. Refer to comments for Indicator 26.

2. Clarification of the indicator and additions to rationale

Refer to clarifications for Indicator 26.

B. Data used in quantifying this indicator

This indicator is calculated by taking the difference in carbon pools in successive years, and dividing the results by the length of the period between successive years to produce an average annual net change in the carbon pools. Carbon pools are estimated using forest inventory data and conversion factors. Forest inventory data are from the USDA Forest Service's Forest Inventory and Analysis (FIA) Program. Volume, area, and other forest characteristics were compiled by Smith and others (2001) for 1953, 1963, 1977, 1987, and 1997. Each inventory year begins on the first calendar day of that year. Detailed data are available in databases for 1997. Refer to this section in Indicator 26 for a more complete description of the data used in quantifying this indicator.

All carbon pools, except soil carbon, are estimated using FIA or imputed inventory data, along with inventory-to-carbon relationships that were developed with information from ecological studies. Live tree volumes are transformed using equations in Smith and others (2003) to estimate above- and belowground carbon in live and dead standing trees. Data on forest type, forest areas, and age are used with equations in Smith and Heath (2002) to estimate carbon in the forest floor. Details about carbon in understory vegetation, soil, and down dead wood are in the corresponding section in Indicator 26.

The only additional information presented in this indicator is the partitioning of carbon sequestration in live trees into growth, removals, and mortality. Volumes for these variables are taken from inventory data in Smith and others (2001), and are transformed into carbon using factors in Birdsey (1992).

C. How should the data be interpreted relative to the rationale from the TAC?

This indicator reports trends in average annual changes in carbon pools, from 1953, the first year in which inventory data were collected using a modern design, through 1997. Changes in soil carbon are not reported because land-use effects have not yet been incorporated into calculations for soil carbon. Also, forest carbon pool changes for Alaska and Hawaii are not presented due to limited historical data. Carbon is presented in megatonnes of carbon per year (Mt/yr). One megatonne equals one million metric tons.

1. Overview

Average annual net change in non-soil forest ecosystem carbon pools from 1953 to 1997 was 175 Mt/yr, carbon absorbed by forests from the atmosphere (Fig. 27.1). The period 1977-1986 (Jan. 1, 1977, to Dec. 31, 1986) had the largest net increase, about 210 Mt/yr; the smallest increase occurred from 1987 to 1996. Live trees, both above- and belowground, accounted for nearly 77 percent of the net increase.

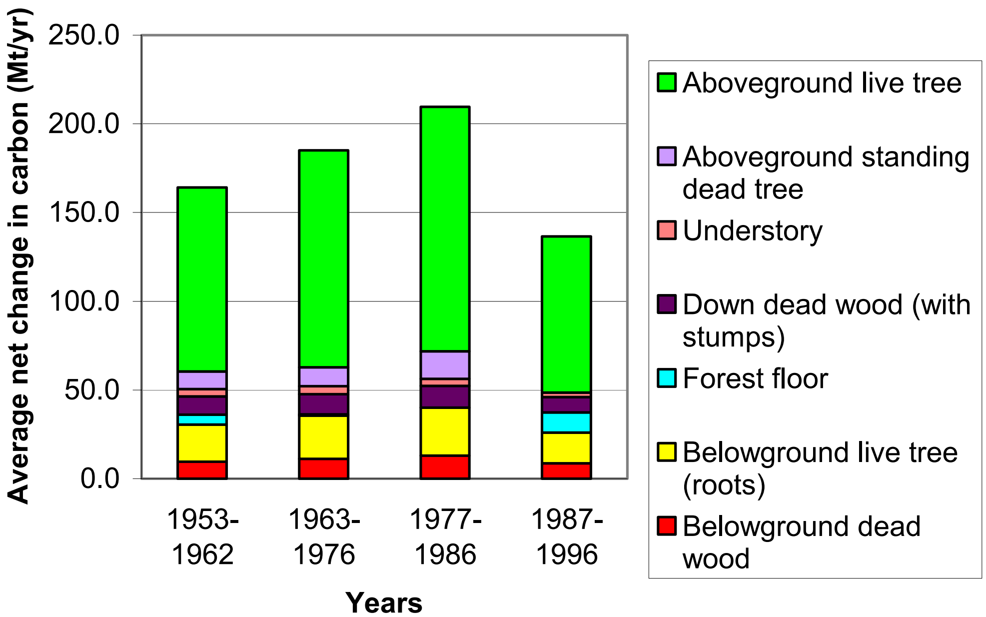

Figure 27.1—Average annual net change in forest ecosystem non-soil carbon pools (Mt/yr) for all forest land of the conterminous United States, 1953-1996. All net carbon stock changes are positive, indicating absorption of carbon by the forest from the atmosphere. The only emission of carbon (-1.7 Mt/yr) occurred for aboveground standing dead trees carbon in 1987-1996.

Increases in forest carbon are net values and not gross absorption; that is, increases in forest ecosystem carbon in Figure 27.1 represent the net difference between inventories. The net growth of live trees can be thought of as gross growth over the period minus mortality. In the United States in 1996, volume removals were about 68% of the volume growth. Thus, harvesting greatly affects the U.S. forest carbon budget.

Figure 27.2 shows the net growth, removals, and mortality in merchantable tree carbon on unreserved U.S. timberland. Net growth increased by 67 percent during the period (January 1, 1953 to December 31, 1996). Carbon in removals has increased by about 37 percent during the period. A gross increase in merchantable tree carbon for 1996 can be estimated by adding net annual growth, 153 Mt/yr, to mortality, or 193 Mt/yr of carbon sequestered in trees. This is approximately the gross absorption of merchantable tree carbon on unreserved timberlands. Removals of 105 Mt/yr do not directly become carbon emissions to the atmosphere. This amount transfers into the carbon in harvested wood products reported in Indicator 28. Some of the transferred carbon is held in long-term storage, and some is burned for energy and emitted. A portion of the transferred carbon is burned without capturing the energy produced, or decayed. Estimates of these emissions are reported in Indicator 28.

Between 1987 and 1996, about 135 Mt/yr of carbon were added to non-soil forest carbon stocks. About 60 Mt/yr were added to carbon stocks in the landfill and wood-in-use categories during

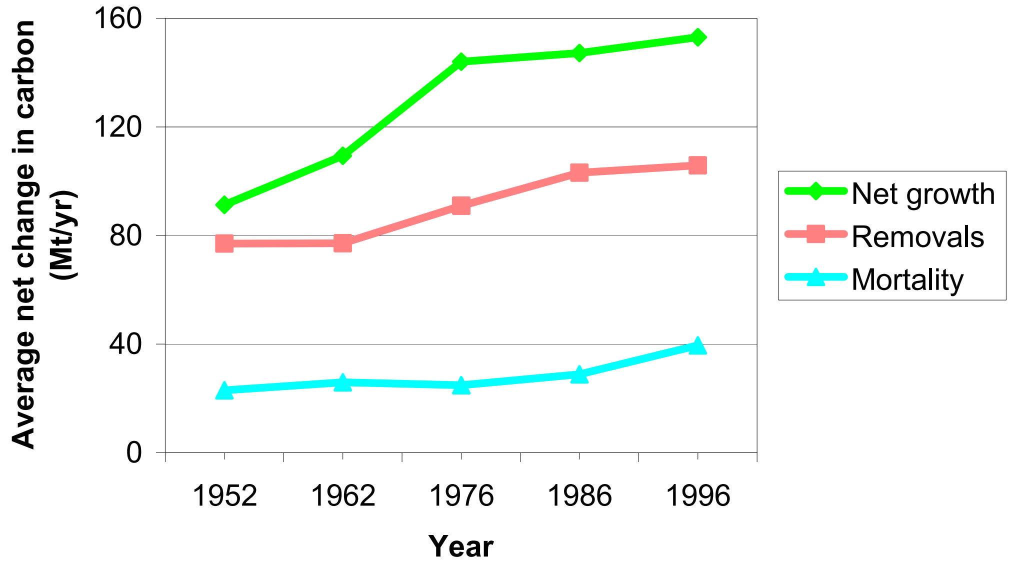

Figure 27.2— Average annual net change in merchantable tree carbon (Mt/yr) for unreserved timberland of the conterminous United States, 1953-1996.

1990 and 1997 (Indicator 28). Adding these two indicators results in 195 Mt/yr, the estimate of net carbon sequestration for the U.S. forest sector for the 1990's, excluding soil carbon.

For context, the net rate of increased atmospheric carbon dioxide content in terms of carbon was 3,200 Mt/yr from 1990 to 1999, according to the Houghton and others (2001). Estimated emissions from burning fossil fuels, along with a small amount from cement production, totaled 6,300 Mt/yr. Seventeen hundred Mt/yr were absorbed from the atmosphere by the oceans, and 1,400 Mt/yr were absorbed from the atmosphere by land-based changes. U.S. forest ecosystems sequester more than 10 percent of the global total for terrestrial ecosystems.

2. Regional trends

Figure 27.3 shows trends in average annual net changes in non-soil forest carbon pools in the seven regions the conterminous United States by period from 1953 to 1996. The figure reveals a pattern of increases when forest-land area and volume increase in the region, and decreases when forest-land area and volume decrease. Should forest-land area and volume change in opposite directions, carbon sequestration may increase, decrease, or remain the same depending on the magnitude of the changes. The North Central region showed a large consistent amount of carbon sequestration over the entire period. The Rocky Mountain region showed a lower, but also fairly consistent change in carbon. The forests of both the Southeast and South Central regions increased in carbon, with more carbon sequestered in the earlier than in the later periods. The Pacific Coast regions changed little in net carbon pools from 1953 to 1996. All regions showed a continuing increase in the net change in carbon pools from 1987 to 1996.

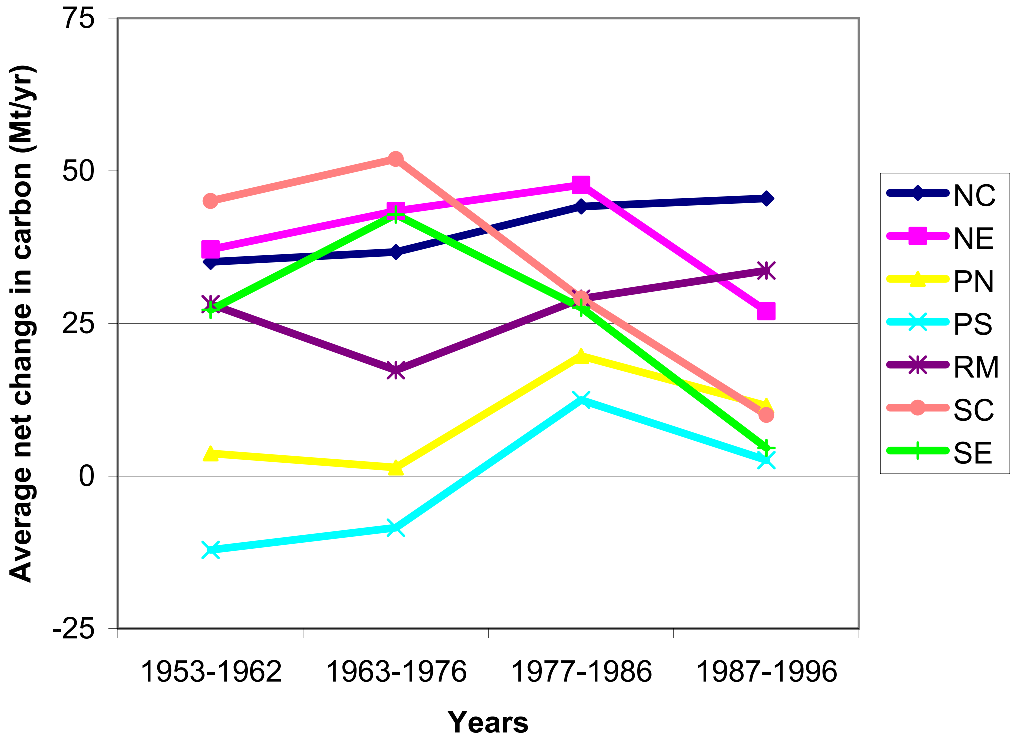

Figure 27.3—Average annual net change in non-soil forest ecosystem carbon (Mt/yr) by region of the conterminous United States, 1953-1996. (NC=North Central, NE=Northeast, PN=Pacific Northwest, PS=Pacific Southwest, RM=Rocky Mountain, SC=South Central, SE=Southeast. Regions are the same as in Smith and others (2001), with the exception of the States of ND, eastern SD, NE, and KS, which are compiled with the NC region.

D. Limitations of data provided

Refer to this section in Indicator 26. As stated earlier, changes in soil carbon are not included because land-use change estimates for this variable have not yet been developed. The data are compiled from a scientifically-based sample that was designed to provide reliable volume and area data at a predetermined level of precision. However, indicator 27 is a measure of change between inventories, so the estimates are more uncertain than the estimates of carbon pools in indicator 26. See Smith and Heath (2001), Smith and Heath (2000), and Heath and Smith (2000) for a discussion of uncertainty in the U.S. forest carbon budget.

E. If current data are not adequate to measure the indicator, what options are available for remedy?

Refer to this section in Indicator 26. The current data and modeling approach are adequate to provide estimates of the indicator. The results seem adequate because other atmosphere-based estimates are generally consistent with respect to the overall flux with the flux derived from land-based estimates (Pacala and others 2001).

II. Problems related to scientific, social/political, economic, and institutional concerns.

See this section in Indicator 26 for a discussion of institutional problems with more precise surveys.

III. Cross-cutting issues/relationships with other indicators

See this section in Indicator 26. Indicator 27 is related to many others. It is directly related to the other Criterion 5 indicators, 26 and 28. Because carbon is related to changes in forest volume and area, this indicator is related to Indicators 2, 11,12, and 21. Carbon as a productivity issue overlaps with Criterion 2, Maintenance of productive capacity of forest ecosystems, and Criterion 4, Conservation and maintenance of soil and water resources**.** The ability to understand carbon pools requires knowledge of the carbon cycle, which should be discussed under Indicator 63, Development of scientific understanding of forest ecosystem characteristics and functions. Forest carbon pools should also be a consideration for Indicator 67, Ability to predict impacts on forests of possible climate change. Two other indicators that should be consistent with the information on which Indicator 26 is based are 60, Availability and extent of up-to-date data, statistics and other information important to measuring or describing indicators associated with criteria 1-7, and 61, Scope, frequency and statistical reliability of forest inventories, assessments, monitoring, and other relevant information.

IV. Suggested guidance on use of the data

FIA data currently have been collected periodically by state over a number of years that do not necessarily correspond to the period of years listed in the figures. Thus, the carbon pool reported for a specific period may not strictly match that period; rather it is the period associated with the compilation of FIA data. Thus, the estimates should not be interpreted as corresponding exactly with the given periods.

Acknowledgments

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Literature Cited

See this section in Indicator 26 for other relevant citations.

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