Appendix H. Forestry

Overview

Forestland emissions refer to the net carbon dioxide (CO_2) flux[1] from forested lands in Minnesota, which account for about 32% of the state's land area.[2] The dominant forest type in Minnesota is Aspen-Birch which makes up about 41% of forested lands. Another common forest type is Spruce-Fir at 27% of forested land. All other forest types make up less than 10% each of the State's forests.

Through photosynthesis, CO_2 is taken up by trees and plants and converted to carbon in biomass within the forests. Carbon dioxide emissions occur from respiration in live trees, decay of dead biomass, and fires. In addition, carbon is stored for long time periods when forest biomass is harvested for use in durable wood products. Carbon dioxide flux is the net balance of CO_2 removals from and emissions to the atmosphere from the processes described above.

Inventory and Reference Case Projections

For over a decade, the United States Forest Service (USFS) has been developing and refining a forest carbon modeling system for the purposes of estimating forest carbon inventories. The methodology is used to develop national forest CO_2 fluxes for the official *US Inventory of Greenhouse Gas Emissions and Sinks*. The national estimates are compiled from state-level data. The Minnesota forest CO_2 flux data in this report come from the national analysis and are provided by the USFS. See the footnotes below for the most current documentation for the forest carbon modeling.[3] Additional forest carbon information is in the form of specific carbon conversion factors.[4]

The forest CO_2 flux methodology relies on input data in the form of plot level forest volume statistics from the Forest Inventory Analysis (FIA). FIA data on forest volumes are converted to values for ecosystem carbon stocks (i.e., the amount of carbon stored in forest carbon pools) using the FORCARB2 modeling system. Coefficients from FORCARB2 are applied to the plot level survey data to give estimates of C density [megagrams (Mg) per hectare] for a number of separate C pools. Additional background on the FORCARB system is provided in a number of

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[1] "Flux" refers to both emissions of CO_2 to the atmosphere and removal (sinks) of CO_2 from the atmosphere.

[2] Total forested acreage is 16.2 million acres in 2003; J. Smith, USFS, personal communication with S. Roe, CCS, April 2007. Acreage by forest type available from the USFS at: http://www.fs.fed.us/ne/global/pubs/books/epa/states/MN.htm. The total land area in Minnesota is 51 million acres (http://www.50states.com/minnesot.htm).

[3] The most current citation for an overview of how USFS calculates the inventory based forest carbon estimates as well as carbon in harvested wood products is the current EPA publication on the national GHG http://epa.gov/climatechange/emissions/usinventoryreport.html. Both Annex 3.12 and Chapter 7 LULUCF are useful sources of reference. See also Smith, J.E., L.S. Heath, and M.C. Nichols (in press), *U.S. Forest Carbon Calculation Tool User's Guide: Forestland Carbon Stocks and Net Annual Stock Change*, Gen Tech Report, Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station.

[4] Smith, J.E., and L.S. Heath (2002). "A model of forest floor carbon mass for United States forest types," Res. Pap. NE-722. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Research Station. 37 p., or Jenkins, J.C., D.C. Chojnacky, L.S. Heath, R.A. Birdsey (2003), "National-scale biomass estimators for United States tree species", *Forest Science*, 49:12-35.

publications.[5]

Carbon dioxide flux is estimated as the change in carbon mass for each carbon pool over a specified time frame. Forest volume data from at least two points in time are required. The change in carbon stocks between time intervals is estimated at the plot level for specific carbon pools (Live Tree, Standing Dead Wood, Understory, Down & Dead Wood, Forest Floor, and Soil Organic Carbon) and divided by the number of years between inventory samples. Annual increases in carbon density reflect carbon sequestration in a specific pool; decreases in carbon density reveal CO_2 emissions or carbon transfers out of that pool (e.g., death of a standing tree transfers carbon from the live tree to standing dead wood pool). The amount of carbon in each pool is also influenced by changes in forest area (e.g., an increase in area could lead to an increase in the associated forest carbon pools and the estimated flux). The sum of carbon stock changes for all forest carbon pools yields a total net CO_2 flux for forest ecosystems.

In preparing these estimates, USFS estimates the amount of forest carbon in different forest types as well as different carbon pools. The different forests include those in the national forest (NF) system and those that are not federally-owned (private and other public forests). Additional details on the forest carbon inventory methods can be found in Annex 3 to the US EPA's 2006 GHG inventory for the US.[6]

Carbon pool data for two FIA cycles were available for the USFS to estimate flux for the 1990-2003 period. These are shown in Table H1 below. These are the most recent USFS estimates available and will be included in EPA's latest national greenhouse gas (GHG) inventory. The underlying FIA data show a net decrease in forested area of 452,000 acres in the 1990-2003 period. There was also a loss of 90 million metric tons of carbon from forested areas during this period.

In addition to the forest carbon pools, additional carbon is stored in biomass removed from the forest for the production of harvested wood products (HWP). Carbon remains stored in the durable wood products pool or is transferred to landfills where much of the carbon remains stored over a long period of time. The USFS uses a model referred to as WOODCARB2 for the purposes of modeling national HWP carbon storage.[7]

As shown in the Table H2, 2.2 million metric tons (MMt) of CO_2 per year (yr) is estimated by

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[5] Smith, J.E., L.S. Heath, and P.B. Woodbury (2004). "How to estimate forest carbon for large areas from inventory data", *Journal of Forestry*, 102: 25-31; Heath, L.S., J.E. Smith, and R.A. Birdsey (2003), "Carbon trends in U.S. forest lands: A context for the role of soils in forest carbon sequestration", In J. M. Kimble, L. S. Heath, R. A. Birdsey, and R. Lal, editors. *The Potential of US Forest Soils to Sequester Carbon and Mitigate the Greenhouse Effect.* CRC Press, New York; and Woodbury, Peter B.; Smith, James E.; Heath, Linda S. 2007, "Carbon sequestration in the U.S. forest sector from 1990 to 2010", *Forest Ecology and Management*, 241:14-27.

[6] Annex 3 to EPA's 2006 report, which contains estimates for calendar year 2004, can be downloaded at: http://yosemite.epa.gov/oar/globalwarming.nsf/UniqueKeyLookup/RAMR6MBLNQ/$File/06_annex_Chapter3.pdf.

[7] Skog, K.E., and G.A. Nicholson (1998), "Carbon cycling through wood products: the role of wood and paper products in carbon sequestration", *Forest Products Journal*, 48(7/8):75-83; or Skog, K.E., K. Pingoud, and J.E. Smith (2004), "A method countries can use to estimate changes in carbon stored in harvested wood products and the uncertainty of such estimates", *Environmental Management*, 33(Suppl. 1): S65-S73.

the USFS to be sequestered annually in wood products.[8] Also, as shown in this table, the total flux estimate including all forest pools is 24.9 $MMtCO_2e$/yr. This total includes a large net source estimate for soil carbon (21.6 $MMtCO_2$/yr). Given the changes noted above in forested area, it appears that much of the positive carbon flux is from the loss of forested lands between 1990 and 2003.

Table H1. USFS Forest Carbon Pool Data for Minnesota

Forest Pool	**1990 (MMtC)**	**2003 (MMtC)**
Live Tree – Above Ground	292	282
Live Tree – Below Ground	58.1	56.2
Understory	12.8	12.5
Standing Dead	29.3	27.4
Down Dead	27.5	26.4
Forest Floor	120	117
Soil Carbon	1,180	1,110
Totals	**1,719**	**1,629**
Forest Area	**1990 (10^3 acres)**	**2003 (10^3 acres)**
All Forests	16,682	16,230
Timberland	14,722	14,759

Positive numbers indicate net emission. Totals may not sum exactly due to independent rounding.
Data source: Jim Smith, USFS, personal communications with S. Roe, CCS, October 2006 and May 2007.

Table H2. USFS Forest Carbon Fluxes for Minnesota

Forest Pool	**1990-2003 Flux (MMtC/yr)**	**1990-2003 Flux ($MMtCO_2$/yr)**
Forest Carbon Pools (non-soil)	1.5	5.5
Soil Organic Carbon	5.9	21.6
Harvested Wood Products	-0.6	-2.2
Totals	**6.8**	**24.9**
Totals (excluding soil carbon)	**0.9**	**3.3**

Positive numbers indicate net emission. Totals may not sum exactly due to independent rounding.
Data source: Jim Smith, USFS, personal communications with S. Roe, CCS, May and July 2007.

Based on discussions with the USFS, CCS recommends excluding the soil carbon pool from the overall forest flux estimates due to high level of uncertainty associated with these estimates. The forest carbon flux estimates provided in the summary tables at the front of this report are those without the soil carbon pool.

[8] Jim Smith, USFS, personal communication with S. Roe, CCS, July 2007.

For historic emission estimates, the Center for Climate Strategies (CCS) used the flux to represent forest carbon flux from 1990 to 2005. For the reference case projections, the forest area and carbon densities of forestlands were assumed to remain at the same levels as in 2003. Information is not available on the near term effects of climate change and their impacts on forest productivity. Nor were data readily-available on projected losses in forested area.

Comparison to Minnesota Pollution Control Agency (MPCA) Estimates
The MPCA provided data to CCS on forest carbon pools in Minnesota. These included estimates of forest carbon based on the same 1990-2003 FIA data (these appear to cover all forest pools except soil carbon and possibly forest floor and understory); carbon pool estimates in Minnesota's landfills; and carbon pool estimates in Minnesota's housing. Based on the pools calculated for 1990 and 2003 a net flux rate of 1.3 MMtC/yr (4.7 $MMtCO_2$/yr) was calculated. The MPCA estimate of 4.7 $MMtCO_2$/yr is fairly close to the USFS estimate of 3.3 $MMtCO_2$/yr, excluding soil carbon. Information was not available on the specific forest carbon pools included in the Minnesota forest carbon analysis, making direct comparison of the estimates difficult. Differences may stem from the inclusion of different forest carbon pools in each analysis, and/or different modeling methods and data sources used by the USFS and MPCA. In addition, the Minnesota analysis accounts for carbon stored in HWP in terms of carbon in landfills and in housing. The USFS categorizes carbon stored in HWP in terms of carbon in landfills and in wood products in use, the latter category being broader than carbon in housing alone.

Key Uncertainties
It should be noted that methane (CH_4) and nitrous oxide (N_2O) emissions from wildfires and prescribed burns have not been included in the estimates presented in Table H1. In work that CCS has completed for a number of western states, where wildfire activity is significant, emission estimates have tended to range from <1 to 3 $MMtCO_2e$/yr. We expect that the emissions from wildfires in Minnesota would be much lower than these levels and to not impact the estimated flux significantly.

It is important to note that there were methodological differences in the two FIA cycles (used to calculate carbon pools and flux) that can produce different estimates of forested area and carbon density. For example, the FIA program modified the definition of forest cover for the woodlands class of forestland (considered to be non-productive forests). Earlier FIA cycles defined woodlands as having a tree cover of at least 10%, while the newer sampling methods used a woodlands definition of tree cover of at least 5% (leading to more area being defined as woodland). In woodland areas, the earlier FIA surveys might not have inventoried trees of certain species or with certain tree form characteristics (leading to differences in both carbon density and forested acreage). It is not clear whether these definitional issues have had a substantial effect on the flux estimates in Minnesota; however CCS' understanding is that these issues have tended to be most important in some western states with significant woodland forested area.

Also, FIA surveys since 1999 include all dead trees on the plots, but data prior to that are variable in terms of these data. The modifications to FIA surveys are a result of an expanded focus in the FIA program, which historically was only concerned with timber resources, while more recent surveys have aimed at a more comprehensive gathering of forest biomass data. In addition, the FIA program has moved from periodic to annual inventory methods. The effect of these changes in survey methods has not been estimated by the USFS.