Appendix H. Forestry & Land Use

Overview

Forestland emissions refer to the net carbon dioxide (CO_2) flux[1] from forested lands in Maryland, which account for about 44% of the state's land area.[2] The dominant forest type in Maryland is Oak-Hickory which makes up about 63% of forested lands. Other common forest types are Loblolly-shortleaf pine at 11% of forested land, and Oak-Pine at 10% of forested land. All other forest types make up less than 6% 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 combustion (both wildfires and biomass removed from forests for energy use). 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.

The forestry sector CO_2 flux is categorized into two primary subsectors:

- *Forested Landscape:* this consists of carbon flux occurring on lands that are not part of the urban landscape. Fluxes covered include net carbon sequestration and carbon stored in harvested wood products (HWP or landfills) ;
- *Urban Forestry and Land Use:* this covers carbon sequestration in urban trees, flux associated with carbon storage from landscape waste and food scraps in landfills, and nitrous oxide emissions from settlement soils (those occurring as a result of application of synthetic fertilizers).

Inventory and Reference Case Projections

Forested Landscape

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 Maryland 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

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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 2.7 million acres in 1997. Acreage by forest type available from the USFS at: http://www.fs.fed.us/ne/global/pubs/books/epa/states/MD.htm. The total land area in Maryland is 6.2 million acres (http://www.50states.com/maryland.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*

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 publications.[5]

Carbon dioxide flux is estimated as the change in carbon mass for each carbon pool over a specified time-frame. Forest biomass data from at least two points in time are required. The change in carbon stocks between time intervals is estimated 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 also include differences in ownership class: 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 2007 GHG inventory for the US.[6]

Carbon pool data for three FIA cycles to estimate flux for two different periods were available for Maryland. The carbon pool data 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 87,000 acres between 1990 and 1999 and a net increase in forested area of 74,000 acres in the 1990-2005 period. Most

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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.

[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 2007 report, which contains estimates for calendar year 2005, can be downloaded at: http://www.epa.gov/climatechange/emissions/downloads06/07Annex3.pdf.

of the forested lands in MD are considered timberland, meaning that these are productive forests. The timberland area is shown to increase by 112,000 acres between 1990 and 2005, which appears to be driving the total gain of 16 million metric tons of carbon from forested areas during that 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] State-level information for MD was provided to CCS by USFS[8].

As shown in Table H2, about 0.3 million metric tons (MMt) of CO_2 per year (yr) is estimated by the USFS to be sequestered annually (1999-2005) in wood products. Also, as shown in this table, the total flux estimate including all forest pools is -8.94 $MMtCO_2e/yr$.[9] This total includes a small net sink estimate for soil carbon (-0.05 $MMtCO_2/yr$). Note that from 1986 to 1999, soil carbon was considered a net source. Given the changes noted above in timberland, it appears that much of the negative carbon flux (sequestration) is from the increase in timberland between 1999 and 2005.

Table H1. USFS Forest Carbon Pool Data for Maryland

Forest Pool	**1990 (MMtC)**	**1999 (MMtC)**	**2005 (MMtC)**
Live Tree – Above Ground	77.8	80.9	91.9
Live Tree – Below Ground	15.0	15.6	17.7
Understory	2.2	2.1	2.2
Standing Dead	4.3	4.2	4.3
Down Dead	6.3	6.5	7.4
Forest Floor	14.4	15.0	13.8
Soil Carbon	68.6	67.1	67.1
Totals	**189**	**191**	**204**
Forest Area	**1990 (10^3 acres)**	**1999 (10^3 acres)**	**2005 (10^3 acres)**
All Forests	2,659	2,572	2,646
Timberland	2,407	2,374	2,519

Totals may not sum exactly due to independent rounding.

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[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.

[8] Obtained from the Harvested Wood Product model developed by Ken Skog, USFS

[9] Jim Smith, USFS, *U.S. Forest Carbon Calculation Tool: Forest-Land Carbon Stocks and Net Annual Stock Change* (http://www.nrs.fs.fed.us/pubs/2394), August 2007.

Data source: Smith, James, et al. *U.S. Forest Carbon Calculation Tool: Forest-Land Carbon Stocks and Net Annual Stock Change* (http://www.nrs.fs.fed.us/pubs/2394), USFS, August 2007.
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Table H2. USFS Forest Carbon Fluxes for Maryland

Forest Pool	1986-1999 Flux (MMtC)	1999-2005 Flux (MMtC)	1986-1999 Flux ($MMtCO_2$)	1999-2005 Flux ($MMtCO_2$)
Forest Carbon Pools (non-soil)	-0.49	-2.34	-1.78	-8.60
Soil Organic Carbon	0.16	-0.01	0.60	-0.05
Harvested Wood Products	-0.08	-0.08	-0.3	-0.3
Forest Wildfires	0.00	0.00	0.01	0.01
Totals	**-0.40**	**-2.44**	**-1.48**	**-8.94**
Totals (excluding soil carbon)	**-0.57**	**-2.42**	**-2.08**	**-8.89**

Totals may not sum exactly due to independent rounding.
Data source: Smith, James, et al. U.S. Forest Carbon Calculation Tool: Forest-Land Carbon Stocks and Net Annual Stock Change (http://www.nrs.fs.fed.us/pubs/2394), USFS, August 2007.
Data source for forest wildfires from MD DNR Forest Service under Wild Fire Acres Burned 2000-2006: http://www.dnr.state.md.us/forests/fire/index.asp

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.

For historic emission estimates, CCS used the 1986-1999 carbon flux to represent forest carbon flux prior to 1999. Current flux estimates (1999 to 2005) are those based on the USFS average for those years. For the reference case projections (2005-2020), the forest area and carbon densities of forestlands were assumed to remain at the same levels as in 2005. 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.

Biomass burned in forest fires emits carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), in addition to many other gases and pollutants. Since CO2 emissions are captured under total carbon flux calculations, CCS used the United States Environmental Protection Agency's (US EPA) State Greenhouse Gas Inventory Tool (SGIT) tool to estimate CH_4 and N_2O emissions. No default data were available for area burned by forest type, so CCS used available state data (2000-2005) from Maryland Department of Natural Resources (MDDNR) Forest Service. An average of the 2000-2006 activity data was used for the years 1990-2005 and the forest type of "other temperate forests" was assumed in the SGIT tool to calculate historical emissions. Projected emissions for 2005-2020 were assumed to be held constant at 2005 emissions.

Urban Forestry & Land Use

GHG emissions for 1990 through 2005 were estimated using the EPA SGIT software and the methods provided in the Emission Inventory Improvement Program (EIIP) guidance document for the sector.[10] In general, the SGIT methodology applies emission factors developed for the US to activity data for the urban forestry sector. Activity data include urban area, urban area with tree cover, amount of landfilled yard trimmings and food scraps, and the total amount of synthetic fertilizer applied to settlement soils (e.g. parks, yards, etc.). This methodology is based on international guidelines developed by sector experts for preparing GHG emissions inventories.[11] Table H3 displays the emissions and reference case projections for Maryland.

Table H3. Urban Forestry Emissions and Reference Case Projections (MMtCO$_2$e)

Subsector	1990	2000	2005	2010	2020
Urban Trees	-1.20	-1.45	-1.58	-1.70	-1.95
Landfilled Yard Trimmings and Food Scraps	-4.51	-1.01	-1.08	-1.20	-1.34
N2O from Settlement Soils	0.02	0.04	0.03	0.03	0.03
Total	**-5.69**	**-2.42**	**-2.62**	**-2.86**	**-3.27**

Data for settlement soils was obtained from AAPFCO (2006) Commercial Fertilizers 2005. Association of American Plant Food Control Officials and The Fertilizer Institute. University of Kentucky, Lexington, KY.

Changes in carbon stocks in urban trees are equivalent to tree growth minus biomass losses resulting from pruning and mortality. Net carbon sequestration was calculated using data on crown cover area. The default urban area data in SGIT (which varied from 3,873 km^2 to 5,083 km^2 between 1990 and 2005) was multiplied by the state estimate of the percent of urban area with tree cover (40% for Maryland) to estimate the total area of urban tree cover. These default SGIT urban area tree cover data represent area estimates taken from the U.S. Census and coverage for years 1990 and 2000.[12] Estimates of urban area in the intervening years (1990-1999) and subsequent years (2001-2005) are interpolated and extrapolated, respectively.

Estimates of net carbon flux of landfilled yard trimmings and food scraps were calculated by estimating the change in landfill carbon stocks between inventory years. The SGIT estimates for the amount of landfilled yard trimmings decreased significantly during the 1990's. CCS believes that this is consistent with changes in the waste management industry during this period.

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[10] GHG emissions were calculated using SGIT, with reference to EIIP, Volume VIII: Chapter 8.

[11] Revised 1996 1ntergovermental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories, published by the National Greenhouse Gas Inventory Program of the IPCC, available at (http://www.ipcc-nggip.iges.or.jp/public/gl/invs1.htm; and Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, published in 2000 by the National Greenhouse Gas Inventory Program of the IPCC, available at: (http://www.ipcc-nggip.iges.or.jp/public/gp/english/).

[12] Dwyer, John F.; Nowak, David J.; Noble, Mary Heather; Sisinni, Susan M. 2000. Connecting people with ecosystems in the 21st century: an assessment of our nation's urban forests. Gen. Tech. Rep. PNW-GTR-490

Therefore, the forecast was based on an extrapolation of the flux from 2000-2005, which show relatively constant rates of landfilling these materials.

Settlement soils include all developed land, transportation infrastructure and human settlements of any size. Projections for urban trees and settlement soils were based on linear extrapolation of the 1990-2005 historical data. Table H4 provides a summary of the estimated flux for the entire forestry and land use sector.

Table H4. Forestry and Land Use Flux and Reference Case Projections (MMtCO$_2$e)

	1990	2000	2005	2010	2020
Forested Landscape (excluding soil carbon)	-2.08	-8.89	-8.89	-8.89	-8.89
Urban Forestry and Land Use	-5.69	-2.42	-2.62	-2.86	-3.27
Sector Total	**-7.77**	**-11.31**	**-11.51**	**-11.75**	**-12.16**

Key Uncertainties

Emissions from wildfires in Maryland were estimated based on an average of acres burned from 2000-2006. 1990-1999 historic emissions were not available to give a better estimate. Future forecasts are hard to estimate given the large swings in fire activity from year to year. Although emissions from wildfires in Maryland are very small and they do not impact the estimated flux significantly.

It is important to note that there were methodological differences in the three 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). Given that the forested land in MD is dominated by timberlands (productive forests), CCS does not believe that the definitional differences noted above have had a significant impact on the forest flux estimates provided in this report.

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.

Much of the urban forestry & land use emission estimates rely on national default data and could be improved with state-specific information.