Appendix H. Forestry and Land Use

Overview

Forestland emissions refer to the net carbon dioxide (CO_2) flux[1] from forested lands in Arkansas, which account for about 57% of the state's land area.[2] The dominant forest types in Arkansas are Oak-hickory which makes up about 39% of forested lands. Other common forest types are Loblolly-shortleaf pine at 28%, Oak-pine at 17%, and at Oak-gum-cypress at 15% of forested land. All other forest types make up less than 2% 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 forest fires 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, carbon stored in harvested wood products (HWP) or landfills, and emissions from forest fires and prescribed burning.
- *Urban Forestry and Land Use:* this covers carbon sequestration in urban trees, flux associated with carbon storage from landscape waste and food scraps into landfills, and nitrous oxide (N_2O) 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 Arkansas 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]

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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 18.8 million acres in 1997. Acreage by forest type available from the USFS at: http://www.fs.fed.us/ne/global/pubs/books/epa/states/AR.htm. The total land area in Arkansas is 33.3 million acres (http://www.50states.com/arkansas.htm).
[3] The most current citation for an overview of how the USFS calculates the inventory based forest carbon estimates as well as carbon in harvested wood products is from the US Inventory of Greenhouse Gas Emissions and Sinks: 1990-2005 (and earlier editions), US Environmental Protection Agency, Report # USEPA #430-R-07-002, April 2007, available at: 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), *US Forest*

The forest CO_2 flux methodology relies on input data in the form of plot-level forest volume statistics from the Forest Inventory and Analysis (FIA) Program. 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 FORCARB2 system is provided in a number of publications.[5]

Carbon dioxide flux is estimated using 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 and 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 designations of 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 Arkansas. The carbon pool data for three points in time are shown in Table H1 below. Note that prior to 1995, the Southern FIA Program took periodic forest inventory surveys for Arkansas (approximately on a 10-year schedule). Beginning in 1999, Arkansas transitioned from periodic to annual inventories as modifications to the FIA program were applied. The annual inventory measures 20% of the plots in Arkansas each year and delivers a complete inventory report every 5 years.

Carbon Calculation Tool User's Guide: Forestland Carbon Stocks and Net Annual Stock Change, Gen Tech Report, Newtown Square, PA: US 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: US 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 US 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 US 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.

The underlying FIA data, as shown in Table H1, display a net increase in forested area: an increase of 1.1 million acres between 1988 and 1995, and an increase in forested area of 40,000 acres between 1995 and 2005. Most of the forested lands in Arkansas are considered timberland, meaning they are unreserved productive forestland producing (or capable of producing) crops of industrial wood. The timberland area is shown to have increased by 1.1 million acres between 1988 and 1995, while it only increased 88,000 acres between 1995 and 2005. This increase in timberland area resulted in the tremendous increase in carbon (81 million metric tons) from forested areas between 1988 and 1995, and a smaller increase in carbon (28 million metric tons) from 1995 to 2005.

Table H1. USFS Forest Carbon Pool Data for Arkansas

Forest Pool	1988 (MMtC)	1995 (MMtC)	2005 (MMtC)
Live Tree – Above Ground	358	402	422
Live Tree – Below Ground	70.7	79.4	83.2
Understory	21.7	22.7	23.0
Standing Dead	16.8	17.9	17.7
Down Dead	28.7	32.6	34.2
Forest Floor	55.9	60.0	62.9
Soil Carbon	302	321	320
Totals	**854**	**935**	**963**
Forest Area	**1988 (10^3acres)**	**1995 (10^3 acres)**	**2005 (10^3 acres)**
All Forests	17,687	18,790	18,830
Timberland	17,247	18,392	18,480

MMtC = million metric tons of carbon. Positive numbers indicate net emission. Multiply MMtC by 3.667 (44/12) to convert to $MMtCO_2$.

Totals may not sum exactly due to independent rounding.

Data source: Smith, James, et al. *US Forest Carbon Calculation Tool: Forest-Land Carbon Stocks and Net Annual Stock Change* (http://www.nrs.fs.fed.us/pubs/2394), December 2007.

Table H2 shows the annualized carbon stocks interpolated from Arkansas FIA data using the Carbon Calculation Tool (CCT)[7]. These annualized carbon stocks differ from the carbon stocks in Table H1 in that they are interpolated values (between forest inventory years) to January 1st of each year. The difference in carbon between each consecutive year is the carbon flux for that year. The carbon fluxes for each period shown in Table H3 are based on these annualized carbon stock estimates.

[7] Smith, James, et al. *US Forest Carbon Calculation Tool: Forest-Land Carbon Stocks and Net Annual Stock Change* (http://www.nrs.fs.fed.us/pubs/2394), November 2007.

Table H2: Annualized Forest Carbon Pool from Carbon Calculation Tool

Forest Pool	1990 (MMtC)	1995 (MMtC)	2005 (MMtC)
Live Tree – Above Ground	370	398	426
Live Tree – Below Ground	73.1	78.7	84.1
Understory	21.9	22.6	23.1
Standing Dead	17.1	17.8	17.6
Down Dead	29.8	32.3	34.7
Forest Floor	57.0	59.6	63.6
Soil Carbon	307	319	320
Totals	**876**	**929**	**969**
Forest Area	**1990 (10^3 acres)**	**1995 (10^3 acres)**	**2005 (10^3 acres)**
All Forests	17,990	18,702	18,839
Timberland	17,561	18,301	18,499

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). HWP include durable wood products (e.g., lumber and furniture) and other wood products (e.g., paper). Carbon remains stored in the durable wood products pool; wood products that become waste are 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 (WOODCARB2 also accounts for wood harvested for energy production).[8] State-level information for Arkansas was provided to CCS by USFS[9].

As shown in Table H3, about 4.7 million metric tons (MMt) of CO_2 per year (yr) is estimated by the USFS to be sequestered annually (1990-2005) in wood products. Also, as shown in this table, the total flux estimate including all forest pools fluctuates between -43 MMtCO_2e/yr (between 1988 and 1995) and -18 MMtCO_2e/yr (between 1995 and 2005).[10] This fluctuation is due to lower forest carbon sequestration both in the non-soil pools as well as the soil organic carbon pool in the second period. Note that from 1988-1995 soil carbon was considered a net sink, and from 1995-2005, it is a net source. These types of changes often relate to conversions in forested land to developed use. Given the changes noted above in timberland, it appears that much of the higher levels of sequestration seen in the earlier period relate to a significant land use change into forested use (possibly from agricultural land use).

[8] 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.
[9] Obtained from the Harvested Wood Product model developed by Ken Skog, USFS
[10] Jim Smith, USFS, *US. Forest Carbon Calculation Tool: Forest-Land Carbon Stocks and Net Annual Stock Change* (http://www.nrs.fs.fed.us/pubs/2394), December 2007.

Table H3. USFS Annual Forest Carbon Fluxes for Arkansas

Forest Pool	1988-1995 Flux ($MMtCO_2$)	1995-2005 Flux ($MMtCO_2$)
Forest Carbon Pools (non-soil)	-29.5	-13.5
Soil Organic Carbon	-8.92	0.36
Harvested Wood Products	-4.69	-4.69
Totals	**-43.2**	**-17.8**
Totals (excluding soil carbon)	**-34.2**	**-18.2**

Totals may not sum exactly due to independent rounding.
Data source: Smith, James, et al. US Forest Carbon Calculation Tool: Forest-Land Carbon Stocks and Net Annual Stock Change (http://www.nrs.fs.fed.us/pubs/2394), USFS, December 2007.

Based on discussions with the USFS, CCS recommends excluding the soil carbon pool from the overall forest flux estimates due to a 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 1988-1995 carbon flux to represent yearly forest carbon flux prior to 1995. Current flux estimates (1995-2005) are from the 1995 inventory and 2005 annual inventory stocks. For the reference case projections (2005-2025), 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.

Forest Fires and Prescribed Burns

Biomass burned in forest fires emits CO_2, methane (CH_4), and N_2O, in addition to many other gases and pollutants. Since CO_2 emissions are captured under the total carbon flux calculations above, CCS used the United States Environmental Protection Agency's (US EPA) State Greenhouse Gas Inventory Tool (SIT) to estimate CH_4 and N_2O emissions. No default data were available for area burned by forest type, so CCS used state data from the Arkansas Forestry Commission.[11] Forest fire acres burned data for each year (1990-2005) were entered in SIT under the "other temperate forests" category to calculate historical emissions. Projected emissions for 2005-2025 were held constant at 2005 levels. The emission estimates are presented at the end of this section. No data were identified for prescribed burn acreage.

[11] Wildfire acres burned data obtained from Arkansas Forestry Commission (http://www.forestry.state.ar.us/protect/firestats.html) under Fires by Month, downloaded December 2007.

Urban Forestry and Land Use

GHG emissions for 1990 through 2005 were estimated using the EPA SIT software and the methods provided in the Emission Inventory Improvement Program (EIIP) guidance document for the sector.[12] In general, the SIT 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.[13] Table H4 displays the emissions and reference case projections for Arkansas.

Table H4. Urban Forestry Emissions and Reference Case Projections (MMtCO$_2$e)

Urban Forestry and Land Use Subsector	1990	2000	2005	2010	2020	2025
Urban Trees	-0.37	-0.46	-0.50	-0.50	-0.50	-0.50
Landfilled Yard Trimmings and Food Scraps	-2.16	-0.50	-0.52	-0.52	-0.52	-0.52
N_2O from Settlement Soils	0.10	0.13	0.11	0.11	0.11	0.11
Total	**-2.43**	**-0.83**	**-0.91**	**-0.91**	**-0.91**	**-0.91**

*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 SIT (which varied from 1,897 square kilometers [km^2] to 2,587 km^2 between 1990 and 2005) was multiplied by the state estimate of the percent of urban area with tree cover (25% for Arkansas) to estimate the total area of urban tree cover. These default SIT urban area tree cover data represent area estimates taken from the US Census and coverage for years 1990 and 2000.[14] 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 SIT estimates for the amount of landfilled yard trimmings decreased significantly during the 1990's.

[12] GHG emissions were calculated using SIT, with reference to EIIP, Volume VIII: Chapter 8.
[13] 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/).
[14] 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

Settlement soils include all developed land, transportation infrastructure and human settlements of any size. Projections for urban trees, landfilled yard trimmings and food scraps, and settlement soils were kept constant at 2005 levels. Table H5 provides a summary of the estimated flux for the entire forestry and land use sector.

Table H5. Forestry and Land Use Flux and Reference Case Projections (MMtCO_2e)

Subsector	1990	2000	2005	2010	2020	2025
Forested Landscape (excluding soil carbon)	-34.2	-18.2	-18.2	-18.2	-18.2	-18.2
Forest Fires and Prescribed Burns	0.17	0.18	0.18	0.18	0.18	0.18
Urban Forestry and Land Use	-2.43	-0.83	-0.91	-0.91	-0.91	-0.91
Sector Total	**-36.5**	**-18.8**	**-18.9**	**-18.9**	**-18.9**	**-18.9**

Key Uncertainties

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 Arkansas 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 surveys 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 and land use emission estimates rely on national default data and could be improved with state-specific information.