Appendix H. Forestry & Land Use

Overview

Forestland emissions refer to the net carbon dioxide (CO_2) flux[1] from forested lands in Florida, which account for about 47% of the state's land area.[2] The dominant forest type in Florida is Longleaf-slash pine which makes up about 36% of forested lands. Other common forest types are Oak-gum-cypress at 26%, Oak-hickory at 13%, and at Oak-pine at 9% 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, carbon stored in harvested wood products (HWP) or landfills, and emissions from forest fires.
- *Urban Forestry and Land Use:* this covers carbon sequestration in urban trees, carbon flux associated with carbon storage from landscape waste and food scraps in landfills, and nitrous oxide (N_2O) emissions from settlement soils (those occurring as a result of application of synthetic fertilizers in urbanized areas).

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 Florida 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 16.2 million acres in 1997. Acreage by forest type available from the USFS at: http://www.fs.fed.us/ne/global/pubs/books/epa/states/FL.htm. The total land area in Florida is 34.6 million acres (http://www.50states.com/Florida.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 (see Table H1 for Florida 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 Florida. 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 Florida (approximately on a 10-year schedule). Beginning in 2001, Florida transitioned from periodic to annual inventories as modifications to the FIA program were applied. The annual inventory measures 20% of the plots in Florida each year and delivers a complete inventory report every 5 years. Florida completed its first annual inventory cycle in 2005.

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.

These underlying FIA data, as shown in Table H1, display a net decrease of 402,000 acres in forested area between 1987 and 2005. Between 1987 and 1995, forested area decreased a significant 663,000 acres; forested area increased 261,000 acres from 1995 to 2005. Most of the forested lands in Florida 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 decreased by 332,000 acres between 1987 and 1995 while it increased 901,000 acres between 1995 and 2005. This increase in timberland area kept total carbon levels in 2005 (1,100 million metric tons) similar to the carbon level in 1987 (1,116 million metric tons). It is not clear based on currently available information how much of this growth in forested area is due to methodological changes (see Key Uncertainties section below) or land use conversion (e.g. agricultural use to forested use).

Table H1. USFS Forest Carbon Pool Data for Florida

Forest Pool	1987 (MMtC)	1995 (MMtC)	2005 (MMtC)
Live Tree – Above Ground	242	236	275
Live Tree – Below Ground	48.9	47.8	55.4
Understory	21.1	20.6	20.5
Standing Dead	11.4	11.2	11.1
Down Dead	19.0	18.7	22.2
Forest Floor	51.4	49.5	51.5
Soil Carbon	722	662	664
Totals	**1,116**	**1,046**	**1,100**
Forest Area	**1987 (10^3 acres)**	**1995 (10^3 acres)**	**2005 (10^3 acres)**
All Forests	16,549	15,866	16,147
Timberland	14,983	14,651	15,552

MMtC = million metric tons of carbon. Positive numbers indicate net emission. Multiply MMtC by 3.67 (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 Florida 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

[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.

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.

Table H2. Annualized Forest Carbon Pools from USFS Carbon Calculation Tool

Forest Pool	1990 (MMtC)	1995 (MMtC)	2005 (MMtC)
Live Tree – Above Ground	240	238	281
Live Tree – Below Ground	48.5	48.3	56.5
Understory	20.9	20.6	20.5
Standing Dead	11.3	11.2	11.1
Down Dead	18.9	18.9	22.7
Forest Floor	50.7	49.6	51.8
Soil Carbon	699	662	665
Totals	**1,090**	**1,049**	**1,108**
Forest Area	**1990 (10^3 acres)**	**1995 (10^3 acres)**	**2005 (10^3 acres)**
All Forests	16,290	15,881	16,188
Timberland	14,857	14,700	15,684

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.[8] State-level information for Florida was provided to CCS by USFS.[9]

As shown in Table H2, about 3.9 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 is 31.5 MMtCO_2e/yr between 1987and 1995, and -25.4 MMtCO_2e/yr between 1995 and 2005.[10] This fluctuation is largely due to significant differences in forest carbon pools from each cycle period (note the differences in Table H2 on forested area between these two periods), as well as the fluctuation in the soil organic carbon pool. Note that from 1995 to 2005, soil carbon was considered a net sink, in addition to each all of the forest carbon pools collectively. Given the changes noted above in timberland, it appears that much of the negative trend in carbon flux (sequestration) is from the increase in timberland between 1995 and 2005.

[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 H2. USFS Annual Forest Carbon Fluxes for Florida

Forest Pool	1987-1995 Flux (MMtCO2)	1995-2005 Flux (MMtCO2)
Forest Carbon Pools (non-soil)	4.85	-20.6
Soil Organic Carbon	30.6	-0.92
Harvested Wood Products	-3.89	-3.89
Totals	**31.5**	**-25.4**
Totals (excluding soil carbon)	**0.96**	**-24.5**

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 1987-1995 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/gains in forested area.

Urban Forestry & Land Use

GHG emissions for 1990 through 2005 were estimated using the EPA State Inventory Tool (SIT) software and the methods provided in the Emission Inventory Improvement Program (EIIP) guidance document for the sector.[11] 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.[12] Table H3 displays the emissions and reference case projections for Florida.

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

Table H3. Urban Forestry Emissions and Reference Case Projections ($MMtCO_2e$)

Urban Forestry & Land Use Subsector	1990	2000	2005	2010	2020	2025
Urban Trees	-1.78	-2.31	-2.58	-2.58	-2.58	-2.58
Landfilled Yard Trimmings and Food Scraps	-12.8	-3.44	-3.75	-3.75	-3.75	-3.75
N_2O from Settlement Soils	0.1	0.1	0.1	0.1	0.1	0.1
Total	**-14.4**	**-5.65**	**-6.23**	**-6.23**	**-6.23**	**-6.23**

*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 12,518 square kilometers [km^2] to 18,131 km^2 between 1990 and 2005) was multiplied by the state estimate of the percent of urban area with tree cover (18% for Florida) 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.[13] 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. Carbon stock estimates were calculated by determining the mass of landfilled carbon resulting from yard trimmings or food scraps discarded in a given year, adding the accumulated landfilled carbon from previous years, and subtracting the portion of carbon landfilled in previous years that decomposed. Default SIT landfilled yard trimmings and food scraps data were estimated using the Florida State population and the national yard trimmings and food scraps ratio. Along with the national trend, Florida's landfilled yard trimmings and food scraps decreased significantly during the 1990's. This is largely due to programs discouraging or banning disposal and a dramatic increase in the number of municipal composting facilities, which reduced the proportion of collected yard trimmings that are discarded in landfills.[14] This decrease in landfilled yard trimmings and food scraps disposal rate has resulted in a decrease in the rate of landfill carbon storage to 3.75 $MMtCO_2e$ in 2005 from 12.8 $MMtCO_2e$ in 1990.

Settlement soils include all developed land, transportation infrastructure and human settlements of any size. N_2O emissions from settlement soils were calculated in SIT using default synthetic fertilizer data multiplied by N_2O emission factor. Future projections of CO_2 fluxes from urban trees, landfilled yard trimmings and food scraps, and settlement soils were kept constant at 2005

(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/).

[13] 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

[14] INVENTORY OF U.S. GREENHOUSE GAS EMISSIONS AND SINKS: 1990-2005, Land Use, Land Use Change and Forestry (http://www.epa.gov/climatechange/emissions/usinventoryreport.html).

levels. Table H4 provides a summary of the estimated flux for the entire forestry and land use sector.

Wildfire and Prescribed Burning Emissions

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 total carbon flux calculations in USFS' modeling described above, CCS used SIT 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 from Florida Department of Agriculture & Consumer Services.[15] Wildfire acres burned data were used for the years 1990-2005 and the forest type of "other temperate forests" was assumed in SIT to calculate historical emissions. Projected emissions for 2005-2025 were assumed to be held constant at 2005 emissions level. The emission estimates are presented at the end of this section.

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

Subsector	1990	2000	2005	2010	2020	2025
Forested Landscape (excluding soil carbon)	0.96	-24.5	-24.5	-24.5	-24.5	-24.5
Urban Forestry and Land Use	-14.5	-5.65	-6.23	-6.23	-6.23	-6.23
Wildfires & Prescribed Burns	1.35	1.15	0.16	0.16	0.16	0.16
Sector Total	**-12.1**	**-29**	**-30.6**	**-30.6**	**-30.6**	**-30.6**

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). This issue is probably of more relevance in the western US. Also, 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 Florida 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; however additional input from technical workgroup members and state foresters is needed.

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

[15] Wildfire acres burned data obtained from Florida Department of Agriculture & Consumer Services, Division of Forestry, Wildland Fire (http://tlhforweb1.doacs.state.fl.us/PublicReports/), December 2007.

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. In particular, the carbon flux estimates associated with landfilled food and yard waste should be reviewed and revised, as data are available. Given, the level of urbanization and population growth in FL during the 1990's, it does not seem likely that levels of landfilled food and yard waste would have fallen during this period.