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INVENTORY OF U.S. GREENHOUSE GAS EMISSIONS AND SINKS:

1990 - 2009

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an urban forest inventory program so that urban forest area estimates will be consistent with FIA forest area estimates outside of urban areas, which would be expected to reduce omissions and overlap of forest area estimates along urban boundary areas.

7.2. Forest Land Remaining Forest Land

Changes in Forest Carbon Stocks (IPCC Source Category 5A1)

For estimating C stocks or stock change (flux), C in forest ecosystems can be divided into the following five storage pools (IPCC 2003):

- Aboveground biomass, which includes all living biomass above the soil including stem, stump, branches, bark, seeds, and foliage. This category includes live understory.
- Belowground biomass, which includes all living biomass of coarse living roots greater than 2 mm diameter.
- Dead wood, which includes all non-living woody biomass either standing, lying on the ground (but not including litter), or in the soil.
- Litter, which includes the litter, fumic, and humic layers, and all non-living biomass with a diameter less than 7.5 cm at transect intersection, lying on the ground.
- Soil organic C (SOC), including all organic material in soil to a depth of 1 meter but excluding the coarse roots of the aboveground pools.

In addition, there are two harvested wood pools necessary for estimating C flux:

- Harvested wood products (HWP) in use.
- HWP in solid waste disposal sites (SWDS).

C is continuously cycled among these storage pools and between forest ecosystems and the atmosphere as a result of biological processes in forests (e.g., photosynthesis, respiration, growth, mortality, decomposition, and disturbances such as fires or pest outbreaks) and anthropogenic activities (e.g., harvesting, thinning, clearing, and replanting). As trees photosynthesize and grow, C is removed from the atmosphere and stored in living tree biomass. As trees die and otherwise deposit litter and debris on the forest floor, C is released to the atmosphere or transferred to the soil by organisms that facilitate decomposition.

The net change in forest C is not equivalent to the net flux between forests and the atmosphere because timber harvests do not cause an immediate flux of C of all vegetation C to the atmosphere. Instead, harvesting transfers a portion of the C stored in wood to a "product pool." Once in a product pool, the C is emitted over time as CO_2 when the wood product combusts or decays. The rate of emission varies considerably among different product pools. For example, if timber is harvested to produce energy, combustion releases C immediately. Conversely, if timber is harvested and used as lumber in a house, it may be many decades or even centuries before the lumber decays and C is released to the atmosphere. If wood products are disposed of in SWDS, the C contained in the wood may be released many years or decades later, or may be stored almost permanently in the SWDS.

This section quantifies the net changes in C stocks in the five forest C pools and two harvested wood pools. The net change in stocks for each pool is estimated, and then the changes in stocks are summed over all pools to estimate total net flux. The focus on C implies that all C-based greenhouse gases are included, and the focus on stock change suggests that specific ecosystem fluxes do not need to be separately itemized in this report. Disturbances from forest fires and pest outbreaks are implicitly included in the net changes. For instance, an inventory conducted after fire counts only the trees that are left. The change between inventories thus accounts for the C changes due to fires; however, it may not be possible to attribute the changes to the disturbance specifically. The IPCC (2003) recommends reporting C stocks according to several land-use types and conversions, specifically *Forest Land Remaining Forest Land* and *Land Converted to Forest Land*. Currently, consistent datasets are just becoming available for the conterminous United States to allow forest land conversions and forest land remaining forest land to be identified, and research is ongoing to properly use that information based on research results. Thus, net changes in all forest-related land, including non-forest land converted to forest and forests converted to non-forest, are reported here.

Forest C storage pools, and the flows between them via emissions, sequestration, and transfers, are shown in Figure 7-2. In the figure, boxes represent forest C storage pools and arrows represent flows between storage pools or between storage pools and the atmosphere. Note that the boxes are not identical to the storage pools identified in this chapter. The storage pools identified in this chapter have been refined in this graphic to better illustrate the processes that result in transfers of C from one pool to another, and emissions to as well as uptake from the atmosphere.

Figure 7-2: Forest Sector Carbon Pools and Flows

Approximately 33 percent (304 million hectares) of the U.S. land area is forested (Smith et al. 2009). The current forest carbon inventory includes 271 million hectares in the conterminous 48 states (USDA Forest Service 2010a, 2010b) that are considered managed and are included in this inventory. An additional 6.1 million hectares of southeast and south central Alaskan forest are inventoried and are included here. Three notable differences exist in forest land defined in Smith et al. (2009) and the forest land included in this report, which is based on USDA Forest Service (2010b). Survey data are not yet available from Hawaii and a large portion of interior Alaska, but estimates of these areas are included in Smith et al. (2009). Alternately, survey data for west Texas has only recently become available, and these forests contribute to overall carbon stock reported below. While Hawaii and U.S. territories have relatively small areas of forest land and will thus probably not influence the overall C budget substantially, these regions will be added to the C budget as sufficient data become available. Agroforestry systems are also not currently accounted for in the inventory, since they are not explicitly inventoried by either the Forest Inventory and Analysis (FIA) program of the U.S. Department of Agriculture (USDA) Forest Service or the National Resources Inventory (NRI) of the USDA Natural Resources Conservation Service (Perry et al. 2005).

Sixty-eight percent of U.S. forests (208 million hectares) are classified as timberland, meaning they meet minimum levels of productivity. Nine percent of Alaska forests overall and 81 percent of forests in the conterminous United States are classified as timberlands. Of the remaining nontimberland forests, 30 million hectares are reserved forest lands (withdrawn by law from management for production of wood products) and 66 million hectares are lower productivity forest lands (Smith et al. 2009). Historically, the timberlands in the conterminous 48 states have been more frequently or intensively surveyed than other forest lands.

Forest land area declined by approximately 10 million hectares over the period from the early 1960s to the late 1980s. Since then, forest area has increased by about 12 million hectares. Current trends in forest area represent average annual change of less than 0.2 percent. Given the low rate of change in U.S. forest land area, the major influences on the current net C flux from forest land are management activities and the ongoing impacts of previous land-use changes. These activities affect the net flux of C by altering the amount of C stored in forest ecosystems. For example, intensified management of forests that leads to an increased rate of growth increases the eventual biomass density of the forest, thereby increasing the uptake of C.[176] Though harvesting forests removes much of the aboveground C, on average the volume of annual net growth nationwide is about 72 percent higher than the volume of annual removals on timberlands (Smith et al. 2009). The reversion of cropland to forest land increases C storage in biomass, forest floor, and soils. The net effects of forest management and the effects of land-use change involving forest land are captured in the estimates of C stocks and fluxes presented in this chapter.

In the United States, improved forest management practices, the regeneration of previously cleared forest areas, and timber harvesting and use have resulted in net uptake (i.e., net sequestration) of C each year from 1990 through 2009. The rate of forest clearing begun in the 17th century following European settlement had slowed by the late 19th century. Through the later part of the 20th century many areas of previously forested land in the United States were allowed to revert to forests or were actively reforested. The impacts of these land-use changes still influence C fluxes from these forest lands. More recently, the 1970s and 1980s saw a resurgence of federally-sponsored forest management programs (e.g., the Forestry Incentive Program) and soil conservation programs (e.g., the Conservation Reserve Program), which have focused on tree planting, improving timber management activities, combating soil erosion, and converting marginal cropland to forests. In addition to forest regeneration and management, forest

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[176] The term "biomass density" refers to the mass of live vegetation per unit area. It is usually measured on a dry-weight basis. Dry biomass is 50 percent C by weight.

harvests have also affected net C fluxes. Because most of the timber harvested from U.S. forests is used in wood products, and many discarded wood products are disposed of in SWDS rather than by incineration, significant quantities of C in harvested wood are transferred to long-term storage pools rather than being released rapidly to the atmosphere (Skog and Nicholson 1998, Skog 2008). The size of these long-term C storage pools has increased during the last century.

Changes in C stocks in U.S. forests and harvested wood were estimated to account for net sequestration of 863 Tg CO_2 Eq. (235 Tg C) in 2009 (Table 7-6, Table 7-7, and Table 7-8). In addition to the net accumulation of C in harvested wood pools, sequestration is a reflection of net forest growth and increasing forest area over this period. Overall, average C in forest ecosystem biomass (aboveground and belowground) increased from 67 to 73 Mg C/ha between 1990 and 2010 (see Annex 3-12 for average C densities by specific regions and forest types). Continuous, regular annual surveys are not available over the period for each state; therefore, estimates for non-survey years were derived by interpolation between known data points. Survey years vary from state to state, and national estimates are a composite of individual state surveys. Therefore, changes in sequestration over the interval 1990 to 2009 are the result of the sequences of new inventories for each state. C in forest ecosystem biomass had the greatest effect on total change through increases in C density and total forest land. Management practices that increase C stocks on forest land, as well as afforestation and reforestation efforts, influence the trends of increased C densities in forests and increased forest land in the United States.

The decline in net additions to HWP carbon stocks continued though 2009 from the recent high point in 2006. This is due to sharp declines in U.S. production of solidwood and paper products in 2009 primarily due to the decline in housing construction. The low level of gross additions to solidwood and paper products in use in 2009 was exceeded by discards from uses. The result is a net reduction in the amount of HWP carbon that is held in products in use during 2009. For 2009, additions to landfills still exceeded emissions from landfills and the net additions to landfills have remained relatively stable. Overall, there were net carbon additions to HWP in use and in landfills combined in 2009.

Table 7-6: Net Annual Changes in C Stocks (Tg CO_2/yr) in Forest and Harvested Wood Pools

Carbon Pool	1990		2000		2005	2006	2007	2008	2009
Forest	**(549.3)**		**(265.4)**		**(806.1)**	**(808.9)**	**(808.9)**	**(808.9)**	**(808.9)**
Aboveground Biomass	(360.0)		(287.0)		(447.9)	(447.9)	(447.9)	(447.9)	(447.9)
Belowground Biomass	(70.9)		(57.5)		(88.4)	(88.4)	(88.4)	(88.4)	(88.4)
Dead Wood	(31.6)		(12.9)		(30.8)	(33.5)	(33.5)	(33.5)	(33.5)
Litter	(32.2)		27.5		(41.9)	(41.9)	(41.9)	(41.9)	(41.9)
Soil Organic Carbon	(54.7)		64.6		(197.2)	(197.2)	(197.2)	(197.2)	(197.2)
Harvested Wood	**(131.8)**		**(112.9)**		**(105.4)**	**(108.6)**	**(103.0)**	**(82.1)**	**(54.3)**
Products in Use	(64.8)		(47.0)		(45.4)	(45.1)	(39.1)	(19.1)	6.8
SWDS	(67.0)		(65.9)		(59.9)	(63.4)	(63.8)	(63.0)	(61.1)
Total Net Flux	**(681.1)**		**(378.3)**		**(911.5)**	**(917.5)**	**(911.9)**	**(891.0)**	**(863.1)**

Note: Forest C stocks do not include forest stocks in U.S. territories, Hawaii, a portion of managed forests in Alaska, or trees on non-forest land (e.g., urban trees, agroforestry systems). Parentheses indicate net C sequestration (i.e., a net removal of C from the atmosphere). Total net flux is an estimate of the actual net flux between the total forest C pool and the atmosphere. Forest area estimates are based on interpolation and extrapolation of inventory data as described in the text and in Annex 3.12. Harvested wood estimates are based on results from annual surveys and models. Totals may not sum due to independent rounding.

Table 7-7: Net Annual Changes in C Stocks (Tg C/yr) in Forest and Harvested Wood Pools

Carbon Pool	1990		2000		2005	2006	2007	2008	2009
Forest	**(149.8)**		**(72.4)**		**(219.9)**	**(220.6)**	**(220.6)**	**(220.6)**	**(220.6)**
Aboveground Biomass	(98.2)		(78.3)		(122.1)	(122.1)	(122.1)	(122.1)	(122.1)
Belowground Biomass	(19.3)		(15.7)		(24.1)	(24.1)	(24.1)	(24.1)	(24.1)
Dead Wood	(8.6)		(3.5)		(8.4)	(9.1)	(9.1)	(9.1)	(9.1)

Litter	(8.8)	7.5	(11.4)	(11.4)	(11.4)	(11.4)	(11.4)
Soil Organic C	(14.9)	17.6	(53.8)	(53.8)	(53.8)	(53.8)	(53.8)
Harvested Wood	**(35.9)**	**(30.8)**	**(28.7)**	**(29.6)**	**(28.1)**	**(22.**4)	**(14.8)**
Products in Use	(17.7)	(12.8)	(12.4)	(12.3)	(10.7)	(5.2)	1.9
SWDS	(18.3)	(18.0)	(16.3)	(17.3)	(17.4)	(17.2)	(16.7)
Total Net Flux	**(185.7)**	**(103.2)**	**(248.6)**	**(250.2)**	**(248.7)**	**(243.**0)	**(235.4)**

Note: Forest C stocks do not include forest stocks in U.S. territories, Hawaii, a portion of managed lands in Alaska, or trees on non-forest land (e.g., urban trees, agroforestry systems). Parentheses indicate net C sequestration (i.e., a net removal of C from the atmosphere). Total net flux is an estimate of the actual net flux between the total forest C pool and the atmosphere. Harvested wood estimates are based on results from annual surveys and models. Totals may not sum due to independent rounding.

Stock estimates for forest and harvested wood C storage pools are presented in Table 7-8. Together, the aboveground live and forest soil pools account for a large proportion of total forest C stocks. C stocks in all non-soil pools increased over time. Therefore, C sequestration was greater than C emissions from forests, as discussed above. Figure 7-4 shows county-average C densities for live trees on forest land, including both above- and belowground biomass.

Table 7-8: Forest area (1000 ha) and C Stocks (Tg C) in Forest and Harvested Wood Pools

	1990	**2000**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Forest Area (1000 ha)	**269,137**	**274,183**	**276,769**	**277,561**	**278,354**	**279,147**	**279,939**	**280,732**
Carbon Pools (Tg C)								
Forest	**42,783**	**44,108**	**44,886**	**45,105**	**45,326**	**45,547**	**45,767**	**45,988**
Aboveground Biomass	15,072	16,024	16,536	16,658	16,780	16,902	17,024	17,147
Belowground Biomass	2,995	3,183	3,285	3,309	3,333	3,357	3,381	3,405
Dead Wood	2,960	3,031	3,060	3,068	3,077	3,086	3,096	3,105
Litter	4,791	4,845	4,862	4,873	4,885	4,896	4,908	4,919
Soil Organic C	16,96	17,025	17,143	17,197	17,251	17,304	17,358	17,412
Harvested Wood	**1,859**	**2,187**	**2,325**	**2,354**	**2,383**	**2,412**	**2,434**	**2,449**
Products in Use	1,231	1,382	1,436	1,448	1,460	1,471	1,476	1,474
SWDS	628	805	890	906	923	941	958	974
Total C Stock	**44,643**	**46,296**	**47,211**	**47,459**	**47,710**	**47,958**	**48,201**	**48,437**

Note: Forest area estimates include portions of managed forests in Alaska for which survey data are available. Forest C stocks do not include forest stocks in U.S. territories, Hawaii, a large portion of Alaska, or trees on non-forest land (e.g., urban trees, agroforestry systems). Wood product stocks include exports, even if the logs are processed in other countries, and exclude imports. Forest area estimates are based on interpolation and extrapolation of inventory data as described in Smith et al. (2010) and in Annex 3.12. Harvested wood estimates are based on results from annual surveys and models. Totals may not sum due to independent rounding. Inventories are assumed to represent stocks as of January 1 of the inventory year. Flux is the net annual change in stock. Thus, an estimate of flux for 2006 requires estimates of C stocks for 2006 and 2007.

Figure 7-3: Estimates of Net Annual Changes in C Stocks for Major C Pools

Figure 7-4: Average C Density in the Forest Tree Pool in the Conterminous United States, 2009

[BEGIN BOX]

Box 7-2: CO_2 Emissions from Forest Fires

As stated previously, the forest inventory approach implicitly accounts for emissions due to disturbances such as forest fires, because only C remaining in the forest is estimated. Net C stock change is estimated by subtracting consecutive C stock estimates. A disturbance removes C from the forest. The inventory data on which net C stock estimates are based already reflect this C loss. Therefore, estimates of net annual changes in C stocks for U.S. forestland already account for CO_2 emissions from forest fires occurring in the lower 48 states as well as in the proportion of Alaska's managed forest land captured in this inventory. Because it is of interest to quantify the magnitude of CO_2 emissions from fire disturbance, these estimates are being highlighted here, using the full extent of available data. Non-CO_2 greenhouse gas emissions from forest fires are also quantified in a separate section below.

The IPCC (2003) methodology and IPCC (2006) default combustion factor for wildfire were employed to estimate CO_2 emissions from forest fires. CO_2 emissions for wildfires and prescribed fires in the lower 48 states and wildfires in Alaska in 2009 were estimated to be 124.3 Tg CO_2/yr. This amount is masked in the estimate of net annual forest carbon stock change for 2009, however, because this net estimate accounts for the amount sequestered minus any emissions.

Table 7-9: Estimates of CO_2 (Tg/yr) emissions for the lower 48 states and Alaska[1]

Year	CO_2 emitted from Wildfires in Lower 48 States (Tg/yr)	CO_2 emitted from Prescribed Fires in Lower 48 States (Tg/yr)	CO_2 emitted from Wildfires in Alaska (Tg/yr)	Total CO_2 emitted (Tg/yr)
1990	42.1	8.5	+	50.7
2000	225.1	2.1	+	227.3
2005	131.0	24.8	+	155.9
2006	313.6	29.3	+	342.9
2007	284.1	34.0	+	318.1
2008	169.0	20.8	+	189.8
2009	97.1	27.3	+	124.3

+ Does not exceed 0.05 Tg CO_2 Eq.
[1] Note that these emissions have already been accounted for in the estimates of net annual changes in C stocks, which account for the amount sequestered minus any emissions.

[END BOX]

Methodology and Data Sources

The methodology described herein is consistent with IPCC (2003, 2006) and IPCC/UNEP/OECD/IEA (1997). Forest ecosystem C stocks and net annual C stock change are determined according to stock-difference methods, which involve applying C estimation factors to forest inventory data and interpolating between successive inventory-based estimates of C stocks. Harvested wood C estimates are based on factors such as the allocation of wood to various primary and end-use products as well as half-life (the time at which half of amount placed in use will have been discarded from use) and expected disposition (e.g., product pool, SWDS, combustion). An overview of the different methodologies and data sources used to estimate the C in forest ecosystems or harvested wood products is provided here. See Annex 3.12 for details and additional information related to the methods and data.

Forest Ecosystem Carbon from Forest Inventory

Forest ecosystem stock and flux estimates are based on the stock-difference method and calculations for all estimates are in units of C. Separate estimates are made for the five IPCC C storage pools described above. All estimates are based on data collected from the extensive array of permanent forest inventory plots in the United States as well as models employed to fill gaps in field data. Carbon conversion factors are applied at the disaggregated level of each inventory plot and then appropriately expanded to population estimates. A combination of tiers as outlined by IPCC (2006) is used. The Tier 3 biomass C values are from forest inventory tree-level data. The Tier 2 dead organic and soil C pools are based on empirical or process models from the inventory data. All carbon conversion factors are specific to regions or individual states within the U.S., which are further classified according to characteristic forest types within each region.

The first step in developing forest ecosystem estimates is to identify useful inventory data and resolve any inconsistencies among datasets. Forest inventory data were obtained from the USDA Forest Service FIA program (Frayer and Furnival 1999, USDA Forest Service 2010b). Inventories include data collected on permanent inventory plots on forest lands[177] and are organized as a number of separate datasets, each representing a complete inventory, or survey, of an individual state at a specified time. Some of the more recent annual inventories reported for some states include "moving window" averages, which means that a portion—but not all—of the previous year's inventory is updated each year (USDA Forest Service 2010d). Forest C calculations are organized according to these state surveys, and the frequency of surveys varies by state. All available data sets are identified for each state starting with pre-1990 data, and all unique surveys are identified for stock and change calculations. Since C stock change is based on differences between successive surveys within each state, accurate estimates of net C flux thus depend on consistent representation of forest land between these successive inventories. In order to achieve this consistency from 1990 to the present, states are sometimes subdivided into sub-state areas where the sum of sub-state inventories produces the best whole-state representation of C change as discussed in Smith et al. (2010).

The principal FIA datasets employed are freely available for download at USDA Forest Service (2010b) as the Forest Inventory and Analysis Database (FIADB) Version 4.0. However, to achieve consistent representation (spatial and temporal), two other general sources of past FIA data are included as necessary. First, older FIA plot- and tree-level data—not in the current FIADB format—are used if available. Second, Resources Planning Act Assessment (RPA) databases, which are periodic, plot-level only, summaries of state inventories, are used mostly to provide the data at or before 1990. An additional forest inventory data source is the Integrated Database (IDB), which is a compilation of periodic forest inventory data from the 1990s for California, Oregon, and Washington (Waddell and Hiserote 2005). These data were identified by Heath et al. (submitted) as the most appropriate non-FIADB sources for these states and are included in this inventory. See USDA Forest Service (2010a) for information on current and older data as well as additional FIA Program features. A detailed list of the specific forest inventory data used in this inventory is in Annex 3.12.

Forest C stocks are estimated from inventory data by a collection of conversion factors and models (Birdsey and Heath 1995, Birdsey and Heath 2001, Heath et al. 2003, Smith et al. 2004, Smith et al. 2006), which have been formalized in an FIADB-to-carbon calculator (Smith et al. 2010). The conversion factors and model coefficients are categorized by region and forest type, and forest C stock estimates are calculated from application of these factors at the scale of FIA inventory plots. The results are estimates of C density (Mg C per hectare) for six forest ecosystem pools: live trees, standing dead trees, understory vegetation, down dead wood, forest floor, and soil organic matter. The six carbon pools used in the FIADB-to-carbon calculator are aggregated to the 5 carbon pools defined by IPCC (2006): aboveground biomass, belowground biomass, dead wood, litter, and soil organic matter. All non-soil pools except forest floor are separated into aboveground and belowground components. The live tree and understory C pools are pooled as biomass, and standing dead trees and down dead wood are pooled as dead wood, in accordance with IPCC (2006).

Once plot-level C stocks are calculated as C densities on *Forest Land Remaining Forest Land* for the five IPCC (2006) reporting pools, the stocks are expanded to population estimates according to methods appropriate to the respective inventory data (for example, see Bechtold and Patterson (2005)). These expanded C stock estimates are summed to state or sub-state total C stocks. Annualized estimates of C stocks are developed by using available FIA inventory data and interpolating or extrapolating to assign a C stock to each year in the 1990 through2010 time series. Flux, or net annual stock change, is estimated by calculating the difference between two successive years and applying the appropriate sign convention; net increases in ecosystem C are identified as negative flux. By convention, inventories are assigned to represent stocks as of January 1 of the inventory year; an estimate of flux for 1996 requires estimates of C stocks for 1996 and 1997, for example. Additional discussion of the use of FIA inventory data and the C conversion process is in Annex 3.12.

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[177] Forest land in the United States includes land that is at least 10 percent stocked with trees of any size. Timberland is the most productive type of forest land, which is on unreserved land and is producing or capable of producing crops of industrial wood.

Carbon in Biomass

Live tree C pools include aboveground and belowground (coarse root) biomass of live trees with diameter at diameter breast height (d.b.h.) of at least 2.54 cm at 1.37 m above the forest floor. Separate estimates are made for full-tree and aboveground-only biomass in order to estimate the belowground component. If inventory plots include data on individual trees, tree C is based on Jenkins et al. (2003) and is a function of species and diameter. Some inventory data do not provide measurements of individual trees; tree C in these plots is estimated from plot-level volume of merchantable wood, or growing-stock volume, of live trees, which is calculated from updates of Smith et al. (2003). These biomass conversion and expansion factors (BCEFs) are applied to about 3 percent of the inventory records, all of which are pre-1998 data. Some inventory data, particularly some of the older datasets, may not include sufficient information to calculate tree C because of incomplete or missing tree or volume data; C estimates for these plots are based on averages from similar, but more complete, inventory data. This applies to an additional 2 percent of inventory records, which represent older (pre-1998) non-timberlands.

Understory vegetation is a minor component of biomass, which is defined as all biomass of undergrowth plants in a forest, including woody shrubs and trees less than 2.54 cm d.b.h. In the current inventory, it is assumed that 10 percent of total understory C mass is belowground. Estimates of C density are based on information in Birdsey (1996). Understory frequently represents over 1 percent of C in biomass, but its contribution rarely exceeds 2 percent of the total.

Carbon in Dead Organic Matter

Dead organic matter is initially calculated as three separate pools with C stocks modeled from inventory data. Estimates are specific to regions and forest types within each region, and stratification of forest land for dead organic matter calculations is identical to that used for biomass through the state and sub-state use of FIA data as discussed above. The two components of dead wood—standing dead trees and down dead wood—are estimated separately. The standing dead tree C pools include aboveground and belowground (coarse root) mass and include trees of at least 2.54 cm d.b.h. Calculations are BCEF-like factors based on updates of Smith et al. (2003). Down dead wood is defined as pieces of dead wood greater than 7.5 cm diameter, at transect intersection, that are not attached to live or standing dead trees. Down dead wood includes stumps and roots of harvested trees. Ratios of down dead wood to live tree are used to estimate this quantity. Litter C is the pool of organic C (also known as duff, humus, and fine woody debris) above the mineral soil and includes woody fragments with diameters of up to 7.5 cm. Estimates are based on equations of Smith and Heath (2002).

Carbon in Forest Soil

Soil organic C (SOC) includes all organic material in soil to a depth of 1 meter but excludes the coarse roots of the biomass or dead wood pools. Estimates of SOC are based on the national STATSGO spatial database (USDA 1991), which includes region and soil type information. SOC determination is based on the general approach described by Amichev and Galbraith (2004). Links to FIA inventory data were developed with the assistance of the USDA Forest Service FIA Geospatial Service Center by overlaying FIA forest inventory plots on the soil C map. This method produced mean SOC densities stratified by region and forest type group. It did not provide separate estimates for mineral or organic soils but instead weighted their contribution to the overall average based on the relative amount of each within forest land. Thus, forest SOC is a function of species and location, and net change also depends on these two factors as total forest area changes. In this respect, SOC provides a country-specific reference stock for 1990-present, but it does not reflect effects of past land use.

Harvested Wood Carbon

Estimates of the HWP contribution to forest C sinks and emissions (hereafter called "HWP Contribution") are based on methods described in Skog (2008) using the WOODCARB II model. These methods are based on IPCC (2006) guidance for estimating HWP C. IPCC (2006) provides methods that allow Parties to report HWP Contribution using one of several different accounting approaches: production, stock change and atmospheric flow, as well as a default method that assumes there is no change in HWP C stocks (see Annex 3.12 for more details about each approach). The United States uses the production accounting approach to report HWP Contribution. Under the production approach, C in exported wood is estimated as if it remains in the United States, and C in imported wood is not included in inventory estimates. Though reported U.S. HWP estimates are based on the production approach, estimates resulting from use of the two alternative approaches, the stock change and atmospheric flow approaches, are also presented for comparison (see Annex 3.12). Annual estimates of change are calculated by tracking the additions to and removals from the pool of products held in end uses (i.e., products in use such as housing or publications) and the pool of products held in solid waste disposal sites (SWDS).

Solidwood products added to pools include lumber and panels. End-use categories for solidwood include single and multifamily housing, alteration and repair of housing, and other end-uses. There is one product category and one end-use category for paper. Additions to and removals from pools are tracked beginning in 1900, with the exception that additions of softwood lumber to housing begins in 1800. Solidwood and paper product production and trade data are from USDA Forest Service and other sources (Hair and Ulrich 1963; Hair 1958; USDC Bureau of Census; 1976; Ulrich, 1985, 1989; Steer 1948; AF&PA 2006a 2006b; Howard 2003, 2007). Estimates for disposal of products reflect the change over time in the fraction of products discarded to SWDS (as opposed to burning or recycling) and the fraction of SWDS that are in sanitary landfills versus dumps.

There are five annual HWP variables that are used in varying combinations to estimate HWP Contribution using any one of the three main approaches listed above. These are:

(1A) annual change of C in wood and paper products in use in the United States,

(1B) annual change of C in wood and paper products in SWDS in the United States,

(2A) annual change of C in wood and paper products in use in the United States and other countries where the wood came from trees harvested in the United States,

(2B) annual change of C in wood and paper products in SWDS in the United States and other countries where the wood came from trees harvested in the United States,

(3) C in imports of wood, pulp, and paper to the United States,

(4) C in exports of wood, pulp and paper from the United States, and

(5) C in annual harvest of wood from forests in the United States.

The sum of variables 2A and 2B yields the estimate for HWP Contribution under the production accounting approach. A key assumption for estimating these variables is that products exported from the United States and held in pools in other countries have the same half lives for products in use, the same percentage of discarded products going to SWDS, and the same decay rates in SWDS as they would in the United States.

Uncertainty and Time Series Consistency

A quantitative uncertainty analysis placed bounds on current flux for forest ecosystems as well as C in harvested wood products through Monte Carlo simulation of the Methods described above and probabilistic sampling of C conversion factors and inventory data. See Annex 3.12 for additional information. The 2009 flux estimate for forest C stocks is estimated to be between -1,014 and -714 Tg CO_2 Eq. at a 95 percent confidence level. This includes a range of -662 to -959 Tg CO_2 Eq. in forest ecosystems and -69 to -41 Tg CO_2 Eq. for HWP.

Table 7-10: Tier 2 Quantitative Uncertainty Estimates for Net CO_2 Flux from Forest Land Remaining Forest Land: Changes in Forest C Stocks (Tg CO_2 Eq. and Percent)

Source	Gas	2009 Flux Estimate (Tg CO_2 Eq.)	Uncertainty Range Relative to Flux Estimate[a] (Tg CO_2 Eq.)		(%)	
			Lower Bound	Upper Bound	Lower Bound	Upper Bound
Forest Ecosystem	CO_2	(808.9)	(959.4)	(661.7)	-19%	-18%
Harvested Wood Products	CO_2	(54.3)	(68.6)	(41.0)	-27%	-24%
Total Forest	**CO_2**	**(863.1)**	**(1,014.4)**	**(713.9)**	**-18%**	**-17%**

Note: Parentheses indicate negative values or net sequestration.
[a]Range of flux estimates predicted by Monte Carlo stochastic simulation for a 95 percent confidence interval.

Methodological recalculations were applied to the entire time-series to ensure time-series consistency from 1990 through 2009. Details on the emission trends through time are described in more detail in the Methodology section, above.

QA/QC and Verification

As discussed above, the FIA program has conducted consistent forest surveys based on extensive statistically-based sampling of most of the forest land in the conterminous United States, dating back to 1952. The main purpose of the FIA program has been to estimate areas, volume of growing stock, and timber products output and utilization factors. The FIA program includes numerous quality assurance and quality control (QA/QC) procedures, including calibration among field crews, duplicate surveys of some plots, and systematic checking of recorded data. Because of the statistically-based sampling, the large number of survey plots, and the quality of the data, the survey databases developed by the FIA program form a strong foundation for C stock estimates. Field sampling protocols, summary data, and detailed inventory databases are archived and are publicly available on the Internet (USDA Forest Service 2010d).

Many key calculations for estimating current forest C stocks based on FIA data were developed to fill data gaps in assessing forest carbon and have been in use for many years to produce national assessments of forest C stocks and stock changes (see additional discussion and citations in the Methodology section above and in Annex 3.12). General quality control procedures were used in performing calculations to estimate C stocks based on survey data. For example, the derived C datasets, which include inventory variables such as areas and volumes, were compared to standard inventory summaries such as the forest resource statistics of Smith et al. (2009) or selected population estimates generated from FIADB 4.0, which are available at an FIA internet site (USDA Forest Service 2009b). Agreement between the C datasets and the original inventories is important to verify accuracy of the data used. Finally, C stock estimates were compared with previous inventory report estimates to ensure that any differences could be explained by either new data or revised calculation methods (see the "Recalculations" discussion, below).

Estimates of the HWP variables and the HWP contribution under the production accounting approach use data from U.S. Census and USDA Forest Service surveys of production and trade. Factors to convert wood and paper to units C are based on estimates by industry and Forest Service published sources. The WOODCARB II model uses estimation methods suggested by IPCC (2006). Estimates of annual C change in solidwood and paper products in use were calibrated to meet two independent criteria. The first criterion is that the WOODCARB II model estimate of C in houses standing in 2001 needs to match an independent estimate of C in housing based on U.S. Census and USDA Forest Service survey data. Meeting the first criterion resulted in an estimated half life of about 80 years for single family housing built in the 1920s, which is confirmed by other U.S. Census data on housing. The second criterion is that the WOODCARB II model estimate of wood and paper being discarded to SWDS needs to match EPA estimates of discards each year over the period 1990 to 2000 (EPA 2006). These criteria help reduce uncertainty in estimates of annual change in C in products in use in the United States and, to a lesser degree, reduce uncertainty in estimates of annual change in C in products made from wood harvested in the United States. In addition, WOODCARB II landfill decay rates have been validated by ensuring that estimates of CH_4 emissions from landfills based on EPA (2006) data are reasonable in comparison with CH_4 estimates based on WOODCARB II landfill decay rates.

Recalculations Discussion

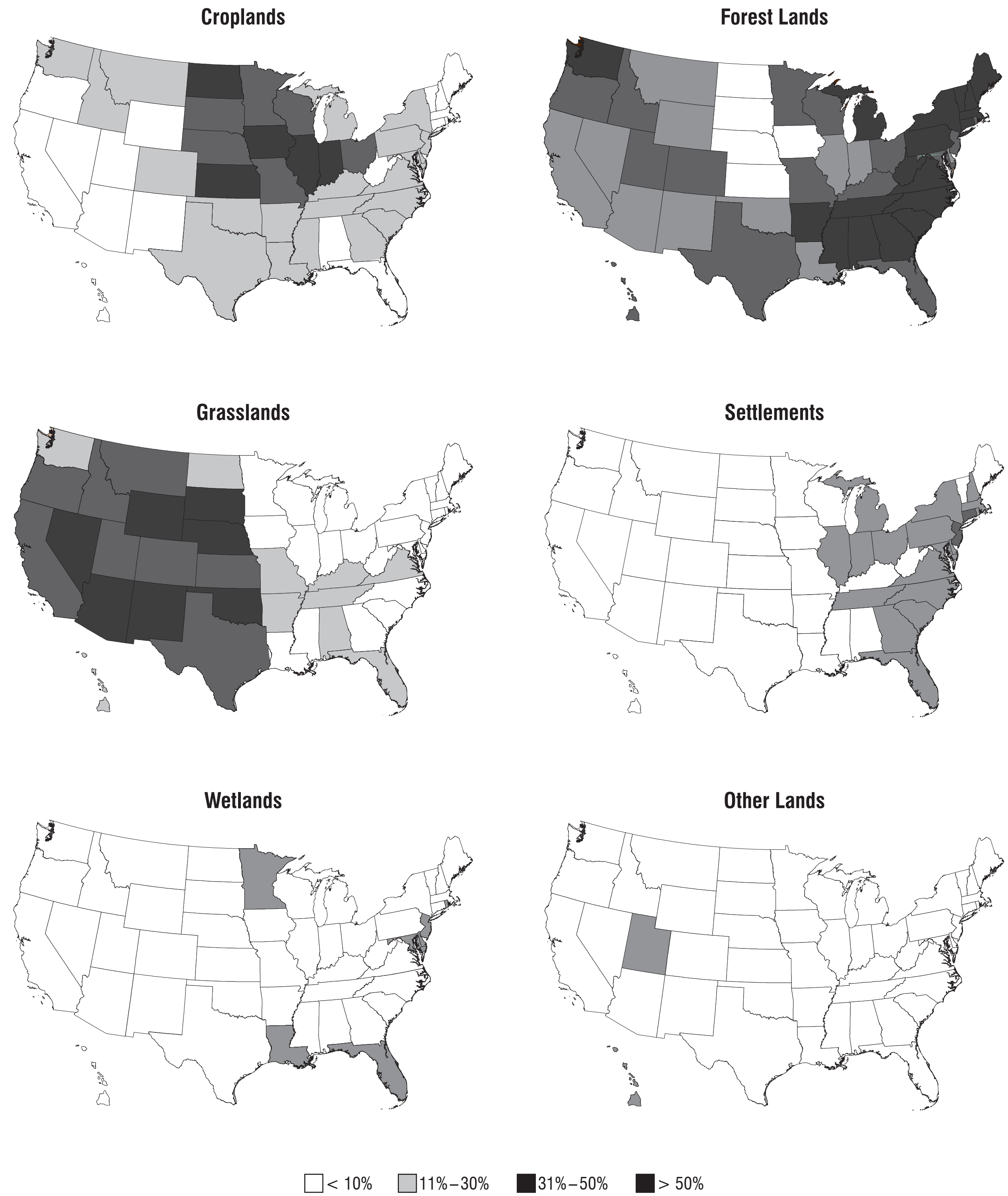
The basic models used to estimate forest ecosystem and HWP C stocks and change are unchanged from the previous Inventory (Smith et al. 2010, Skog 2008). Many of the state-level estimates for 1990 through the present are relatively similar to the values previously reported (EPA 2010). Recent forest inventory additions to the FIADB include newer annual inventory data for most states including Oklahoma, which had the effect of increasing overall net sequestration estimated for the interval from 2000 through 2008. An additional change to the FIADB was the addition of some older periodic inventories for some southern states; these were incorporated into the calculations but did not appreciably affect national trends. The addition of the IDB forest inventories for a part of the series for California, Oregon, and Washington did affect recalculations for those states and the United States as a whole; it tended to decrease net sequestration throughout the 1990 to 2008 interval. However, the decreased sequestration associated with the use of the IDB was offset by the increased sequestration associated with newer annual inventory data for the post-2000 interval.

Planned Improvements

The ongoing annual surveys by the FIA Program will improve precision of forest C estimates as new state surveys

Figure 7-1

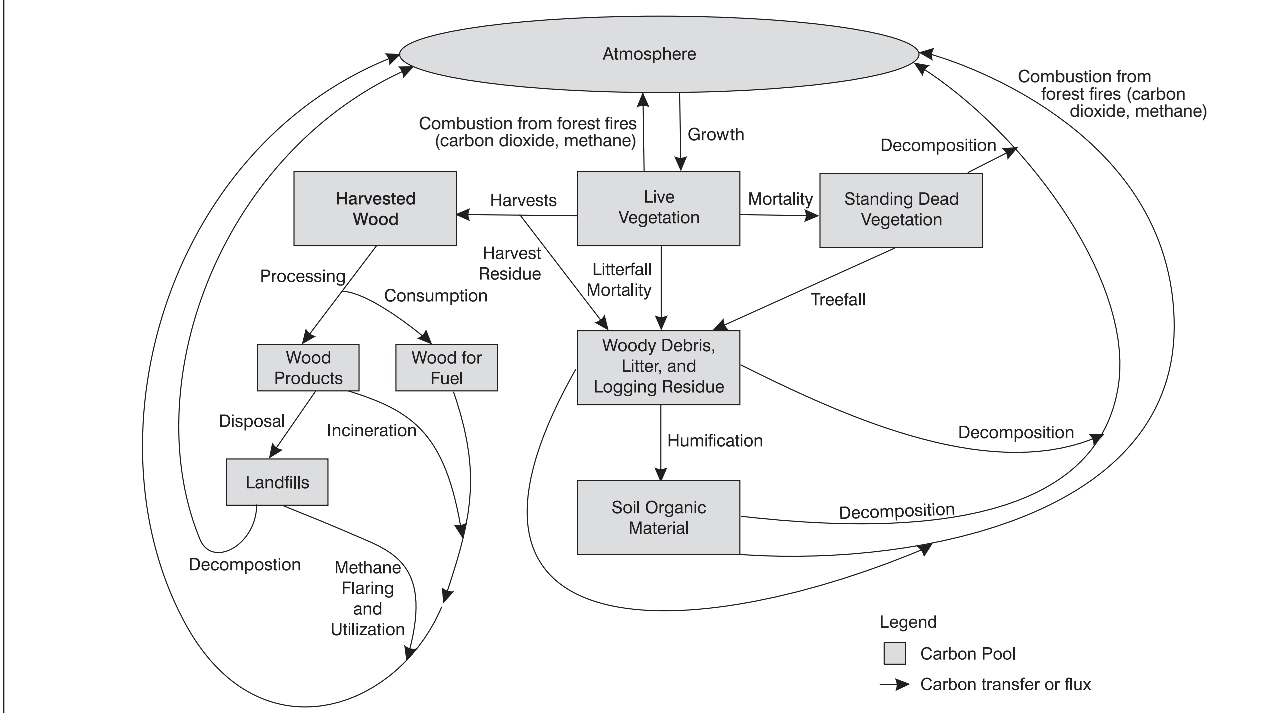
Percent of Total Land Area in the General Land Use Categories for 2009



Note: Land use/land-use change categories were aggregated into the 6 general land-use categories based on the current use in 2009.

Figure 7-2

Forest Sector Carbon Pools and Flows



Source: Heath et al. 2003

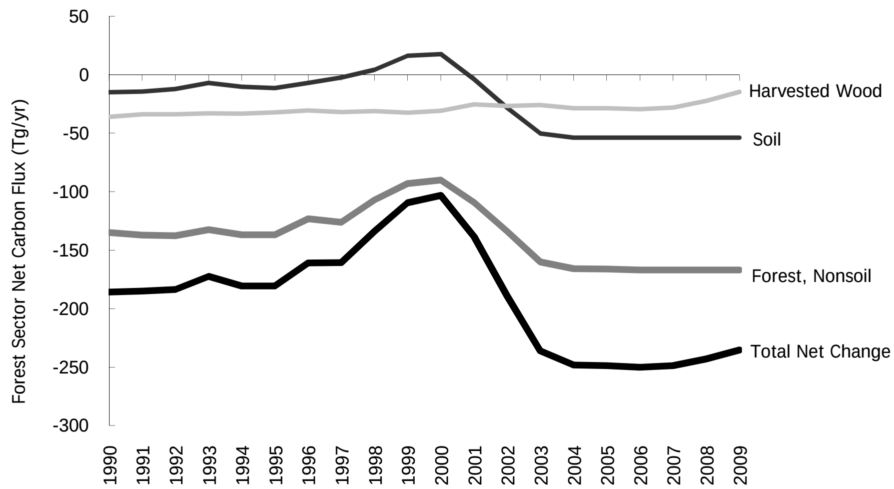


Figure 7-3: Estimates of Net Annual Changes in C Stocks for Major C Pools

Figure 7-4

Average C Density in the Forest Tree Pool in the Conterminous United States, 2009

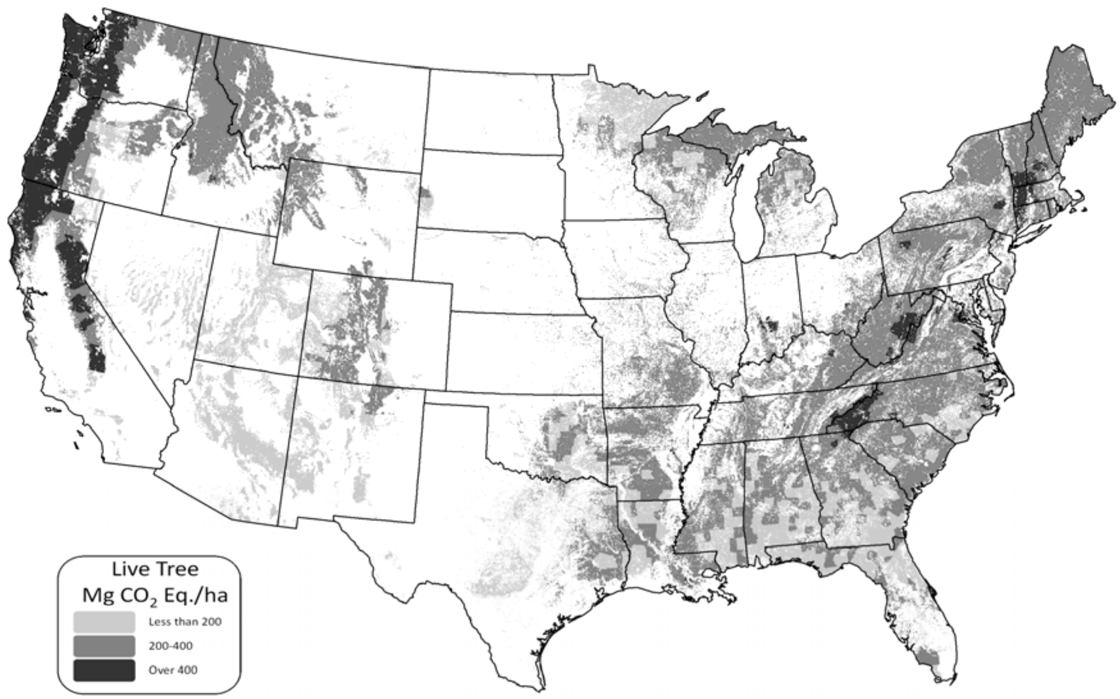
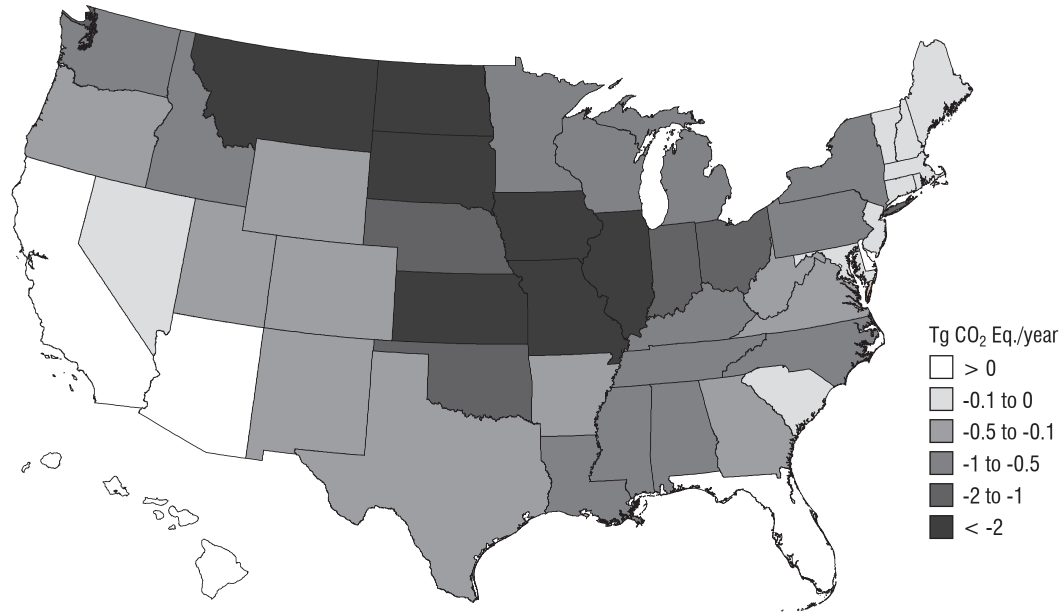


Figure 7-5

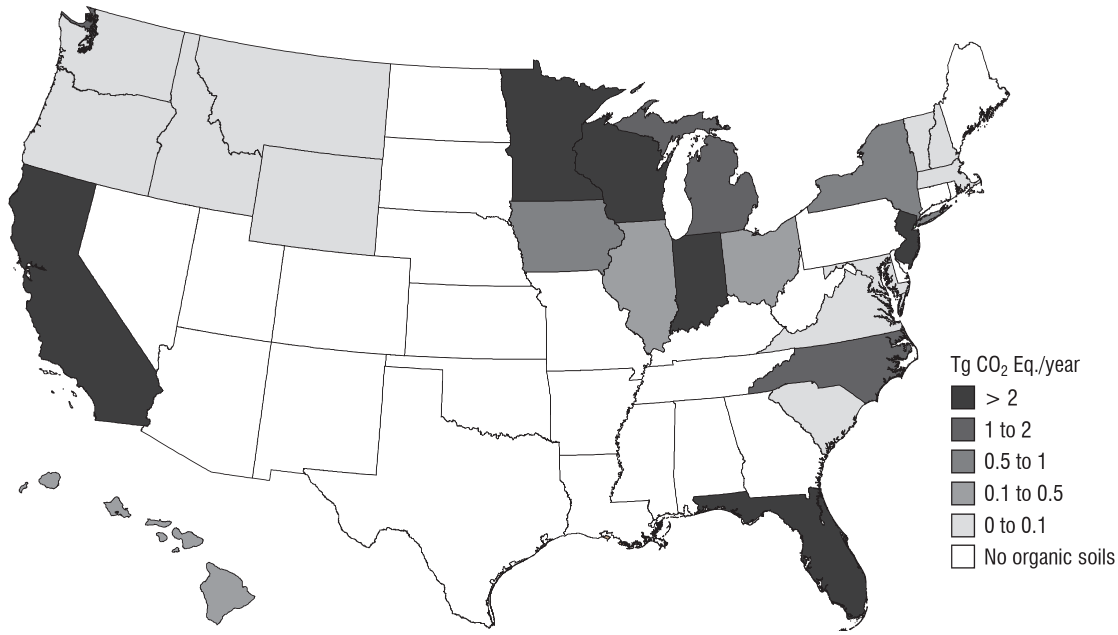
Total Net Annual CO_2 Flux for Mineral Soils Under Agricultural Management within States, 2009, *Cropland Remaining Cropland*



Note: Values greater than zero represent emissions, and values less than zero represent sequestration. Map accounts for fluxes associated with the Tier 2 and 3 Inventory computations. See Methodology for additional details.

Figure 7-6

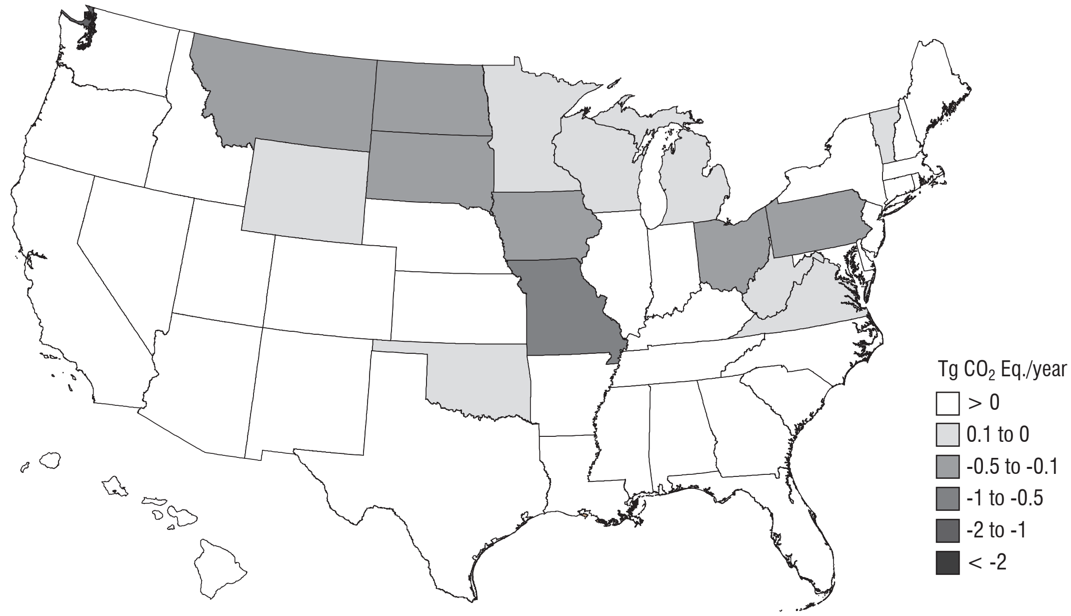
Total Net Annual CO_2 Flux for Organic Soils Under Agricultural Management within States, 2009, *Cropland Remaining Cropland*



Note: Values greater than zero represent emissions.

Figure 7-7

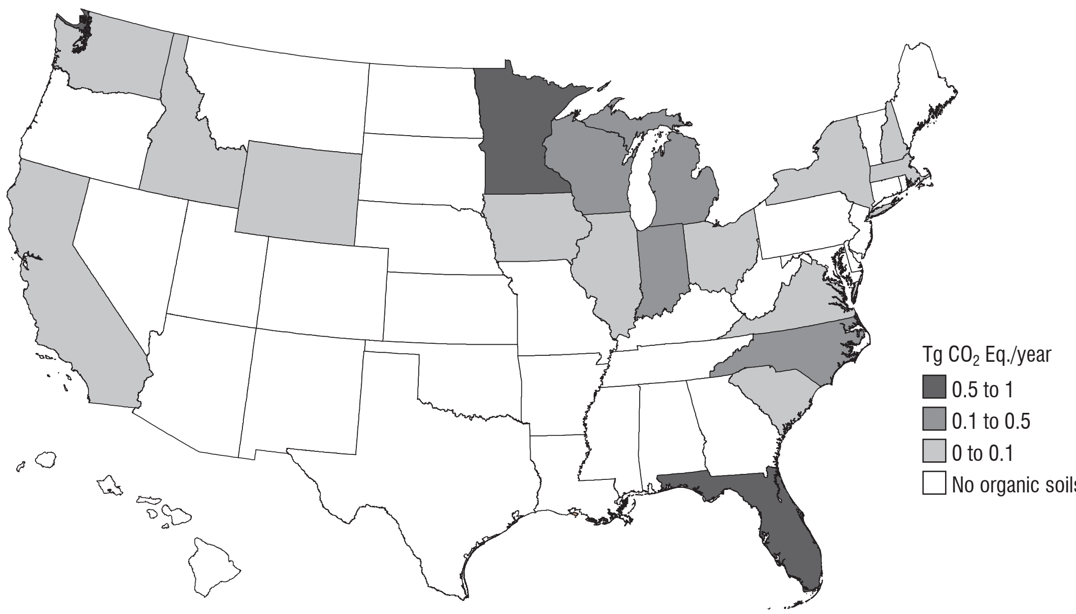
Total Net Annual CO_2 Flux for Mineral Soils Under Agricultural Management within States, 2009, *Land Converted to Cropland*



Note: Values greater than zero represent emissions, and values less than zero represent sequestration. Map accounts for fluxes associated with the Tier 2 and 3 Inventory computations. See Methodology for additional details.

Figure 7-8

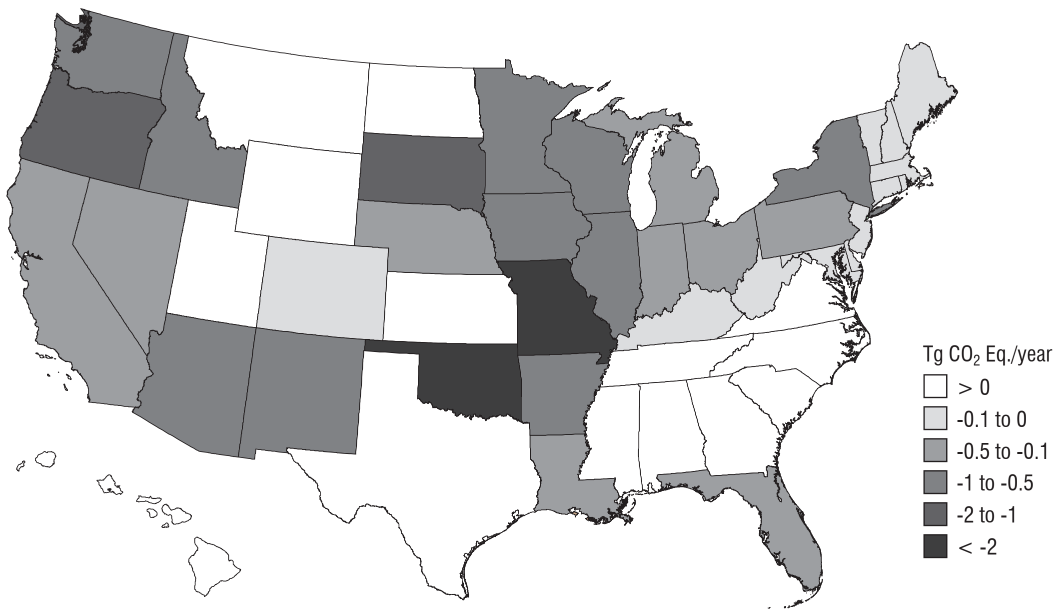
Total Net Annual CO_2 Flux for Organic Soils Under Agricultural Management within States, 2009, *Land Converted to Cropland*



Note: Values greater than zero represent emissions.

Figure 7-9

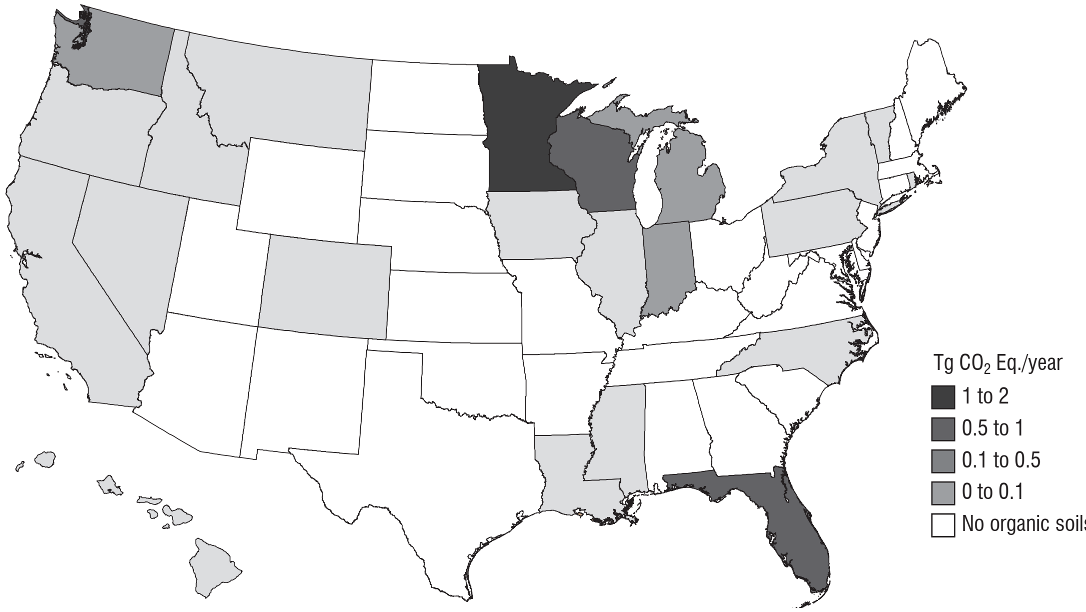
Total Net Annual CO_2 Flux for Mineral Soils Under Agricultural Management within States, 2009, *Grassland Remaining Grassland*



Note: Values greater than zero represent emissions, and values less than zero represent sequestration. Map accounts for fluxes associated with the Tier 2 and 3 Inventory computations. See Methodology for additional details.

Figure 7-10

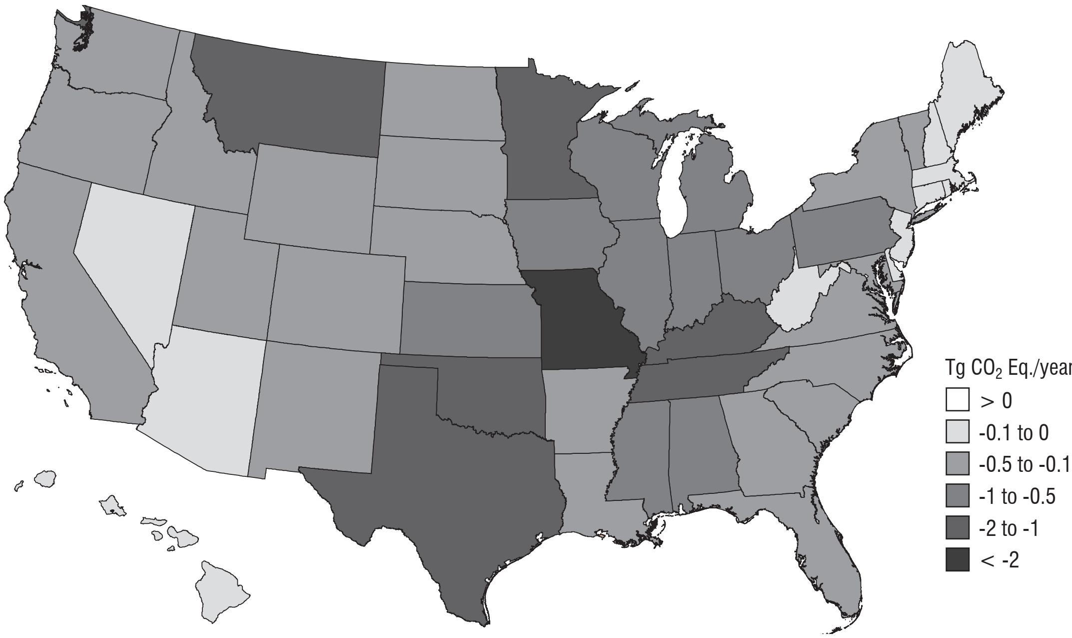
Total Net Annual CO_2 Flux for Organic Soils Under Agricultural Management within States, 2009, *Grassland Remaining Grassland*



Note: Values greater than zero represent emissions.

Figure 7-11

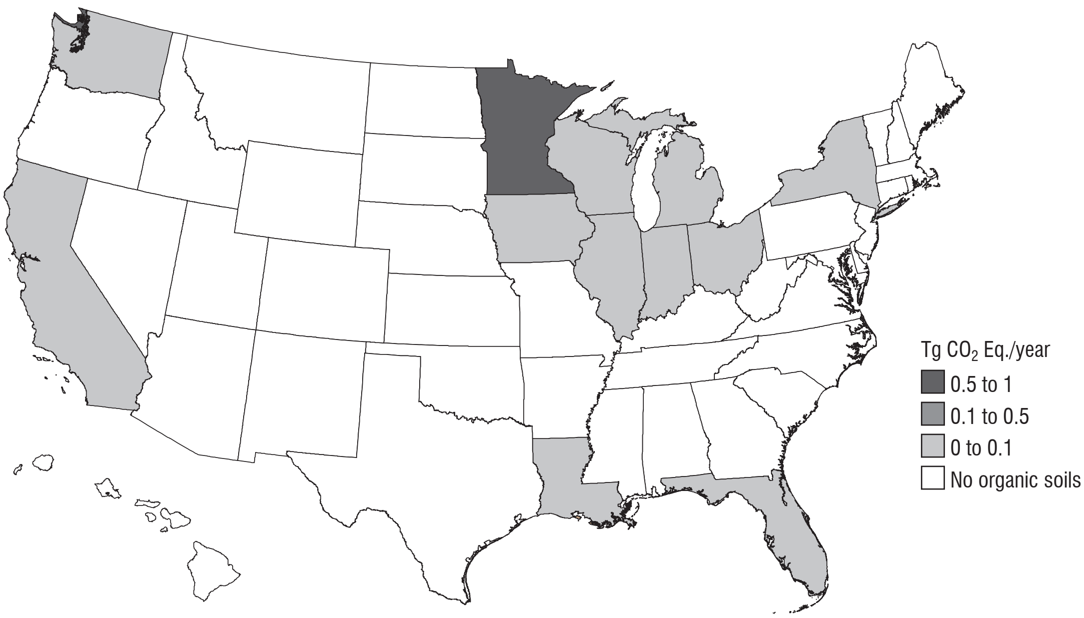
Total Net Annual CO_2 Flux for Mineral Soils Under Agricultural Management within States, 2009, *Land Converted to Grassland*



Note: Values greater than zero represent emissions, and values less than zero represent sequestration. Map accounts for fluxes associated with the Tier 2 and 3 Inventory computations. See Methodology for additional details.

Figure 7-12

Total Net Annual CO_2 Flux for Organic Soils Under Agricultural Management within States, 2009, *Land Converted to Grassland*



Note: Values greater than zero represent emissions.

3.12. Methodology for Estimating Net Carbon Stock Changes in Forest Lands Remaining Forest Lands

This sub-annex expands on the methodology used to calculate net changes in carbon (C) stocks in forest ecosystems and in harvested wood products. Some of the details of C conversion factors and procedures for calculating net CO_2 flux for forests are provided below; full details of selected topics may be found in the cited references.

Carbon Stocks and Net Changes in Forest Ecosystem Carbon Stocks

At least two forest inventories exist for most forest land in the United States. C stocks are estimated based on data from each inventory, at the level of permanent inventory plots. C per hectare (for a sample location) is multiplied by the total number of hectares that the plot represents, and then totals are summed for an area of interest, such as the state of Maine. Net annual C stock changes are calculated by taking the difference between the inventories and dividing by the number of years between the inventories for a selected state or sub-state area.

Forest inventory data

The estimates of forest C stocks are based on data derived from forest inventory surveys. Forest inventory data were obtained from the USDA Forest Service, Forest Inventory and Analysis (FIA) program (Frayer and Furnival 1999). FIA data include remote sensing information and collection of measurements in the field at sample locations called plots. Tree measurements include diameter and species. On a subset of plots, additional measurements or samples are taken of down dead wood, litter, and soil C; however, these are not yet available nationwide for C estimation. The field protocols are thoroughly documented and available for download from the USDA Forest Service (2010c). The inventory was designed for timber volume estimation rather than C stock estimation, so most C pools are not measured directly or are sampled only on a subset of plots. Bechtold and Patterson (2005) provide the estimation procedures for standard forest inventory results. The data are freely available for download at USDA Forest Service (2010b) as the Forest Inventory and Analysis Database (FIADB) Version 4.0; these data are the primary sources of forest inventory used to estimate forest C stocks.

Forest surveys have begun in the U.S. territories and in Hawaii. Meanwhile this inventory assumes that these areas account for a net C change of zero. Survey data are available for the temperate oceanic ecoregion of Alaska (southeast and south central). Inventory data are publicly available for 6.1 million hectares of forest land, and these inventoried lands, comprising 12% of the total forest land in Alaska, contribute to the forest carbon stocks presented here.

Agroforestry systems are also not currently accounted for in the U.S. Inventory, since they are not explicitly inventoried by either of the two primary national natural resource inventory programs: the FIA program of the USDA Forest Service and the National Resources Inventory (NRI) of the USDA Natural Resources Conservation Service (Perry et al. 2005). The majority of these tree-based practices do not meet the size and definitions for forests within each of these resource inventories. The size characteristics that exclude them from inventories also allow these systems to provide their many services without taking the land out of agricultural production, making them an appealing C sequestration option. Agroforestry in the United States has been defined as "intensive land-use management that optimizes the benefits (physical, biological, ecological, economic, social) from bio-physical interactions created when trees and/or shrubs are deliberately combined with crops and/or livestock" (Gold et al. 2000). In the United States, there are six categories of agroforestry practices: riparian forest buffers, windbreaks, alley cropping, silvopasture, forest farming and special applications.[63] These practices are used to address many issues facing agricultural lands, such as economic diversification, habitat fragmentation, and water quality. While providing these services and regardless of intent, these tree-based plantings will also reduce atmospheric CO_2. This occurs directly through CO_2 sequestration into woody biomass, and indirectly through enhancement of agricultural production, trapping wind-blown and surface runoff sediments, and/or reducing CO_2 emissions through fuel-use savings (Quam et al. 1992). The effects of these individual practices can potentially be quite large when taken into account within a whole-farm or within an aggregating larger entity (i.e., state-level) (Quam et al. 1992, Schoeneberger 2006). One estimate of the sequestration potential through agroforestry practices in the United States is 90.3 Mt C/year by 2025 (Nair and Nair 2003).

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63 More information on agroforestry practices can be found online at <http://www.unl.edu/nac>.

Summing state-level C stocks to calculate United States net C flux in forest ecosystems

The overall approach for determining forest C stocks and stock change is based on methodology and algorithms coded into the computer tool described in Smith et al. (2010). It focuses on estimating forest C stocks based on data from two or more forest surveys conducted several years apart for each state or sub-state. There are generally two or more surveys available for download for each state. C stocks are calculated separately for each state based on available inventories conducted since 1990 and for the inventory closest to, but prior to, 1990 if such data are available and consistent with these methods. This approach ensures that the period 1990 (the base year) to present can be adequately represented. Surveys conducted prior to and in the early to mid 1990s focused on land capable of supporting timber production (timberland).[64] As a result, information on less productive forest land or lands reserved from harvest was limited. Inventory field crews periodically measured all the plots in a state at a frequency of every 5 to 14 years. Generally, forests in states with fast-growing (and therefore rapidly changing) forests tended to be surveyed more often than states with slower-growing (and therefore slowly changing) forests. Older surveys for some states, particularly in the West, also have National Forest System (NFS) lands or reserved lands that were surveyed at different times than productive, privately-owned forest land in the state. Periodic data for each state thus became available at irregular intervals and determining the year of data collection associated with the survey can sometimes be difficult.

Table A-212: Source of Unique Forest Inventory and Average Year of Field Survey Used to Estimate Statewide Carbon Stocks

State/Substate[a]	Source of Inventory Data, Report/Inventory Year[b]	Average Year Assigned to Inventory[c]
Alabama	FIADB 4.0, 1982	1982
	FIADB 4.0, 1990	1990
	FIADB 4.0, 2000	1999
	FIADB 4.0, 2005	2003
Alaska, non-reserved Southcentral	FIADB 4.0, 2009	2007
Alaska, non-reserved Southeast	FIADB 4.0, 2009	2007
Alaska, reserved Southcentral	FIADB 4.0, 2009	2006
Alaska, reserved Southeast	FIADB 4.0, 2009	2006
Arizona, NFS non-woodlands	1987 RPA	1985
	FIADB 4.0, 1999	1996
	FIADB 4.0, 2009	2005
Arizona, NFS woodlands	1987 RPA	1984
	FIADB 4.0, 1999	1996
	FIADB 4.0, 2009	2005
Arizona, non-NFS non-woodlands	FIADB 4.0, 1985	1986
	FIADB 4.0, 1999	1996
	FIADB 4.0, 2009	2006
Arizona, non-NFS woodlands	FIADB 4.0, 1999	1990
	FIADB 4.0, 2009	2006
Arkansas	FIADB 4.0, 1988	1988
	FIADB 4.0, 1995	1996

64 Forest land is defined as land at least 120 feet wide and 1 acre in size with at least 10 percent cover (or equivalent stocking by live trees of any size, including land that formerly had such tree cover and that will be naturally or artificially regenerated. . Forest land includes transition zones, such as areas between forest and nonforest lands that have at least 10 percent cover (or equivalent stocking) with live trees and forest areas adjacent to urban and built-up lands. Roadside, streamside, and shelterbelt strips of trees must have a crown width of at least 120 feet and continuous length of at least 363 feet to qualify as forest land. Unimproved roads and trails, streams, and clearings in forest areas are classified as forest if they are less than 120 feet wide or an acre in size. Tree-covered areas in agricultural production settings, such as fruit orchards, or tree-covered areas in urban settings, such as city parks, are not considered forest land. (Smith et al. 2009) Timberland is the most productive type of forest land, which is on unreserved land and is producing or capable of producing crops of industrial wood. Productivity is at a minimum rate of 20 cubic feet of industrial wood per acre per year (Woudenberg and Farrenkopf 1995). There are about 203 million hectares of timberland in the conterminous United States, which represents 81 percent of all forest lands over the same area (Smith et al. 2009).

	FIADB 4.0, 2005	2003
	FIADB 4.0, 2009	2007
California, NFS	IDB, 1990s	1997
	FIADB 4.0, 2009	2006
California, non-NFS	IDB, 1990s	1993
	FIADB 4.0, 2009	2006
Colorado, NFS non-woodlands	1997 RPA	1981
	FIADB 4.0, 2009	2006
Colorado, NFS woodlands	1997 RPA	1975
	FIADB 4.0, 1984	1997
	FIADB 4.0, 2009	2006
Colorado, non-NFS non-woodlands	Westwide, 1983	1980
	FIADB 4.0, 2009	2006
Colorado, non-NFS woodlands	Westwide, 1983	1983
	FIADB 4.0, 2009	2006
Connecticut	FIADB 4.0, 1985	1985
	FIADB 4.0, 1998	1998
	FIADB 4.0, 2007	2006
Delaware	FIADB 4.0, 1986	1986
	FIADB 4.0, 1999	1999
	FIADB 4.0, 2008	2007
Florida	FIADB 4.0, 1987	1987
	FIADB 4.0, 1995	1995
	FIADB 4.0, 2007	2005
Georgia	FIADB 4.0, 1989	1989
	FIADB 4.0, 1997	1997
	FIADB 4.0, 2004	2001
	FIADB 4.0, 2008	2006
Idaho, Caribou-Targhee NF	Westwide, 1991	1992
	FIADB 4.0, 2009	2007
Idaho, Kootenai NF	1987 RPA	1988
	FIADB 4.0, 1991	1995
	FIADB 4.0, 2009	2007
Idaho, non-NFS non-woodlands	FIADB 4.0, 1991	1990
	FIADB 4.0, 2009	2007
Idaho, non-NFS woodlands	FIADB 4.0, 1991	1982
	FIADB 4.0, 2009	2007
Idaho, other NFS	Westwide, 1991	1988
	FIADB 4.0, 1991	2000
	FIADB 4.0, 2009	2007
Idaho, Payette NF	1987 RPA	1982
	FIADB 4.0, 2009	2007
Idaho, Salmon-Challis NF	1987 RPA	1978
	FIADB 4.0, 2009	2007
Idaho, Sawtooth NF	Westwide, 1991	1983
	FIADB 4.0, 1991	1996
	FIADB 4.0, 2009	2007
Illinois	FIADB 4.0, 1985	1985
	FIADB 4.0, 1998	1998
	FIADB 4.0, 2005	2004

	FIADB 4.0, 2008	2006
Indiana	FIADB 4.0, 1986	1986
	FIADB 4.0, 1998	1998
	FIADB 4.0, 2003	2001
	FIADB 4.0, 2008	2007
Iowa	FIADB 4.0, 1990	1990
	FIADB 4.0, 2003	2002
	FIADB 4.0, 2008	2006
Kansas	FIADB 4.0, 1981	1981
	FIADB 4.0, 1994	1994
	FIADB 4.0, 2005	2003
	FIADB 4.0, 2008	2007
Kentucky	FIADB 4.0, 1988	1987
	FIADB 4.0, 2004	2002
	FIADB 4.0, 2007	2005
Louisiana	FIADB 4.0, 1984	1984
	FIADB 4.0, 1991	1991
	FIADB 4.0, 2005	2004
Maine	Eastwide, 1982	1983
	FIADB 4.0, 1995	1995
	FIADB 4.0, 2003	2002
	FIADB 4.0, 2008	2007
Maryland	FIADB 4.0, 1986	1986
	FIADB 4.0, 1999	2000
	FIADB 4.0, 2008	2007
Massachusetts	FIADB 4.0, 1985	1985
	FIADB 4.0, 1998	1998
	FIADB 4.0, 2007	2006
Michigan	FIADB 4.0, 1980	1980
	FIADB 4.0, 1993	1993
	FIADB 4.0, 2004	2003
	FIADB 4.0, 2008	2006
Minnesota	FIADB 4.0, 1990	1989
	FIADB 4.0, 2003	2001
	FIADB 4.0, 2008	2006
Mississippi	FIADB 4.0, 1987	1987
	FIADB 4.0, 1994	1994
	FIADB 4.0, 2006	2007
Missouri	FIADB 4.0, 1989	1988
	FIADB 4.0, 2003	2002
	FIADB 4.0, 2008	2006
Montana, NFS	1987 RPA	1988
	FIADB 4.0, 1989	1996
	FIADB 4.0, 2009	2007
Montana, non-NFS non-reserved	FIADB 4.0, 1989	1989
	FIADB 4.0, 2009	2006
Montana, non-NFS reserved	1997 RPA	1990
	FIADB 4.0, 2009	2007
Nebraska	FIADB 4.0, 1983	1983
	FIADB 4.0, 1994	1995

	FIADB 4.0, 2005	2004
	FIADB 4.0, 2008	2006
Nevada, NFS non-woodlands	1987 RPA	1974
	FIADB 4.0, 1989	1997
	FIADB 4.0, 2005	2005
Nevada, NFS woodlands	1987 RPA	1978
	FIADB 4.0, 1989	1997
	FIADB 4.0, 2005	2005
Nevada, non-NFS non-woodlands	1997 RPA	1985
	FIADB 4.0, 2005	2005
Nevada, non-NFS woodlands	FIADB 4.0, 1989	1980
	FIADB 4.0, 2005	2005
New Hampshire	FIADB 4.0, 1983	1983
	FIADB 4.0, 1997	1997
	FIADB 4.0, 2007	2005
New Jersey	FIADB 4.0, 1987	1987
	FIADB 4.0, 1999	1999
	FIADB 4.0, 2008	2007
New Mexico, NFS non-woodlands	1987 RPA	1986
	FIADB 4.0, 1999	1997
New Mexico, NFS woodlands	1987 RPA	1986
	FIADB 4.0, 1999	1997
New Mexico, non-NFS non-woodlands	FIADB 4.0, 1987	1987
	FIADB 4.0, 1999	1999
New Mexico, non-NFS woodlands	FIADB 4.0, 1999	1989
New York, non-reserved	Eastwide, 1980	1981
	FIADB 4.0, 1993	1993
	FIADB 4.0, 2007	2005
New York, reserved	1987 RPA	1988
	FIADB 4.0, 2007	2005
North Carolina	FIADB 4.0, 1984	1984
	FIADB 4.0, 1990	1990
	FIADB 4.0, 2002	2001
	FIADB 4.0, 2007	2006
North Dakota	FIADB 4.0, 1980	1979
	FIADB 4.0, 1995	1995
	FIADB 4.0, 2005	2003
	FIADB 4.0, 2008	2007
Ohio	FIADB 4.0, 1991	1991
	FIADB 4.0, 2006	2005
Oklahoma, Central & West	FIADB 4.0, 1989	1989
Oklahoma, East	FIADB 4.0, 1986	1986
	FIADB 4.0, 1993	1993
	FIADB 4.0, 2008	2008
Oregon, NFS East	IDB, 1990s	1995
	FIADB 4.0, 2009	2006
Oregon, NFS West	IDB, 1990s	1996
	FIADB 4.0, 2009	2006
Oregon, non-NFS East	Westwide, 1992	1991
	IDB, 1990s	1999

	FIADB 4.0, 2009	2005
Oregon, non-NFS West	Westwide, 1992	1989
	IDB, 1990s	1997
	FIADB 4.0, 2009	2006
Pennsylvania	FIADB 4.0, 1989	1990
	FIADB 4.0, 2004	2003
	FIADB 4.0, 2008	2007
Rhode Island	FIADB 4.0, 1985	1985
	FIADB 4.0, 1998	1999
	FIADB 4.0, 2007	2006
South Carolina	FIADB 4.0, 1986	1986
	FIADB 4.0, 1993	1993
	FIADB 4.0, 2001	2001
	FIADB 4.0, 2006	2005
South Dakota, NFS	1997 RPA	1986
	FIADB 4.0, 1995	1999
	FIADB 4.0, 2005	2004
	FIADB 4.0, 2008	2006
South Dakota, non-NFS	1987 RPA	1986
	FIADB 4.0, 1995	1995
	FIADB 4.0, 2005	2004
	FIADB 4.0, 2008	2007
Tennessee	FIADB 4.0, 1989	1989
	FIADB 4.0, 1999	1998
	FIADB 4.0, 2004	2003
	FIADB 4.0, 2007	2006
Texas, Central & West	FIADB 4.0, 2007	2006
Texas, East	FIADB 4.0, 1986	1986
	FIADB 4.0, 1992	1992
	FIADB 4.0, 2003	2003
	FIADB 4.0, 2008	2006
Utah, non-woodlands	FIADB 4.0, 1993	1993
	FIADB 4.0, 2009	2005
Utah, woodlands	FIADB 4.0, 1993	1994
	FIADB 4.0, 2009	2005
Vermont	FIADB 4.0, 1983	1983
	FIADB 4.0, 1997	1997
	FIADB 4.0, 2007	2006
Virginia	FIADB 4.0, 1985	1985
	FIADB 4.0, 1992	1991
	FIADB 4.0, 2001	2000
	FIADB 4.0, 2007	2005
Washington, NFS East	IDB, 1990s	1996
	FIADB 4.0, 2009	2006
Washington, NFS West	IDB, 1990s	1996
	FIADB 4.0, 2009	2006
Washington, non-NFS East	IDB, 1990s	1992
	FIADB 4.0, 2009	2006
Washington, non-NFS West	IDB, 1990s	1990
	FIADB 4.0, 2009	2006

West Virginia	FIADB 4.0, 1989	1988
	FIADB 4.0, 2000	2001
	FIADB 4.0, 2008	2007
Wisconsin	FIADB 4.0, 1983	1982
	FIADB 4.0, 1996	1995
	FIADB 4.0, 2004	2002
	FIADB 4.0, 2008	2006
Wyoming, NFS	1997 RPA	1982
	FIADB 4.0, 2000	2000
Wyoming, non-NFS non-reserved non-woodlands	FIADB 4.0, 1984	1984
	FIADB 4.0, 2000	2002
Wyoming, non-NFS non-reserved woodlands	FIADB 4.0, 1984	1984
	FIADB 4.0, 2000	2002
Wyoming, non-NFS reserved	1997 RPA	1985
	FIADB 4.0, 2000	2000

[a] Substate areas (Smith et al. 2010) include National Forests (NFS), all forest ownerships except National Forest (non-NFS), woodlands (forest land dominated by woodland species, such as pinyon and juniper, where stocking cannot be determined (USDA Forest Service 2010c)), non-woodlands (used for clarity to emphasize that woodlands are classified separately), reserved (forest land withdrawn from timber utilization through statute, administrative regulation, or designation, Smith et al. (2009)), and non-reserved (forest land that is not reserved, used for clarity). Some National Forests are listed individually by name, e.g., Payette NF. Oregon and Washington were divided into eastern and western forests (east or west of the crest of the Cascade Mountains). Oklahoma and Texas are divided into East versus Central & West according to forest inventroy survey units (USDA Forest Service 2010d). Alaska is represented by a portion of forest land, in the southcentral and southeast part of the state.

[b] FIADB 4.0 is the current, publicly available, format of FIA inventory data, and these files were downloaded from the Internet September 12, 2010 (USDA Forest Service 2010b). IDB (Integrated Database) data are a compilation of periodic inventory data from the 1990s for California, Oregon, and Washington (Waddell and Hiserote 2005). Eastwide (Hansen et al. 1992) and Westwide (Woudenberg and Farrenkopf 1995) inventory data are formats that predate the FIADB data. RPA data are periodic national summaries. The year is the nominal, or reporting, year associated with each dataset.

[c] Average year is based on average measurement year of forest land survey plots and rounded to the nearest integer year.

A new national plot design and annualized sampling (USDA Forest Service 2010a) was introduced by FIA with most new surveys beginning after 1998. These surveys include sampling of all forest land including reserved and lower productivity lands. Most states have annualized inventory data available as of September 2010. Annualized sampling means that a portion of plots throughout the state is sampled each year, with the goal of measuring all plots once every 5 to 10 years, depending on the region of the United States. The full unique set of data with all measured plots, such that each plot has been measured one time, is called a cycle. Sampling is designed such that partial inventory cycles provide usable, unbiased samples of forest inventory, but with higher sampling errors than the full cycle. After all plots have been measured once, the sequence continues with remeasurement of the first year's plots, starting the next new cycle. Most Eastern states have completed the first full cycle of the annualized inventories and are providing annual updates to the state's forest inventory with each year's remeasurements, such that one plot's measurements are included in subsequent year's annual updates. Thus, annually updated estimates of forest C stocks are accurate, but estimates of stock change cannot utilize the annually updated inventory measurements directly, as there is redundancy in the data used to generate the annual updates of C stock. For example, a typical annual inventory update for an eastern state will include new data from remeasurement on 20 percent of plots; data from the remaining 80 percent of plots is identical to that included in the previous year's annual update. The interpretation and use of the sequence of annual inventory updates can affect trends in annualized stock and stock change. In general, the C stock and stock change calculations use annual inventory summaries (updates) with unique sets of plot-level data (that is, without redundant sets); the most-recent annual update is the exception because it is included in stock change calculations if at least half of the plots in a state include new measurements. Table A-212 lists the specific surveys used in this report, and this list can be compared with the full set of summaries available for download (USDA Forest Service 2010b).

For each pool in each state in each year, C stocks are estimated by linear interpolation between survey years. Similarly, fluxes, or net stock changes, are estimated for each pool in each state by dividing the difference between two successive stocks by the number of intervening years between surveys. Thus, the number of separate stock change estimates for each state or sub-state is one less than the number of available inventories. Annual estimates of stock and net change since the most recent survey are based on linear extrapolation. C stock and flux estimates for each pool are summed over all forest land in all states as identified in Table A-212 to form estimates for the United States. Summed net annual stock change and stock are presented in Table A-213 and Table A-214, respectively. Table A-214 also provides an estimate of forest area based on the interpolation and extrapolation procedure described above. Estimated net stock change of non-soil forest ecosystem carbon for 2009 for each of the states is shown in Table A-215, which also includes estimated forest area and total non-soil forest carbon stock. The state-level forest areas and carbon stocks are from the most recent inventory available (USDA Forest Service 2010a), and the estimate for net stock change is the mean of the 2000 through 2009 estimates from the carbon calculator (Smith et al. 2010).

Table A-213: Net Annual Changes in Carbon Stocks (Tg C yr^{-1}) in Forest and Harvested Wood Pools, 1990–2009

Carbon Pool	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Forest	(149.8)	(151.4)	(149.8)	(139.5)	(147.1)	(148.4)	(130.3)	(128.6)	(102.8)	(76.9)	(72.4)	(113.0)	(162.3)	(210.3)	(219.6)	(219.9)	(220.6)	(220.6)	(220.6)	(220.6)
Live, aboveground	(98.2)	(99.9)	(100.5)	(97.4)	(101.5)	(102.8)	(92.7)	(95.8)	(84.7)	(78.3)	(78.3)	(89.3)	(103.0)	(118.9)	(122.1)	(122.1)	(122.1)	(122.1)	(122.1)	(122.1)
Live, belowground	(19.3)	(19.7)	(19.8)	(19.3)	(20.1)	(20.5)	(18.4)	(19.0)	(16.9)	(15.7)	(15.7)	(17.9)	(20.5)	(23.5)	(24.1)	(24.1)	(24.1)	(24.1)	(24.1)	(24.1)
Dead Wood	(8.6)	(8.6)	(8.3)	(7.6)	(7.7)	(7.7)	(7.1)	(6.2)	(4.8)	(4.0)	(3.5)	(4.0)	(5.2)	(7.6)	(8.1)	(8.4)	(9.1)	(9.1)	(9.1)	(9.1)
Litter	(8.8)	(8.8)	(9.0)	(8.1)	(7.6)	(6.0)	(5.1)	(5.1)	(0.5)	4.9	7.5	1.8	(5.3)	(9.9)	(11.4)	(11.4)	(11.4)	(11.4)	(11.4)	(11.4)
Soil Organic Carbon	(14.9)	(14.4)	(12.1)	(7.2)	(10.2)	(11.4)	(7.1)	(2.5)	4.1	16.2	17.6	(3.7)	(28.3)	(50.3)	(53.8)	(53.8)	(53.8)	(53.8)	(53.8)	(53.8)
Harvested Wood	(35.9)	(33.8)	(33.8)	(32.9)	(33.4)	(32.3)	(30.6)	(32.0)	(31.1)	(32.5)	(30.8)	(25.5)	(26.8)	(25.9)	(28.7)	(28.7)	(29.6)	(28.1)	(22.4)	(14.8)
Products in Use	(17.7)	(14.9)	(16.3)	(15.0)	(15.9)	(15.1)	(14.1)	(14.7)	(13.4)	(14.1)	(12.8)	(8.7)	(9.6)	(9.7)	(12.4)	(12.4)	(12.3)	(10.7)	(5.2)	1.9
SWDS	(18.3)	(18.8)	(17.4)	(17.9)	(17.5)	(17.2)	(16.5)	(17.3)	(17.7)	(18.4)	(18.0)	(16.8)	(17.2)	(16.2)	(16.3)	(16.3)	(17.3)	(17.4)	(17.2)	(16.7)
Total Net Flux	(185.7)	(185.1)	(183.6)	(172.4)	(180.5)	(180.7)	(160.9)	(160.7)	(133.9)	(109.4)	(103.2)	(138.5)	(189.1)	(236.1)	(248.3)	(248.6)	(250.2)	(248.7)	(243.0)	(235.4)

Table A-214: Carbon Stocks (Tg C) in Forest and Harvested Wood Pools, 1990–2010

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Forest Area (1000 ha)	269,137	269,764	270,395	270,992	271,535	272,071	272,602	273,081	273,553	273,950	274,183	274,386	274,717	275,234	275,976	276,769	277,561	278,354	279,147	279,939	280,732
Carbon Pool																					
Forest	42,783	42,933	43,085	43,234	43,374	43,521	43,669	43,800	43,928	44,031	44,108	44,180	44,293	44,456	44,666	44,886	45,105	45,326	45,547	45,767	45,988
Live, aboveground	15,072	15,171	15,271	15,371	15,468	15,570	15,673	15,765	15,861	15,946	16,024	16,102	16,192	16,295	16,414	16,536	16,658	16,780	16,902	17,024	17,147
Live, belowground	2,995	3,014	3,034	3,053	3,073	3,093	3,113	3,132	3,151	3,168	3,183	3,199	3,217	3,237	3,261	3,285	3,309	3,333	3,357	3,381	3,405
Dead Wood	2,960	2,969	2,978	2,986	2,994	3,001	3,009	3,016	3,022	3,027	3,031	3,035	3,039	3,044	3,052	3,060	3,068	3,077	3,086	3,096	3,105
Litter	4,791	4,799	4,808	4,817	4,825	4,833	4,839	4,844	4,849	4,850	4,845	4,837	4,835	4,841	4,851	4,862	4,873	4,885	4,896	4,908	4,919
Soil Organic Carbon	16,965	16,980	16,995	17,007	17,014	17,024	17,035	17,043	17,045	17,041	17,025	17,007	17,011	17,039	17,089	17,143	17,197	17,251	17,304	17,358	17,412
Harvested Wood	1,859	1,895	1,929	1,963	1,996	2,029	2,061	2,092	2,124	2,155	2,187	2,218	2,244	2,271	2,296	2,325	2,354	2,383	2,412	2,434	2,449
Products in Use	1,231	1,249	1,264	1,280	1,295	1,311	1,326	1,340	1,355	1,368	1,382	1,395	1,404	1,413	1,423	1,436	1,448	1,460	1,471	1,476	1,474
SWDS	628	646	665	683	701	718	735	752	769	787	805	823	840	857	873	890	906	923	941	958	974
Total Carbon Stock	44,643	44,828	45,014	45,197	45,370	45,550	45,731	45,892	46,052	46,186	46,296	46,399	46,537	46,726	46,962	47,211	47,459	47,710	47,958	48,201	48,437

Table A-215: State-level forest area, carbon stock, and net annual stock change. Estimates are forest ecosystem carbon and do not include harvested wood

State	Mean year of field data collection	Forest area (1000 ha)	Nonsoil C stock (Mt C)	Mean net annual nonsoil stock change 2000–2009 (Mt C/yr)
Alabama	2006	9,219	682	(1.2)
Alaska	2007	6,132	1,217	0.0
Arizona	2006	7,572	436	2.0
Arkansas	2007	7,560	644	(3.6)
California	2006	13,333	2,165	(5.2)
Colorado	2006	9,294	915	(5.2)
Connecticut	2007	698	89	0.7
Delaware	2007	143	18	(0.1)
Florida	2005	6,838	471	(5.0)
Georgia	2006	10,046	802	(7.7)
Idaho	2007	8,656	1,053	2.1
Illinois	2006	1,942	215	(5.3)
Indiana	2007	1,920	225	(3.7)
Iowa	2006	1,227	113	(2.8)
Kansas	2007	902	74	(1.5)
Kentucky	2005	5,006	502	(5.3)
Louisiana	2004	5,722	447	0.1
Maine	2007	7,146	741	(1.9)
Maryland	2007	1,009	131	(1.2)
Massachusetts	2007	1,222	166	(0.4)
Michigan	2006	8,021	826	(6.5)
Minnesota	2006	6,876	536	(4.1)
Mississippi	2007	7,941	610	(6.2)
Missouri	2006	6,231	605	(10.5)
Montana	2007	10,356	1,132	(4.2)
Nebraska	2006	538	44	(0.6)
Nevada	2005	4,520	247	(0.8)
New Hampshire	2006	1,944	254	(0.5)
New Jersey	2007	810	86	(0.0)
New Mexico	1994	6,753	484	(3.8)
New York	2006	7,669	943	(6.3)
North Carolina	2006	7,521	727	(6.8)
North Dakota	2007	289	20	0.2
Ohio	2007	3,255	353	(3.0)
Oklahoma	2003	3,235	237	(0.8)
Oregon	2006	12,163	2,007	(8.2)
Pennsylvania	2007	6,739	804	(7.0)
Rhode Island	2007	141	17	(0.0)
South Carolina	2006	5,239	440	(5.7)
South Dakota	2007	753	51	(0.9)
Tennessee	2006	5,659	576	(3.8)
Texas	2006	24,363	977	(2.4)
Utah	2005	7,396	510	(3.4)
Vermont	2007	1,857	250	(0.3)
Virginia	2006	6,400	683	(3.4)
Washington	2006	9,060	1,711	(10.0)
West Virginia	2007	4,846	592	(4.6)
Wisconsin	2006	6,757	620	(6.0)
Wyoming	2001	4,633	468	(1.1)

Table A-216 shows average C density values for forest ecosystem C pools according to region and forest types based on forest lands in this Inventory. These values were calculated by applying plot-level C estimation procedures as described below to the most recent inventory per state as available 12 September 2010 (USDA 2010b). C density values reflect the most recent survey for each state as available in the FIADB, not potential maximum C storage. C densities are affected by the distribution of stand sizes within a forest type, which can range from regenerating to mature stands. A large proportion of young stands in a particular forest type are likely to reduce the regional average for C density.

Table A-216: Average carbon density (Mg C/ha) by carbon pool and forest area (1000 ha) according to region and forest type, based on the most recent inventory survey available for each state from FIA, corresponding to an average year of 2006

Region (States) Forest Types	Above-ground Biomass	Below-ground Biomass	Dead Wood	Litter	Soil Organic Carbon	Forest Area
	Carbon Density (Mg C/ha)					(1,000 ha)
Northeast						
(CT,DE,MA,MD,ME,NH,NJ,NY,OH,PA,RI,VT,WV)						
White/Red/Jack Pine	91.6	19.0	11.9	13.7	78.1	1,584
Spruce/Fir	52.7	11.2	13.3	30.7	98.0	2,970
Oak/Pine	77.0	15.2	9.8	27.4	66.9	1,234
Oak/Hickory	82.5	15.6	11.1	8.1	53.1	13,007
Elm/Ash/Cottonwood	59.3	11.3	9.9	6.9	111.7	1,450
Maple/Beech/Birch	77.9	15.0	13.3	27.1	69.6	13,673
Aspen/Birch	48.1	9.5	9.3	8.6	87.4	1,704
Minor Types and Nonstocked	48.2	9.5	10.3	10.9	73.7	1,855
All	74.5	14.4	11.9	17.8	69.0	37,478
Northern Lake States						
(MI,MN,WI)						
White/Red/Jack Pine	54.1	11.3	9.0	12.3	120.8	1,821
Spruce/Fir	40.5	8.6	8.6	33.1	261.8	3,213
Oak/Hickory	70.4	13.3	10.8	7.9	97.1	3,815
Elm/Ash/Cottonwood	52.4	10.0	9.2	7.5	179.9	2,118
Maple/Beech/Birch	74.1	14.2	11.5	27.3	134.3	4,301
Aspen/Birch	40.9	7.9	9.5	8.3	146.1	5,272
Minor Types and Nonstocked	34.5	6.8	8.8	18.0	122.6	1,113
All	54.5	10.7	9.9	16.4	152.3	21,654
Northern Prairie States						
(IA,IL,IN,KS,MO,ND,NE,SD)						
Ponderosa Pine	40.3	8.5	7.1	14.3	48.5	576
Oak/Pine	52.0	10.1	7.5	25.5	40.1	551
Oak/Hickory	69.8	13.2	9.7	7.7	49.4	9,570
Elm/Ash/Cottonwood	74.7	14.0	11.8	6.8	83.2	1,874
Minor Types and Nonstocked	41.6	8.1	8.3	17.9	60.3	1,231
All	66.0	12.5	9.7	9.5	54.5	13,803
Ponderosa Pine	40.3	8.5	7.1	14.3	48.5	576
South Central						
(AL,AR,KY,LA,MS,OK,TN,TX)	40.6	8.3	5.5	10.9	55.5	1,198
Loblolly/Shortleaf Pine	45.8	9.4	7.0	9.6	41.9	13,256
Pinyon/Juniper	16.4	3.2	1.9	12.2	37.7	3,894
Oak/Pine	48.1	9.4	6.6	9.3	41.7	5,115
Oak/Hickory	58.5	11.0	6.8	6.4	38.6	24,619
Oak/Gum/Cypress	76.2	14.5	9.2	6.5	52.8	5,131
Elm/Ash/Cottonwood	51.9	9.8	7.1	5.9	49.9	3,441
Woodland Hardwoods	10.3	1.7	0.9	5.0	65.0	8,977
Minor Types and Nonstocked	32.3	6.2	5.8	7.1	54.3	4,271
All	45.9	8.8	5.9	7.4	45.5	68,704
Loblolly/Shortleaf Pine	45.8	9.4	7.0	9.6	41.9	13,256
Southeast						
(FL,GA,NC,SC,VA)						
Longleaf/Slash Pine	34.7	7.1	6.2	9.7	110.0	4,139
Loblolly/Shortleaf Pine	48.6	10.0	8.5	9.6	72.9	9,137
Oak/Pine	52.6	10.3	6.7	9.3	61.4	4,054
Oak/Hickory	73.1	13.8	8.9	6.4	45.3	12,014
Oak/Gum/Cypress	74.2	14.3	9.7	6.5	158.0	4,551
Elm/Ash/Cottonwood	57.9	10.9	9.7	5.6	95.7	760
Minor Types and Nonstocked	45.7	8.7	9.0	5.8	107.0	1,389
All	59.0	11.5	8.4	7.9	79.2	36,044
Coastal Alaska						
(approximately 12 percent of						

forest land in Alaska)						
Spruce/Fir	24.2	5.0	5.6	33.8	62.1	367
Fir/Spruce/Mountain Hemlock	96.0	20.3	26.8	43.2	62.1	2,233
Hemlock/Sitka Spruce	142.2	30.0	37.5	50.5	116.3	2,754
Aspen/Birch	42.0	8.0	9.1	10.6	42.5	310
Minor Types and Nonstocked	40.0	7.8	10.7	19.5	75.7	469
All	105.5	22.2	28.2	42.5	86.5	6,132
Spruce/Fir	24.2	5.0	5.6	33.8	62.1	367
Pacific Northwest, Westside (Western OR and WA)						
Douglas-fir	146.2	30.7	39.0	32.0	94.8	5,956
Fir/Spruce/Mountain Hemlock	150.1	31.7	41.6	38.3	62.1	1,187
Hemlock/Sitka Spruce	174.7	36.8	50.0	37.8	116.3	1,566
Alder/Maple	84.8	16.6	24.2	7.6	115.2	1,189
Minor Types and Nonstocked	68.9	13.7	18.0	13.5	85.9	1,216
All	135.6	28.3	37.0	28.8	95.5	11,114
Pacific Northwest, Eastside (Eastern OR and WA)						
Douglas-fir	77.5	16.2	19.5	36.3	94.8	2,089
Ponderosa Pine	48.8	10.2	11.2	22.5	50.7	2,742
Fir/Spruce/Mountain Hemlock	95.3	20.1	27.8	37.9	62.1	1,781
Lodgepole Pine	41.2	8.7	12.0	21.1	52.0	1,041
Western Larch	63.5	13.3	19.2	35.7	45.1	204
Other Western Softwoods	15.7	3.0	4.5	36.2	78.8	1,252
Minor Types and Nonstocked	36.0	7.1	16.1	25.1	81.5	999
All	57.1	11.9	15.8	30.1	68.4	10,109
Pacific Southwest (CA)						
Pinyon/Juniper	24.1	4.7	2.3	21.1	26.3	742
Douglas-fir	162.8	33.8	37.3	35.7	40.1	442
Ponderosa Pine	63.7	13.2	15.0	22.4	41.3	899
Fir/Spruce/Mountain Hemlock	158.0	33.4	45.0	38.3	51.9	824
Redwood	219.6	45.9	48.1	60.5	53.8	299
Other Western Softwoods	33.7	6.6	7.6	37.5	49.8	806
California Mixed Conifer	127.8	26.8	32.8	37.9	49.8	3,159
Western Oak	67.0	12.8	7.9	29.7	27.6	3,791
Tanoak/Laurel	132.0	26.0	20.1	28.0	27.6	830
Minor Types and Nonstocked	57.8	11.7	17.7	25.2	37.0	1,540
All	92.0	18.7	20.0	31.9	38.6	13,333
Rocky Mountain, North (ID,MT)						
Douglas-fir	72.8	15.4	14.5	37.0	38.8	5,587
Ponderosa Pine	40.0	8.3	8.2	22.9	34.3	1,865
Fir/Spruce/Mountain Hemlock	67.6	14.3	22.1	37.4	44.1	4,471
Lodgepole Pine	50.3	10.7	10.9	23.1	37.2	2,761
Western Larch	60.1	12.7	15.4	36.3	34.2	492
Other Western Softwoods	44.8	9.4	6.9	39.3	31.4	649
Aspen/Birch	31.8	6.0	12.5	26.8	56.6	533
Minor Types and Nonstocked	28.4	5.7	17.0	22.5	42.9	2,655
Rocky Mountain, South (AZ,CO,NM,NV,UT,WY)						
Pinyon/Juniper	22.9	4.7	1.0	21.1	19.7	18,738
Douglas-fir	74.7	15.9	16.9	38.1	30.9	1,797
Ponderosa Pine	47.3	10.0	8.2	23.6	24.1	3,570
Fir/Spruce/Mountain Hemlock	79.6	16.9	22.9	38.8	31.5	4,262
Lodgepole Pine	52.0	11.1	13.0	24.0	27.0	2,024
Aspen/Birch	56.9	11.0	13.2	28.5	58.8	2,555
Woodland Hardwoods	19.0	3.6	4.6	28.2	25.9	4,135
Minor Types and Nonstocked	18.7	3.6	7.9	22.6	25.4	3,088
All	36.3	7.5	6.9	25.4	25.8	40,168
United States (forest land included in Inventory)	**60.0**	**11.9**	**11.1**	**17.6**	**62.0**	**277,552**

Note: The forest area values in this table do not equal the forest area values reported in Table A-214, because the forest area values in this table are estimated using the most recent dataset per state, with an average year of 2006. The time series of forest area values reported in Table A-214, in contrast, is constructed following the CCT methods used to construct the carbon stock series. The forest area values reported in Table A-214 and Table A-216 would only be identical if all states were measured simultaneously or they all had identical rates of change.

The Inventory is derived primarily from the current FIADB 4.0 data (USDA Forest Service 2010b), but it also draws on older FIA survey data where necessary. The Resources Planning Act Assessment (RPA) database, which includes periodic summaries of state inventories, is one example. Information about the RPA data is available on the Internet (USDA Forest Service 2010a, see Program Features), and compilations of analytical estimates based on these databases are found in Waddell et al. (1989) and Smith et al. (2001). The basic difference between the RPA database and the FIADB is that the FIADB includes some informative additional details such as individual-tree data. Having only plot-level information (such as volume per hectare) limits the conversion to biomass. This does not constitute a substantial difference for the overall state-wide estimates, but it does affect plot-level precision (Smith et al. 2004). In the past, FIA made their data available in tree-level Eastwide (Hansen et al. 1992) or Westwide (Woudenberg and Farrenkopf 1995) formats, which included inventories for Eastern and Western states, respectively. The current Inventory estimates rely in part on older tree-level data that are not available on the current FIADB site. The Integrated Database (IDB) is a compilation of periodic forest inventory data from the 1990s for California, Oregon, and Washington (Waddell and Hiserote 2005). These data were identified by Heath et al. (submitted) as the most appropriate non-FIADB sources for these states.

An historical focus of the FIA program was to provide information on timber resources of the United States. For this reason, prior to 1998, some forest land, which were less productive or reserved (i.e., land where harvesting was prohibited by law), were less intensively surveyed. This generally meant that on these less productive lands, forest type and area were identified but data were not collected on individual tree measurements. The practical effect that this evolution in inventories has had on estimating forest C stocks from 1990 through the present is that some older surveys of lands do not have the stand-level values for merchantable volume of wood or stand age. Any data gaps identified in the surveys taken before 1998 were filled by assigning average C densities calculated from the more complete, later inventories from the respective states. The overall effect of this necessary approach to generate estimates for C stock is that no net change in C density occurs on those lands with gaps in past surveys.

Estimating C stocks from forest inventory data

For each inventory summary in each state, data are converted to C units or augmented by other ecological data. This collection of conversion factors and models used for inventory-based forest carbon estimates (Smith et al. 2010, Heath et al. in press) was intitially developed as an offshoot of the forest carbon simulation model FORCARB (Heath et al. 2010) and is incorporated into a number of applications (Birdsey and Heath 1995, Birdsey and Heath 2001, Heath et al. 2003, Smith et al. 2004, Smith et al. 2007, Hoover and Rebain 2008). The conversion factors and model coefficients are usually categorized by region, and forest type. Classifications for both region and forest type are subject to change depending on the particular coefficient set. Thus, region and type are specifically defined for each set of estimates. Factors are applied to the survey data at the scale of FIA inventory plots. The results are estimates of C density (Mg per hectare) for the various forest pools. C density for live trees, standing dead trees, understory vegetation, down dead wood, litter, and soil organic matter are estimated. All non-soil pools except litter can be separated into aboveground and belowground components. The live tree and understory C pools are pooled as biomass in this inventory. Similarly, standing dead trees and down dead wood are pooled as dead wood in this inventory. C stocks and fluxes for *Forest Land Remaining Forest Land* are reported in pools following IPCC (2003).

Live tree C pools

The tree C pools include aboveground and belowground (coarse root) C mass of live trees. Separate estimates are made for full-tree and aboveground-only biomass to estimate the belowground component. Most tree C estimates are based on Jenkins et al. (2003) and are functions of species groups and diameter. For example, the equation for estimating aboveground biomass for a live tree of a species in the aspen/alder/cottonwood/willow group is:

$$\text{Biomass (kg dry weight)} = e^{(-2.2094 + 2.3867 \times \ln(\text{diameter}))}$$

Diameter is cm at diameter breast height (d.b.h.), which is measured at 1.37 m above the forest floor. C is calculated by multiplying biomass by 0.5 because biomass is 50 percent of dry weight (IPCC/UNEP/OECD/IEA 1997). A full set of coefficients can be found in Jenkins et al. (2003; Table 4). Belowground root biomass is estimated as a ratio of roots to total aboveground biomass. The equation for ratio of root biomass of a live tree in the aspen/alder/cottonwood/willow group is:

$$\text{Ratio} = e^{(-1.6911 + 0.8160/\text{diameter})}$$

Belowground biomass is calculated by multiplying the ratio by total aboveground biomass. A full set of coefficients can be found in Jenkins et al. (2003; Table 6). The C per tree is summed for each plot, and multiplied by the appropriate expansion factors to obtain a C stock estimate for the plot.

Some inventory data do not provide measurements of individual trees; tree C in these plots is estimated from plot-level growing stock volume of live trees and equations given in Table A-217 and Table A-218. These equations are updates of those in Smith et al. (2003), modified to reduce error and correspond to common forest types defined by inventories. Separate estimates are made for whole-tree and aboveground-only biomass based on forest type group and region. The belowground portion is determined as the difference between the two estimates. C density is estimated based on the growing stock volume of the plot, where growing stock includes live trees of commercial species meeting specified standards. Only trees 12.7 cm (5 inches) d.b.h. and larger are included in growing stock volume. The full sets of coefficients are in Table A-217 and Table A-218. For example, the total C in tree biomass per hectare of aspen-birch in the North averages 8.1 Mg C/ha if growing-stock volume is zero. If growing-stock volume is greater than zero, the estimate is in two parts. Average C density of non-growing-stock trees (sapling and cull trees) is 14.3 Mg C/ha, and the equation for C in growing-stock trees is:

$$\text{Growing-stock trees (Mg C/ha)} = e^{(-0.337 + \ln(\text{volume}) \times 0.933)}$$

Units for volume are m^3/ha.

Table A-217: Coefficients for estimating carbon density of live trees (above- and below-ground, MgC/ha) by region and type for plot-level data such as RPA data[a]

Region[b]	Forest type group[c]	Carbon density, if Growing Stock Volume (GSV) = 0	C density for non-Growing Stock (GS), if GSV > 0	Coefficient A	Coefficient B
North	Aspen/Birch	8.138	14.335	-0.337	0.933
	Elm/Ash/Cottonwood	16.187	18.707	-0.206	0.920
	Maple/Beech/Birch	6.938	17.054	-0.170	0.925
	Oak/Hickory	13.083	15.914	-0.079	0.932
	Hardwood minor types	10.376	14.127	0.002	0.890
	Oak/Pine	4.079	15.473	-0.146	0.908
	Ponderosa Pine & Exotic Softwood	2.595	6.895	-0.074	0.886
	Loblolly/Shortleaf Pine	6.277	9.766	-0.415	0.943
	Spruce/Fir	6.424	16.903	-0.487	0.947
	White/Red/Jack Pine	3.908	12.117	-0.349	0.924
	Softwood minor types	6.277	17.234	-0.380	0.970
	Non-stocked	1.054	1.238	-0.174	0.866
Pacific Coast	Alder/Maple	8.425	4.444	0.056	0.828
	Other Western Hardwoods	8.425	10.483	0.041	0.864
	Tanoak/Laurel	8.425	10.203	-0.167	0.917
	Western Oak	8.425	7.400	0.344	0.850
	Hardwood minor types	8.425	4.802	0.333	0.770
	California Mixed Conifer	10.102	4.727	0.137	0.843
	Douglas-fir	2.752	4.961	0.180	0.834
	Fir/Spruce/Mt. Hemlock	10.102	6.462	0.171	0.834
	Hemlock/Sitka Spruce	10.102	8.034	0.085	0.830
	Lodgepole Pine	10.102	5.733	-0.129	0.857
	Pinyon/Juniper	22.552	5.065	-0.070	0.842
	Ponderosa Pine	10.102	2.262	0.145	0.813
	Western Larch	10.102	5.254	-0.264	0.853
	Softwood minor types	10.102	6.771	0.466	0.783
	RPA Western Hardwoods	8.425	7.460	0.302	0.831
	Non-stocked	0.880	0.300	0.049	0.806
Rocky Mountain	Aspen/Birch	4.594	9.516	0.324	0.792
	Harwood minor types	4.866	11.844	0.266	0.814
	Douglas-fir	1.987	5.363	0.331	0.825
	Fir/Spruce/Mt. Hemlock	1.987	6.693	0.065	0.825
	Lodgepole Pine	1.080	8.051	0.003	0.804
	Other Western Softwoods	1.987	12.217	0.361	0.796
	Ponderosa Pine	1.987	5.574	0.382	0.771
	Softwood minor types	1.987	5.496	-0.152	0.836
	RPA Western Hardwood	13.714	11.678	0.246	0.807
	Pinyon/Juniper	22.927	23.301	0.254	0.794

	West. Oak/Other West. Hardwoods	14.441	18.544	0.215	0.796
	Non-stocked	1.111	0.568	0.257	0.732
South	Elm/Ash/Cottonwood	12.841	21.633	-0.144	0.896
	Oak/Gum/Cypress	7.176	23.919	-0.216	0.907
	Oak/Hickory	14.594	20.007	-0.031	0.886
	Hardwood minor types	47.316	40.194	-0.442	0.960
	Oak/Pine	4.106	17.933	-0.086	0.858
	Loblolly/Shortleaf Pine	3.892	12.466	0.206	0.773
	Longleaf/Slash Pine	4.441	8.694	0.110	0.772
	Softwood minor types	7.161	20.189	-0.085	0.868
	Non-stocked	0.467	0.943	0.019	0.734

[a] Prediction of C in growing-stock trees is based on exp(A + B*ln(growing stock volume)).
[b] Regions are North (CT, DE, IA, IL, IN, KS, MA, MD, ME, MI, MN, MO, ND, NE, NH, NJ, NY, OH, PA, RI, SD, VT, WI, WV); Pacific Coast (CA, OR, WA); Rocky Mountain (AZ, CO, ID, MT, NM, NV, UT, WY); and South (AL, AR, FL, GA, KY, LA, MS, NC, OK, SC, TN, TX, VA).
[c] Forest type groups are identified in FIADB and RPA data (Smith et al. (2001, USDA Forest Service 2010d).

Table A-218: Coefficients for estimating carbon density of live trees (aboveground only, MgC/ha) by region and type for plot-level data such as RPA data[a]

Region[b]	Forest type group[c]	Carbon density, if Growing Stock Volume (GSV)=0	C density for non-GS, if GSV > 0	Coefficient A	Coefficient B
North	Aspen/Birch	6.697	11.880	-0.521	0.934
	Elm/Ash/Cottonwood	13.585	15.653	-0.387	0.922
	Maple/Beech/Birch	5.762	14.219	-0.352	0.926
	Oak/Hickory	10.960	13.306	-0.260	0.933
	Hardwood minor types	8.647	11.796	-0.166	0.888
	Oak/Pine	3.368	12.881	-0.335	0.909
	Ponderosa Pine & Exotic Softwood	2.116	5.671	-0.269	0.886
	Loblolly/Shortleaf Pine	5.098	8.070	-0.620	0.946
	Spruce/Fir	5.206	13.833	-0.684	0.948
	White/Red/Jack Pine	3.174	10.010	-0.548	0.926
	Softwood minor types	5.098	14.246	-0.570	0.971
	Non-stocked	0.880	1.032	-0.357	0.866
Pacific Coast	Alder/Maple	7.006	3.676	-0.138	0.830
	Other Western Hardwoods	7.006	8.709	-0.154	0.867
	Tanoak/Laurel	7.006	8.469	-0.355	0.918
	Western Oak	7.006	6.163	0.167	0.850
	Hardwood minor types	7.006	3.974	0.136	0.773
	California Mixed Conifer	8.309	3.883	-0.061	0.844
	Douglas-fir	2.235	4.072	-0.017	0.835
	Fir/Spruce/Mt. Hemlock	8.309	5.285	-0.027	0.835
	Hemlock/Sitka Spruce	8.309	6.586	-0.113	0.831
	Lodgepole Pine	8.309	4.674	-0.327	0.858
	Pinyon/Juniper	18.583	4.170	-0.263	0.842
	Ponderosa Pine	8.309	1.849	-0.053	0.814
	Western Larch	8.309	4.282	-0.461	0.853
	Softwood minor types	8.309	5.563	0.267	0.784
	RPA Western Hardwoods	7.006	6.202	0.119	0.831
	Non-stocked	0.724	0.247	-0.146	0.808
Rocky Mountain	Aspen/Birch	3.798	7.914	0.139	0.793
	Harwood minor types	4.027	9.936	0.084	0.815
	Douglas-fir	1.616	4.388	0.134	0.826
	Fir/Spruce/Mt. Hemlock	1.616	5.466	-0.133	0.826
	Lodgepole Pine	0.871	6.571	-0.195	0.805
	Other Western Softwoods	1.616	10.031	0.165	0.797
	Ponderosa Pine	1.616	4.569	0.185	0.772
	Softwood minor types	1.616	4.473	-0.350	0.837
	RPA Western Hardwood	11.341	9.704	0.054	0.809
	Pinyon/Juniper	18.867	19.173	0.059	0.794
	West. Oak/Other West. Hardwoods	11.942	15.353	0.021	0.796
	Non-stocked	0.916	0.466	0.061	0.733
South	Elm/Ash/Cottonwood	10.749	18.129	-0.323	0.897
	Oak/Gum/Cypress	5.987	20.004	-0.400	0.909
	Oak/Hickory	12.223	16.731	-0.215	0.888

Hardwood minor types	39.737	33.739	-0.631	0.964
Oak/Pine	3.394	14.923	-0.277	0.859
Loblolly/Shortleaf Pine	3.172	10.288	0.012	0.773
Longleaf/Slash Pine	3.634	7.176	-0.088	0.773
Softwood minor types	5.893	16.751	-0.280	0.869
Non-stocked	0.388	0.788	-0.171	0.735

[a] Prediction of aboveground C in growing-stock trees is based on exp(A + B*ln(growing stock volume).
[b] Regions are North (CT, DE, IA, IL, IN, KS, MA, MD, ME, MI, MN, MO, ND, NE, NH, NJ, NY, OH, PA, RI, SD, VT, WI, WV); Pacific Coast (CA, OR, WA); Rocky Mountain (AZ, CO, ID, MT, NM, NV, UT, WY); and South (AL, AR, FL, GA, KY, LA, MS, NC, OK, SC, TN, TX, VA).
[c] Forest type groups are identified in FIADB and RPA data (Smith et al. 2001, USDA Forest Service 2010d).

Understory vegetation

Understory vegetation is a minor component of biomass. Understory vegetation is defined as all biomass of undergrowth plants in a forest, including woody shrubs and trees less than one-inch d.b.h. In this inventory, it is assumed that 10 percent of understory C mass is belowground. This general root-to-shoot ratio (0.11) is near the lower range of temperate forest values provided in IPCC (2006) and was selected based on two general assumptions: ratios are likely to be lower for light-limited understory vegetation as compared with larger trees, and a greater proportion of all root mass will be less than 2 mm diameter.

Estimates of C density are based on information in Birdsey (1996), which was applied to FIA permanent plots. These were fit to the equation:

$$\text{Ratio} = e^{(A - B \times \ln(\text{live tree C density})}$$

In this equation, "ratio" is the ratio of understory C density (Mg C/ha) to live tree C density (above- and below-ground) in Mg C/ha. An additional coefficient is provided as a maximum ratio; that is, any estimate predicted from the equation that is greater than the maximum ratio is set equal to the maximum ratio. A full set of coefficients is in Table A-219. Regions and forest types are the same classifications described in Smith et al. (2003). As an example, the basic calculation for understory C in aspen-birch forests in the Northeast is:

$$\text{Understory (Mg C/ha)} = (\text{live tree C density}) \times e^{(0.855 - 1.03 \times \ln(\text{tree C density}))}$$

This calculation is followed by three possible modifications. First, the maximum value for the ratio is set to 2.02 (see value in column "maximum ratio"); this also applies to stands with zero tree C, which is undefined in the above equation. Second, the minimum ratio is set to 0.005 (Birdsey 1996). Third, nonstocked and pinyon/juniper stands are set to coefficient A, which is a carbon density (Mg C/ha) for these types only.

Table A-219: Coefficients for estimating the ratio of carbon density of understory vegetation (above- and belowground, MgC/ha)[a] by region and forest type. The ratio is multiplied by tree carbon density on each plot to produce understory vegetation

Region[b]	Forest Type[b]	A	B	Maximum ratio[c]
NE	Aspen-Birch	0.855	1.032	2.023
	MBB/Other Hardwood	0.892	1.079	2.076
	Oak-Hickory	0.842	1.053	2.057
	Oak-Pine	1.960	1.235	4.203
	Other Pine	2.149	1.268	4.191
	Spruce-Fir	0.825	1.121	2.140
	White-Red-Jack Pine	1.000	1.116	2.098
	Nonstocked	2.020	2.020	2.060
NLS	Aspen-Birch	0.777	1.018	2.023
	Lowland Hardwood	0.650	0.997	2.037
	Maple-Beech-Birch	0.863	1.120	2.129
	Oak-Hickory	0.965	1.091	2.072
	Pine	0.740	1.014	2.046
	Spruce-Fir	1.656	1.318	2.136
	Nonstocked	1.928	1.928	2.117
NPS	Conifer	1.189	1.190	2.114
	Lowland Hardwood	1.370	1.177	2.055
	Maple-Beech-Birch	1.126	1.201	2.130
	Oak-Hickory	1.139	1.138	2.072
	Oak-Pine	2.014	1.215	4.185

	Nonstocked	2.052	2.052	2.072
PSW	Douglas-fir	2.084	1.201	4.626
	Fir-Spruce	1.983	1.268	4.806
	Hardwoods	1.571	1.038	4.745
	Other Conifer	4.032	1.785	4.768
	Pinyon-Juniper	4.430	4.430	4.820
	Redwood	2.513	1.312	4.698
	Nonstocked	4.431	4.431	4.626
PWE	Douglas-fir	1.544	1.064	4.626
	Fir-Spruce	1.583	1.156	4.806
	Hardwoods	1.900	1.133	4.745
	Lodgepole Pine	1.790	1.257	4.823
	Pinyon-Juniper	2.708	2.708	4.820
	Ponderosa Pine	1.768	1.213	4.768
	Nonstocked	4.315	4.315	4.626
PWW	Douglas-fir	1.727	1.108	4.609
	Fir-Spruce	1.770	1.164	4.807
	Other Conifer	2.874	1.534	4.768
	Other Hardwoods	2.157	1.220	4.745
	Red Alder	2.094	1.230	4.745
	Western Hemlock	2.081	1.218	4.693
	Nonstocked	4.401	4.401	4.589
RMN	Douglas-fir	2.342	1.360	4.731
	Fir-Spruce	2.129	1.315	4.749
	Hardwoods	1.860	1.110	4.745
	Lodgepole Pine	2.571	1.500	4.773
	Other Conifer	2.614	1.518	4.821
	Pinyon-Juniper	2.708	2.708	4.820
	Ponderosa Pine	2.099	1.344	4.776
	Nonstocked	4.430	4.430	4.773
RMS	Douglas-fir	5.145	2.232	4.829
	Fir-Spruce	2.861	1.568	4.822
	Hardwoods	1.858	1.110	4.745
	Lodgepole Pine	3.305	1.737	4.797
	Other Conifer	2.134	1.382	4.821
	Pinyon-Juniper	2.757	2.757	4.820
	Ponderosa Pine	3.214	1.732	4.820
	Nonstocked	4.243	4.243	4.797
SC	Bottomland Hardwood	0.917	1.109	1.842
	Misc. Conifer	1.601	1.129	4.191
	Natural Pine	2.166	1.260	4.161
	Oak-Pine	1.903	1.190	4.173
	Planted Pine	1.489	1.037	4.124
	Upland Hardwood	2.089	1.235	4.170
	Nonstocked	4.044	4.044	4.170
SE	Bottomland Hardwood	0.834	1.089	1.842
	Misc. Conifer	1.601	1.129	4.191
	Natural Pine	1.752	1.155	4.178
	Oak-Pine	1.642	1.117	4.195
	Planted Pine	1.470	1.036	4.141
	Upland Hardwood	1.903	1.191	4.182
	Nonstocked	4.033	4.033	4.182

[a]Prediction of ratio of understory C to live tree C is based on the equation: Ratio=exp(A-B*ln(tree_carbon_tph)), where "ratio" is the ratio of understory C density to live tree (above-and below- ground) C density, and "tree_carbon_density" is live tree (above-and below- ground) C density in Mg C/ha.
[b] Regions and types as defined in Smith et al. (2003)
[c]Maximum ratio: any estimate predicted from the equation that is greater than the maximum ratio is set equal to the maximum ratio.

Dead Wood

The standing dead tree C pools include aboveground and belowground (coarse root) mass. Estimates for standing dead tree C are not based on newly available FIA standing dead tree data because updated methodology is not yet available for integrating dead wood carbon estimates based on both older (which do not have consistent measurements of dead wood) and newer surveys. Instead, the estimates are based on a ratio of growing stock volume of live trees, stratified by region and forest type groups, applied at the FIA plot-level. The standing dead tree equations estimate mass; they are converted to C mass by multiplying by 0.5. An example calculation for standing dead tree C in aspen-birch forests in the Northeast is:

$$\text{Dry weight of dead trees (Mg/ha)} = 1.0 \times (\text{growing stock volume})^{0.499}$$

It is multiplied by 0.5 to obtain Mg C/ha. All coefficients are provided in Table A-220. Note that nonstocked stands are assigned a constant C density (the value of Coefficient A).

Down dead wood is defined as pieces of dead wood greater than 7.5 cm diameter, at transect intersection, that are not attached to live or standing dead trees. Down dead wood includes stumps and roots of harvested trees. Ratio estimates of down dead wood to live tree biomass were developed using FORCARB2 simulations and applied at the plot level (Smith et al. 2004). Estimates for down dead wood correspond to the region and forest type classifications described in Smith et al. (2003). A full set of ratios is provided in Table A-221. An additional component of down dead wood is a regional average estimate of logging residue based on Smith et al. (2006) applied at the plot level. These are based on a regional average C density at age zero and first order decay; initial densities and decay coefficients are provided in Table A-222. These amounts are added to explicitly account for down dead wood following harvest. In practice, this modification resulted in minor changes to the estimates. Example calculations of the two components for down dead wood in 25-year-old aspen-birch forests in the Northeast are:

C density (Mg C/ha) = (live tree C density, above- and below-ground) × (0.078) = 7.8% of live tree C

Conversion to C units is not necessary because the live tree value is already in terms of C.

C density additional for logging residue (Mg C/ha) = $13.9 \times e^{(-25/12.1)} = 1.8$ (Mg C/ha)

Table A-220: Coefficients for estimating standing dead tree carbon (MgC/ha) by region and forest type group[a]

Region[b]	Forest type group[c]	Coefficient A	Coefficient B
MTN	Douglas-fir	3.935	0.312
	Fir/Spruce/Mt. Hemlock	4.550	0.358
	Hemlock/Sitka Spruce	1.000	0.569
	Lodgepole Pine	1.177	0.501
	Ponderosa Pine	1.000	0.455
	Nonstocked	12.855	--
MTS	Douglas-fir	2.200	0.460
	Fir/Spruce/Mt. Hemlock	6.923	0.293
	Lodgepole Pine	1.177	0.501
	Ponderosa Pine	1.944	0.292
	Nonstocked	4.232	--
NC	Aspen/Birch	1.962	0.400
	Elm/Ash/Cottonwood	3.755	0.253
	Maple/Beech/Birch	3.442	0.219
	Planted Pine	1.000	0.298
	Oak/Hickory	2.949	0.236
	Oak/Pine	1.364	0.394
	Spruce/Fir	1.320	0.472
	White/Red/Jack Pine	2.844	0.266
	Nonstocked	2.634	--
NE	Aspen/Birch	1.000	0.499
	Elm/Ash/Cottonwood	4.992	0.134
	Maple/Beech/Birch	3.041	0.306
	Oak/Hickory	3.332	0.191
	Oak/Pine	1.725	0.311
	Spruce/Fir	5.893	0.190
	White/Red/Jack Pine	2.841	0.254
	Nonstocked	2.876	--
PC	California Mixed Conifer	1.000	0.608
	Douglas-fir	1.237	0.559
	Douglas-fir Planted	10.145	0.112
	Fir/Spruce/Mt. Hemlock	4.235	0.415
	Hemlock/Sitka Spruce	1.546	0.562
	Redwood	5.385	0.287
	Nonstocked	7.377	--
SC	Elm/Ash/Cottonwood	2.393	0.284
	Loblolly/Shortleaf Pine	1.203	0.271

	Loblolly/Shortleaf Planted	1.000	0.138
	Oak/Gum/Cypress	4.234	0.121
	Oak/Hickory	2.396	0.186
	Oak/Pine	1.133	0.337
	Nonstocked	0.286	--
SE	Elm/Ash/Cottonwood	1.358	0.476
	Loblolly/Shortleaf Pine	1.000	0.324
	Loblolly/Shortleaf Planted	1.000	0.265
	Oak/Gum/Cypress	1.770	0.329
	Oak/Hickory	2.256	0.257
	Oak/Pine	1.000	0.351
	Nonstocked	0.349	--
South	Longleaf/Slash Pine	1.000	0.184
	Longleaf/Slash Planted	1.000	0.106
West	Alder/Maple	2.190	0.466
	Aspen/Birch	3.062	0.376
	Pinyon/Juniper	3.163	0.100
	Tanoak/Laurel	1.000	0.593
	Western Hardwood/Woodlands	5.595	0.181
	Western Larch	2.049	0.449
	Western Oak	1.996	0.348

[a]Standing dead tree C is based on the equation: mass (Mg/ha) = A* (live-tree growing stock volume)^B. Note that nonstocked stands are assigned a constant C density (the value listed under coefficient A). Note that the standing dead tree equations are for biomass. To convert to C mass, multiply by 0.5.
[b]Regions are PC (CA,OR-West,WA-West), MTN (OR-East,WA-East,ID,MT), MTS (AZ,CO,NM,NV,UT,WY), West (regions PC, MTN, and MTS), NC (IA, IL, IN, KS, MI, MN, MO, ND, NE, SD, WI), NE (CT, DE, MA, MD, ME, NH, NJ, NY, OH, PA, RI, VT, WV), SC (AL, AR, KY, LA, MS, OK, TN, TX), SE (FL, GA, NC, SC, VA), and South (regions SC and SE).
[c]Forest types are described in FIADB documentation (USDA Forest Service, 2010d). Minor forest types within a region that are not explicitly defined/listed in the table of coefficients are assigned to a similar hardwood or softwood forest type.

Table A-221: Ratio for estimating down dead wood by region and forest type. The ratio is multiplied by the live tree carbon density on a plot to produce down dead wood carbon density (MgC/ha)

Region[a]	Forest type[a]	Ratio
NE	Aspen-Birch	0.078
	MBB/Other Hardwood	0.071
	Oak-Hickory	0.068
	Oak-Pine	0.061
	Other Pine	0.065
	Spruce-Fir	0.092
	White-Red-Jack Pine	0.055
	Nonstocked	0.019
NLS	Aspen-Birch	0.081
	Lowland Hardwood	0.061
	Maple-Beech-Birch	0.076
	Oak-Hickory	0.077
	Pine	0.072
	Spruce-Fir	0.087
	Nonstocked	0.027
NPS	Conifer	0.073
	Lowland Hardwood	0.069
	Maple-Beech-Birch	0.063
	Oak-Hickory	0.068
	Oak-Pine	0.069
	Nonstocked	0.026
PSW	Douglas-fir	0.091
	Fir-Spruce	0.109
	Hardwoods	0.042
	Other Conifer	0.100
	Pinyon-Juniper	0.031
	Redwood	0.108
	Nonstocked	0.022
PWE	Douglas-fir	0.103
	Fir-Spruce	0.106
	Hardwoods	0.027

Region (cont'd)	Forest type (cont'd)	Ratio (cont'd)
PWW	Douglas-fir	0.100
	Fir-Spruce	0.090
	Other Conifer	0.073
	Other Hardwoods	0.062
	Red Alder	0.095
	Western Hemlock	0.099
	Nonstocked	0.020
RMN	Douglas-fir	0.062
	Fir-Spruce	0.100
	Hardwoods	0.112
	Lodgepole Pine	0.058
	Other Conifer	0.060
	Pinyon-Juniper	0.030
	Ponderosa Pine	0.087
	Nonstocked	0.018
RMS	Douglas-fir	0.077
	Fir-Spruce	0.079
	Hardwoods	0.064
	Lodgepole Pine	0.098
	Other Conifer	0.060
	Pinyon-Juniper	0.030
	Ponderosa Pine	0.082
	Nonstocked	0.020
SC	Bottomland Hardwood	0.063
	Misc. Conifer	0.068
	Natural Pine	0.068
	Oak-Pine	0.072
	Planted Pine	0.077
	Upland Hardwood	0.067
	Nonstocked	0.013
SE	Bottomland Hardwood	0.064

Lodgepole Pine	0.093	Misc. Conifer	0.081
Pinyon-Juniper	0.032	Natural Pine	0.081
Ponderosa Pine	0.103	Oak-Pine	0.063
Nonstocked	0.024	Planted Pine	0.075
		Upland Hardwood	0.059
		Nonstocked	0.012

[a] Regions and types as defined in Smith et al. (2003).

Table A-222: Coefficients for estimating logging residue component of down dead wood.

Region[a]	Forest Type Group[b] (softwood/hardwood)	Initial Carbon Density (Mg/ha)	Decay Coefficient
Alaska	hardwood	6.9	12.1
Alaska	softwood	8.6	32.3
NE	hardwood	13.9	12.1
NE	softwood	12.1	17.9
NLS	hardwood	9.1	12.1
NLS	softwood	7.2	17.9
NPS	hardwood	9.6	12.1
NPS	softwood	6.4	17.9
PSW	hardwood	9.8	12.1
PSW	softwood	17.5	32.3
PWE	hardwood	3.3	12.1
PWE	softwood	9.5	32.3
PWW	hardwood	18.1	12.1
PWW	softwood	23.6	32.3
RMN	hardwood	7.2	43.5
RMN	softwood	9.0	18.1
RMS	hardwood	5.1	43.5
RMS	softwood	3.7	18.1
SC	hardwood	4.2	8.9
SC	softwood	5.5	17.9
SE	hardwood	6.4	8.9
SE	softwood	7.3	17.9

[a] Regions are defined in Smith et al. (2003) with the addition of coastal Alaska.
[b] Forest types are according to majority hardwood or softwood species.

Litter carbon

C of the litter layer is currently sampled on a subset of the FIA plots. However, these data are not yet available electronically for general application to all inventories in Table A-1. Litter C is the pool of organic C (including material known as duff, humus, and fine woody debris) above the mineral soil and includes woody fragments with diameters of up to 7.5 cm. Estimates therefore continue to be based on equations of Smith and Heath (2002) and applied at the plot level. The equations describe processes for decay or loss of forest floor following harvest and the net accumulation of new forest floor material following stand growth. For example, total forest floor C at a given number of years after a clearcut harvest for aspen-birch forests in the North is:

$$\text{Total forest floor C (Mg C/ha)} = (18.4\times\text{years})/(53.7+\text{years}) + 10.2\times e^{(-\text{years}/9.2)}$$

See Table 4 of Smith and Heath (2002) for the complete set of coefficients. Note that these are direct estimates of C density; the 0.5 conversion does not apply to litter.

Soil organic carbon

Soil organic carbon (SOC) is currently sampled to a 20 cm depth on subsets of FIA plots, however, these data are not available for the entire United States. Thus, estimates of SOC are based on the national STATSGO spatial database (USDA 1991), and the general approach described by Amichev and Galbraith (2004). In their procedure, SOC was calculated for the conterminous United States using the STATSGO database, and data gaps were filled by representative values from similar soils. Links to region and forest type groups were developed with the assistance of the USDA Forest Service FIA Geospatial Service Center by overlaying FIA forest inventory plots on the soil C map. The average SOC densities are provided in Table A-216.

Carbon in Harvested Wood Products

Estimates of the harvested wood product (HWP) contribution to forest C sinks and emissions (hereafter called “HWP Contribution”) are based on methods described in Skog (2008) using the WOODCARB II model. These methods are based on IPCC (2006) guidance for estimating HWP carbon. The 2006 IPCC Guidelines provide methods that allow Parties to report HWP Contribution using one of several different accounting approaches: production, stock change, and atmospheric flow, as well as a default method. The various approaches are described below. The approaches differ in how HWP Contribution is allocated based on production or consumption as well as what processes (atmospheric fluxes or stock changes) are emphasized.

- **Production approach**: Accounts for the net changes in carbon stocks in forests and in the wood products pool, but attributes both to the producing country.
- **Stock change approach**: Accounts for changes in the product pool within the boundaries of the consuming country.
- **Atmospheric flow approach**: Accounts for net emissions or removals of carbon to and from the atmosphere within national boundaries. C removal due to forest growth is accounted for in the producing country while C emissions to the atmosphere from oxidation of wood products are accounted for in the consuming country.
- **Default approach**: Assumes no change in C stocks in HWP. IPCC (2006) requests that such an assumption be justified if this is how a Party is choosing to report.

The United States uses the production accounting approach (as in previous years) to report HWP Contribution (Table A-223). Though reported U.S. HWP estimates are based on the production approach, estimates resulting from use of the two alternative approaches—the stock change and atmospheric flow approaches—are also presented for comparison (see Table A-224). Annual estimates of change are calculated by tracking the additions to and removals from the pool of products held in end uses (i.e., products in use such as housing or publications) and the pool of products held in solid waste disposal sites (SWDS).

Estimates of five HWP variables that can be used to calculate HWP contribution for the stock change and atmospheric flow approaches for imports and exports are provided in Table A-223. The HWP variables estimated are:

(1A) annual change of C in wood and paper products in use in the United States,

(1B) annual change of C in wood and paper products in SWDS in the United States,

(2A) annual change of C in wood and paper products in use in the United States and other countries where the wood came from trees harvested in the United States,

(2B) annual change of C in wood and paper products in SWDS in the United States and other countries where the wood came from trees harvested in the United States,

(3) C in imports of wood, pulp, and paper to the United States,

(4) C in exports of wood, pulp and paper from the United States, and

(5) C in annual harvest of wood from forests in the United States.

Table A-223: Harvested wood products from wood harvested in United States—Annual additions of carbon to stocks and total stocks

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Net carbon additions per year (Tg C per year)																					
Total Harvested wood carbon	(35.9)	(33.8)	(33.8)	(32.9)	(33.4)	(32.3)	(30.6)	(32.0)	(31.1)	(32.5)	(30.8)	(25.5)	(26.8)	(25.9)	(28.7)	(28.7)	(29.6)	(28.1)	(22.4)	(14.8)	
Products in use	(17.7)	(14.9)	(16.3)	(15.0)	(15.9)	(15.1)	(14.1)	(14.7)	(13.4)	(14.1)	(12.8)	(8.7)	(9.6)	(9.7)	(12.4)	(12.4)	(12.3)	(10.7)	(5.2)	1.9	
Solid wood products	(14.4)	(11.9)	(12.6)	(12.2)	(12.1)	(11.2)	(11.5)	(11.8)	(11.4)	(12.1)	(11.9)	(10.1)	(10.7)	(10.1)	(11.6)	(11.9)	(10.6)	(8.7)	(4.4)	0.6	
Paper products	(3.3)	(3.1)	(3.7)	(2.8)	(3.8)	(3.8)	(2.6)	(3.0)	(2.0)	(2.0)	(1.0)	1.4	1.1	0.4	(0.8)	(0.5)	(1.7)	(2.0)	(0.8)	1.3	
Products in SWDS	(18.3)	(18.8)	(17.4)	(17.9)	(17.5)	(17.2)	(16.5)	(17.3)	(17.7)	(18.4)	(18.0)	(16.8)	(17.2)	(16.2)	(16.3)	(16.3)	(17.3)	(17.4)	(17.2)	(16.7)	
Solid wood products	(9.9)	(11.1)	(9.5)	(9.7)	(9.8)	(10.7)	(10.6)	(10.3)	(10.2)	(10.6)	(10.7)	(10.7)	(11.1)	(11.1)	(11.3)	(11.5)	(11.6)	(11.7)	(11.5)	(11.2)	
Paper products	(8.3)	(7.7)	(7.9)	(8.3)	(7.7)	(6.5)	(6.0)	(6.9)	(7.5)	(7.8)	(7.3)	(6.0)	(6.1)	(5.1)	(5.0)	(4.8)	(5.7)	(5.7)	(5.7)	(5.4)	
Total Carbon stocks (Tg C)																					
Total Harvested wood carbon	1,859	1,895	1,929	1,963	1,996	2,029	2,061	2,092	2,124	2,155	2,187	2,218	2,244	2,271	2,296	2,325	2,354	2,383	2,412	2,434	2,449
Products in use	1,231	1,249	1,264	1,280	1,295	1,311	1,326	1,340	1,355	1,368	1,382	1,395	1,404	1,413	1,423	1,436	1,448	1,460	1,471	1,476	1,474
Products in SWDS	628	646	665	683	701	718	735	752	769	787	805	823	840	857	873	890	906	923	941	958	974

Note: Parentheses indicate net C sequestration (i.e., a net removal of C from the atmosphere).

Table A-224: Comparison of Net Annual Change in Harvested Wood Products Carbon Stocks Using Alternative Accounting Approaches

	HWP Contribution to LULUCF Emissions/ removals (Tg CO_2 Eq.)		
Inventory Year	**Stock Change Approach**	**Atmospheric Flow Approach**	**Production Approach**
1990	(129.6)	(138.4)	(131.8)
1991	(116.3)	(131.4)	(123.8)
1992	(120.0)	(131.6)	(123.8)
1993	(126.8)	(127.8)	(120.7)
1994	(130.0)	(129.9)	(122.5)
1995	(126.0)	(128.0)	(118.4)
1996	(122.3)	(122.5)	(112.2)
1997	(131.4)	(127.4)	(117.3)
1998	(139.8)	(122.7)	(114.1)
1999	(149.4)	(127.3)	(119.1)
2000	(143.2)	(120.3)	(112.9)
2001	(128.3)	(100.3)	(93.4)
2002	(135.6)	(103.1)	(98.2)
2003	(134.6)	(99.2)	(94.8)
2004	(163.0)	(109.1)	(105.3)
2005	(161.4)	(109.0)	(105.4)
2006	(138.6)	(114.2)	(108.6)
2007	(115.4)	(112.1)	(103.0)

2008	(78.4)	(94.3)	(82.1)
2009	(41.9)	(68.3)	(54.3)

Note: Parentheses indicate net C sequestration (i.e., a net removal of C from the atmosphere).

Table A-225: Harvested Wood Products Sectoral Background Data for LULUCF—United States (production approach)

Inventory year	1A Annual Change in stock of HWP in use from consumption	1B Annual Change in stock of HWP in SWDS from consumption	2A Annual Change in stock of HWP in use produced from domestic harvest	2B Annual Change in stock of HWP in SWDS produced from domestic harvest	3 Annual Imports of wood, and paper products + wood fuel, pulp, recovered paper, roundwood/ chips	4 Annual Exports of wood, and paper products + wood fuel, pulp, recovered paper, roundwood/ chips	5 Annual Domestic Harvest	6 Annual release of carbon to the atmosphere from HWP consumption (from fuelwood & products in use and products in SWDS)	7 Annual release of carbon to the atmosphere from HWP (including firewood) where wood came from domestic harvest (from products in use and products in SWDS)	8 HWP Contribution to AFOLU CO2 emissions/ removals
	$\Delta C_{HWP\ IU\ DC}$	$\Delta C_{HWP\ SWDS\ DC}$	$\Delta C_{HWP\ IU\ DH}$	$\Delta C_{HWP\ SWDS\ DH}$	P_{IM}	P_{EX}	H	$\uparrow C_{HWP\ DC}$	$\uparrow C_{HWP\ DH}$	
									Gg C /yr	Gg CO_2 /yr
1990	17,044	18,308	17,659	18,278	12,680	15,078	142,297	104,547	106,359	(131,772)
1991	13,129	18,602	14,940	18,812	11,552	15,667	144,435	108,588	110,682	(123,758)
1992	15,718	17,006	16,334	17,427	12,856	16,032	139,389	103,489	105,627	(123,791)
1993	16,957	17,627	14,971	17,949	14,512	14,788	134,554	99,694	101,633	(120,708)
1994	18,221	17,221	15,930	17,479	15,685	15,665	134,750	99,328	101,342	(122,498)
1995	17,307	17,051	15,065	17,229	16,712	17,266	137,027	102,115	104,733	(118,411)
1996	17,018	16,348	14,092	16,513	16,691	16,733	134,477	101,069	103,872	(112,219)
1997	18,756	17,090	14,740	17,263	17,983	16,877	135,439	100,699	103,436	(117,344)
1998	20,311	17,818	13,376	17,735	19,722	15,057	135,021	101,558	103,911	(114,071)
1999	22,035	18,714	14,123	18,353	21,266	15,245	134,939	100,211	102,464	(119,078)
2000	20,491	18,560	12,828	17,962	22,426	16,185	134,458	101,648	103,667	(112,898)
2001	17,295	17,691	8,711	16,774	22,975	15,336	128,621	101,274	103,136	(93,447)
2002	18,629	18,357	9,570	17,207	24,604	15,744	127,567	99,441	100,791	(98,179)
2003	19,180	17,532	9,676	16,186	25,962	16,303	124,949	97,896	99,086	(94,828)
2004	26,384	18,077	12,429	16,298	31,650	16,948	130,460	100,700	101,733	(105,332)
2005	25,777	18,249	12,394	16,347	31,714	17,423	131,711	101,976	102,971	(105,382)
2006	19,010	18,780	12,308	17,302	25,485	18,836	127,064	95,922	97,454	(108,567)
2007	12,999	18,497	10,673	17,409	21,603	20,670	120,922	90,360	92,840	(102,967)
2008	3,589	17,786	5,203	17,188	16,822	21,156	108,339	82,630	85,948	(82,101)
2009	(5,401)	16,825	(1,857)	16,652	13,281	20,485	95,130	76,501	80,334	(54,250)

Note: $\uparrow C_{HWP\ DC} = H + P_{IM} - P_{EX} - \Delta C_{HWP\ IU\ DC} - \Delta C_{HWP\ SWDS\ DC}$ AND $\uparrow C_{HWP\ DH} = H - \Delta C_{HWP\ IU\ DH} - \Delta C_{HWP\ SWDS\ DH}$. Parentheses indicate net C sequestration (i.e., a net removal of C from the atmosphere).

Annual estimates of variables 1A, 1B, 2A and 2B were calculated by tracking the additions to and removals from the pool of products held in end uses (e.g., products in uses such as housing or publications) and the pool of products held in SWDS. In the case of variables 2A and 2B, the pools include products exported and held in other countries and the pools in the United States exclude products made from wood harvested in other countries. Solidwood products added to pools include lumber and panels. End-use categories for solidwood include single and multifamily housing, alteration and repair of housing, and other end uses. There is one product category and one end-use category for paper. Additions to and removals from pools are tracked beginning in 1900, with the exception that additions of softwood lumber to housing begins in 1800. Solidwood and paper product production and trade data are from USDA Forest Service and other sources (Hair and Ulrich 1963; Hair 1958; USDC Bureau of Census 1976; Ulrich, 1985, 1989; Steer 1948; AF&PA 2006a, 2006b; Howard 2003).

The rate of removals from products in use and the rate of decay of products in SWDS are specified by first order (exponential) decay curves with given half-lives (time at which half of amount placed in use will have been discarded from use). Half-lives for products in use, determined after calibration of the model to meet two criteria, are shown in Table A-226. The first criterion is that the WOODCARB II model estimate of C in houses standing in 2001 needed to match an independent estimate of C in housing based on U.S. Census and USDA Forest Service survey data. The second criterion is that the WOODCARB II model estimate of wood and paper being discarded to SWDS needed to match EPA estimates of discards over the period 1990 to 2000. This calibration strongly influences the estimate of variable 1A, and to a lesser extent variable 2A. The calibration also determines the amounts going to SWDS. In addition ,WOODCARB II landfill decay rates have been validated by making sure that estimates of methane emissions from landfills based on EPA data are reasonable in comparison to methane estimates based on WOODCARB II landfill decay rates.

Decay parameters for products in SWDS are shown in Table A-227. Estimates of 1B and 2B also reflect the change over time in the fraction of products discarded to SWDS (versus burning or recycling) and the fraction of SWDS that are sanitary landfills versus dumps.

Variables 2A and 2B are used to estimate HWP contribution under the production accounting approach. A key assumption for estimating these variables is that products exported from the United States and held in pools in other countries have the same half lives for products in use, the same percentage of discarded products going to SWDS, and the same decay rates in SWDS. Summaries of net fluxes and stocks for harvested wood in products and SWDS are in Table A-213 and Table A-214. The decline in net additions to HWP carbon stocks continued though 2009 from the recent high point in 2006. This is due to sharp declines in U.S. production of solidwood and paper products in 2009 primarily due to the decline in housing construction. The low level of gross additions to solidwood and paper products in use in 2009 was exceeded by discards from uses. The result is a net reduction in the amount of HWP carbon that is held in products in use during 2009. For 2009 additions to landfills still exceeded emissions from landfills and the net additions to landfills have remained relatively stable. Overall, there were net carbon additions to HWP in use and in landfills combined.

Table A-226: Half-life of solidwood and paper products in end uses

Parameter	Value	Units
Half life of wood in single family housing 1920 and before	78.0	Years
Half life of wood in single family housing 1920–1939	78.0	Years
Half life of wood in single family housing 1940–1959	80.0	Years
Half life of wood in single family housing 1960–1979	81.9	Years
Half life of wood in single family housing 1980 +	83.9	Years
Ratio of multifamily half live to single family half life	0.61	
Ratio of repair and alterations half life to single family half life	0.30	
Half life for other solidwood product in end uses	38.0	Years
Half life of paper in end uses	2.54	Years

Source: Skog, K.E. (2008) "Sequestration of carbon in harvested wood products for the United States." *Forest Products Journal* 58:56-72.

Table A-227: Parameters determining decay of wood and paper in SWDS

Parameter	Value	Units
Percentage of wood and paper in dumps that is subject to decay	100%	
Percentage of wood in landfills that is subject to decay	23%	
Percentage of paper in landfills that is subject to decay	56%	
Half life of wood in landfills / dumps (portion subject to decay)	29	Years
Half life of paper in landfills/ dumps (portion subject to decay)	14.5	Years

Source: Skog, K.E. (2008) "Sequestration of carbon in harvested wood products for the United States." *Forest Products Journal* 58:56-72

Uncertainty Analysis

The uncertainty analyses for total net flux of forest C (see uncertainty table in LULUCF chapter) are consistent with the IPCC-recommended Tier 2 methodology (IPCC 2006). Separate analyses are produced for forest ecosystem and HWP flux. The uncertainty estimates are from Monte Carlo simulations of the respective models and input data. Methods generally follow those described in Heath and Smith (2000), Smith and Heath (2000), and Skog et al. (2004). Uncertainties surrounding input data or model processes are quantified as probability distribution functions (PDFs), so that a series of sample values can be randomly selected from the distributions. Model simulations are repeated a large number of times to numerically simulate the effect of the random PDF selections on estimated total C flux. The separate results from the ecosystem and HWP simulations are pooled for total uncertainty (see uncertainty table in LULUCF chapter).

Uncertainty surrounding current net C flux in forest ecosystems is based on the value for 2007 as obtained from the Monte Carlo simulation. C stocks are based on forest condition level (plot-level) calculations, and, therefore, uncertainty analysis starts probabilistic sampling at the plot level. Uncertainty surrounding C density (Mg/ha) is defined for each of six C pools for each inventory plot. Live trees are generally assigned normal PDFs, which are defined according to variability information in Jenkins et al. (2003) and the species and number of trees measured on each FIA plot. Plot-level live tree C estimates from RPA data are based on volume; these PDFs also include an additional level of uncertainty based on their respective regression equations. Similarly, the normally-distributed PDFs for standing dead trees are based on both volume regression and the individual-tree uncertainties related to the Jenkins et al. (2003) based estimates. Definitions of these normal distributions, which centered on expected values, depend on region, type, and specific plot information. Where data gaps—tree or volume—are identified for older inventory data, corresponding averages from later data are applied for live and standing dead tree C densities. Uniform PDFs with a range of ±90 percent of the average are used for these plots.

Distributions for the remaining C pools are triangular or uniform, which partly reflects the lower level of information available about these estimates. Down dead wood, understory, and litter are assigned triangular distributions with the mean at the expected value for each plot and the minimum and mode at 10 percent of the expected value. The use of these PDFs skewed to the right reflects the assumption that a small proportion of plots will have relatively high C densities. Joint sampling of PDFs is specified for two pairs of samples: understory PDF sampling is slightly negatively correlated with live tree PDF sampling, and down dead wood sampling is slightly positively correlated with live tree sampling. This also reflects the structure of the estimates, which are dependent on live tree C. Soil organic C is defined as a uniform PDF at ±50 percent of the mean. Sub-state or state total carbon stocks associated with each survey are the cumulative sum of random samples from the plot-level PDFs, which are then appropriately expanded to population estimates. These expected values for each carbon pool include uncertainty associated with sampling, which is also incorporated in the Monte Carlo simulation. Sampling errors are determined according to methods described for the FIADB (Bechtold and Patterson 2005), are normally distributed, and are assigned a slight positive correlation between successive surveys for Monte Carlo sampling. More recent annual inventories are assigned higher sampling correlation between successive surveys based on the proportion of plot data jointly included in each. Errors for older inventory data are not available, and these surveys are assigned values consistent with those obtained from the FIADB.

Uncertainty about net C flux in HWP is based on Skog et al. (2004) and Skog (2008). Latin hypercube sampling is the basis for the HWP Monte Carlo simulation. Estimates of the HWP variables and HWP Contribution under the production approach are subject to many sources of uncertainty. An estimate of uncertainty is provided that evaluated the effect of uncertainty in 13 sources, including production and trade data and parameters used to make the estimate. Uncertain data and parameters include data on production and trade and factors to convert them to C, the Census-based estimate of C in housing in 2001, the EPA estimate of wood and paper discarded to SWDS for 1990 to 2000, the limits on decay of wood and paper in SWDS, the decay rate (half-life) of wood and paper in SWDS, the proportion of products produced in the United States made with wood harvested in the United States, and the rate of storage of wood and paper C in other countries that came from United States harvest, compared to storage in the United States.

A total of ten thousand samples are drawn from the PDF input to separately determine uncertainties about forest ecosystem and HWP flux before they are combined for a quantitative estimate of total forest carbon uncertainty (see uncertainty table in LULUCF chapter). Again this year, true Monte Carlo sampling is used for the forest ecosystem estimates (in contrast to Latin hypercube sampling, which was used in some previous estimates), and a part of the QA/QC process includes verifying that the PDFs are adequately sampled.