Data sources and estimation/modeling procedures for National Forest System carbon stocks and stock change estimates derived from the US National Greenhouse Gas Inventory

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The primary documentation for the development of NFS carbon baselines are the annexes (annex 3.12) of the 2012 National Greenhouse Gas Inventory (website) and the desktop application used to disaggregate that national inventory to states/regions (Carbon Calculation Tool; CCT; website). The following documentation paraphrases these primary documents.

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 a particular National Forest. 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 National Forest or portion of a National Forest.

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, USDA Forest Service 2013a, USDA Forest Service 2013b). 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 (2013c). Bechtold and Patterson (2005) provide the estimation procedures for standard forest inventory results. The data are freely available for download at USDA Forest Service (2013b) as the Forest Inventory and Analysis Database (FIADB) Version 5.1 (O'Connell et al. 2013); these data are the primary sources of forest inventory used to estimate forest C stocks.

Forest surveys have begun in Hawaii, but are not yet available for analysis. Survey data are available for the temperate oceanic ecoregion of Alaska (southeast and south central). Inventory data are publicly available for 6 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.

The overall approach for determining forest C stocks and stock change is essentially based on methodology and algorithms coded into the computer tool described in Smith et al. (2010). A change in methods for the present inventory involves a modification of the down dead wood estimates to incorporate population estimates of down woody material measured on a subset of the inventory plots (Domke et al. 2013, Woodall and Monleon 2008, Woodall et al. In Press). The carbon calculation tool focuses on estimating forest C stocks based on data from two or more forest surveys conducted several years apart for each National Forest portion within a state or sub-state. There are generally two or more surveys available for download for each state. C stocks are calculated separately for each Forest within each state or sub-state division based on available inventories conducted since 1990 and for inventories 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).[1] As a result, information on less productive forest land or lands reserved from harvest was

[1] 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.

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-1: Source of Forest Inventory and Average Year of Field Survey Used to Estimate National Forest Carbon Stocks

National Forest/State/Substate[a]	Source of Inventory Data, Report/Inventory Year[b]	Average Year Assigned to Inventory[c]
REGION 1		
Beaverhead-Deerlodge, Montana	Westwide, 1989	1997
	FIADB 5.1, 2011	2007
Bitterroot, Idaho	1987 RPA	1987
	Westwide, 1991	1995
	FIADB 5.1, 2011	2008
Bitterroot, Montana	2002 RPA	1995
	FIADB 5.1, 2011	2007
Clearwater, Idaho	1987 RPA	1987
	FIADB 5.1, 1991	1999
	FIADB 5.1, 2011	2008
Custer, Montana	FIADB 5.1, 1989	1997
	FIADB 5.1, 2011	2007
Custer, South Dakota	FIADB 5.1, 1995	1995
	FIADB 5.1, 2005	2002
	FIADB 5.1, 2010	2007
	FIADB 5.1, 2011	2010
Dakota Prairie Grassland, North Dakota	FIADB 5.1, 1980	1979
	FIADB 5.1, 2005	2003
	FIADB 5.1, 2010	2008
Flathead, Montana	2002 RPA	1993
	FIADB 5.1, 2011	2007
Gallatin, Montana	Westwide, 1989	1997
	FIADB 5.1, 2011	2007
Helena, Montana	Westwide, 1989	1996
	FIADB 5.1, 2011	2007
Idaho Panhandle, Idaho	2002 RPA	1987
	FIADB 5.1, 1991	2001
	FIADB 5.1, 2011	2008
Idaho Panhandle, Montana	Westwide, 1989	1994
	FIADB 5.1, 2011	2007
Idaho Panhandle, Washington	1997 RPA	1987
	FIADB 5.1, 2011	2007
Kootenai, Idaho	1987 RPA	1987

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).

	1997 RPA	1995
	FIADB 5.1, 2011	2007
Kootenai, Montana	2002 RPA	1993
	FIADB 5.1, 2011	2007
Lewis and Clark, Montana	Westwide, 1989	1996
	FIADB 5.1, 2011	2007
Lolo, Montana	1987 RPA	1987
	1997 RPA	1995
	FIADB 5.1, 2011	2007
Nez Perce, Idaho	1987 RPA	1987
	1997 RPA	1990
	2002 RPA	1993
	FIADB 5.1, 1991	2001
	FIADB 5.1, 2011	2008
REGION 2		
Arapaho-Roosevelt, Colorado, non-woodlands	1987 RPA	1986
	1997 RPA	1990
	2002 RPA	1993
	FIADB 5.1, 2011	2007
Arapaho-Roosevelt, Colorado, woodlands	1987 RPA	1986
Bighorn, Wyoming	1997 RPA	1984
	FIADB 5.1, 2000	2000
Black Hills, South Dakota	1997 RPA	1985
	1987 RPA	1988
	FIADB 5.1, 1995	1999
	FIADB 5.1, 2005	2003
	FIADB 5.1, 2010	2008
Black Hills, Wyoming	1997 RPA	1985
	2002 RPA	1999
Buffalo Gap NGL, South Dakota	1997 RPA	1994
Grand Mesa-Uncompahgre-Gunnison, Colorado, non-woodlands	1997 RPA	1967
	1987 RPA	1986
	FIADB 5.1, 1984	1997
	FIADB 5.1, 2011	2007
Grand Mesa-Uncompahgre-Gunnison, Colorado, woodlands	FIADB 5.1, 1984	1997
	FIADB 5.1, 2011	2007
Medicine Bow-Routt, Colorado, non-woodlands	1997 RPA	1988
	FIADB 5.1, 2011	2007
Medicine Bow-Routt, Colorado, woodlands	FIADB 5.1, 2011	2008
Medicine Bow-Routt, Wyoming	1997 RPA	1984
	FIADB 5.1, 2000	2001
Nebraska, Nebraska	FIADB 5.1, 1983	1982
	1987 RPA	1986
	FIADB 5.1, 1994	1994
	FIADB 5.1, 2005	2003
	FIADB 5.1, 2010	2007
Pike and San Isabel, Colorado, non-woodlands	1997 RPA	1979

	2002 RPA	1983
	1987 RPA	1986
	FIADB 5.1, 2011	2007
Pike and San Isabel, Colorado, woodlands	FIADB 5.1, 2011	2007
Rio Grande, Colorado, non-woodlands	1997 RPA	1982
	2002 RPA	1987
	FIADB 5.1, 2011	2007
Rio Grande, Colorado, woodlands	1987 RPA	1986
	FIADB 5.1, 2010	2006
San Juan, Colorado, non-woodlands	1997 RPA	1984
	2002 RPA	1987
	FIADB 5.1, 2011	2007
San Juan, Colorado, woodlands	FIADB 5.1, 2011	2007
Shoshone, Wyoming	1997 RPA	1984
	FIADB 5.1, 2000	1999
White River, Colorado, non-woodlands	1997 RPA	1985
	FIADB 5.1, 2011	2007
White River, Colorado, woodlands	FIADB 5.1, 2011	2007
REGION 3		
Apache-Sitgreaves, Arizona, non-woodlands	1987 RPA	1985
	FIADB 5.1, 1999	1996
	FIADB 5.1, 2010	2005
Apache-Sitgreaves, Arizona, woodlands	1987 RPA	1985
	FIADB 5.1, 1999	1996
	FIADB 5.1, 2010	2006
Carson, New Mexico, non-woodlands	1987 RPA	1985
	FIADB 5.1, 1999	1998
	FIADB 5.1, 2012	2010
Carson, New Mexico, woodlands	1997 RPA	1992
	FIADB 5.1, 1999	1998
	FIADB 5.1, 2012	2011
Cibola, New Mexico, non-woodlands	1987 RPA	1986
	1997 RPA	1992
	FIADB 5.1, 1999	1997
	FIADB 5.1, 2012	2011
Cibola, New Mexico, woodlands	FIADB 5.1, 1999	1997
	FIADB 5.1, 2012	2010
Coconino, Arizona, non-woodlands	1987 RPA	1986
	FIADB 5.1, 1999	1995
	FIADB 5.1, 2010	2005
Coconino, Arizona, woodlands	1987 RPA	1986
	FIADB 5.1, 1999	1995
	FIADB 5.1, 2010	2005
Coronado, Arizona, non-woodlands	1987 RPA	1983
	FIADB 5.1, 2010	2006
Coronado, Arizona, woodlands	1987 RPA	1983
	FIADB 5.1, 1999	1997
	FIADB 5.1, 2010	2005
Coronado, New Mexico, non-woodlands	FIADB 5.1, 1999	1997

Coronado, New Mexico, woodlands	FIADB 5.1, 1987	1985
	FIADB 5.1, 1999	1997
	FIADB 5.1, 2012	2011
Gila, New Mexico, non-woodlands	1987 RPA	1985
	FIADB 5.1, 1999	1994
	FIADB 5.1, 2012	2011
Gila, New Mexico, woodlands	1987 RPA	1985
	FIADB 5.1, 1999	1994
	FIADB 5.1, 2012	2011
Kaibab, Arizona, non-woodlands	1987 RPA	1986
	FIADB 5.1, 1999	1995
	FIADB 5.1, 2010	2006
Kaibab, Arizona, woodlands	1987 RPA	1986
	FIADB 5.1, 1999	1995
	FIADB 5.1, 2010	2005
Lincoln, New Mexico, non-woodlands	1987 RPA	1985
	FIADB 5.1, 1999	1997
	FIADB 5.1, 2012	2010
Lincoln, New Mexico, woodlands	1987 RPA	1985
	FIADB 5.1, 1999	1997
	FIADB 5.1, 2012	2011
Prescott, Arizona, non-woodlands	1987 RPA	1983
	FIADB 5.1, 2011	2007
Prescott, Arizona, woodlands	1987 RPA	1983
	FIADB 5.1, 1999	1996
	FIADB 5.1, 2010	2006
Santa Fe, New Mexico, non-woodlands	1987 RPA	1986
	1997 RPA	1992
	FIADB 5.1, 1999	1998
	FIADB 5.1, 2012	2011
Santa Fe, New Mexico, woodlands	1987 RPA	1986
	1997 RPA	1992
	FIADB 5.1, 1999	1998
	FIADB 5.1, 2012	2010
Tonto, Arizona, non-woodlands	1987 RPA	1981
	FIADB 5.1, 2010	2005
Tonto, Arizona, woodlands	1987 RPA	1981
	1997 RPA	1992
	FIADB 5.1, 1999	1996
	FIADB 5.1, 2010	2005
REGION 4		
Ashley, Utah, non-woodlands	1987 RPA	1976
	1997 RPA	1993
	FIADB 5.1, 2009	2005
Ashley, Utah, woodlands	1987 RPA	1972
	Westwide, 1993	1993
	FIADB 5.1, 2009	2005
Boise, Idaho	Westwide, 1991	1984
	FIADB 5.1, 1991	1996
	FIADB 5.1, 2011	2008

Bridger-Teton, Wyoming	1997 RPA	1976
	FIADB 5.1, 2000	1999
Caribou-Targhee, Idaho	1987 RPA	1975
	Westwide, 1991	1992
	FIADB 5.1, 2011	2008
Caribou-Targhee, Utah	Westwide, 1993	1993
	FIADB 5.1, 2011	2002
Caribou-Targhee, Wyoming	1997 RPA	1979
	FIADB 5.1, 2000	2001
Desert Range Experiment Station, Utah	FIADB 5.1, 2011	2005
Dixie, Utah, non-woodlands	1987 RPA	1980
	FIADB 5.1, 2009	2004
Dixie, Utah, woodlands	1987 RPA	1980
	Westwide, 1993	1994
	FIADB 5.1, 2009	2005
Fishlake, Utah, non-woodlands	1997 RPA	1993
	FIADB 5.1, 2009	2004
Fishlake, Utah, woodlands	FIADB 5.1, 1993	1993
	FIADB 5.1, 2009	2004
Humboldt-Toiyabe, California	1997 RPA	1985
	IDB, 1990s	1997
	FIADB 5.1, 2010	2005
Humboldt-Toiyabe, Nevada, non-woodlands	1987 RPA	1971
	FIADB 5.1, 1989	1996
	FIADB 5.1, 2005	2005
Humboldt-Toiyabe, Nevada, woodlands	1987 RPA	1978
	FIADB 5.1, 1989	1996
	FIADB 5.1, 2005	2005
Manti-La Sal, Colorado, non-woodlands	1987 RPA	1978
	FIADB 5.1, 1984	1993
	FIADB 5.1, 2010	2006
Manti-La Sal, Colorado, woodlands	2002 RPA	1993
	FIADB 5.1, 2011	2008
Manti-La Sal, Utah, non-woodlands	1987 RPA	1978
	2002 RPA	1993
	FIADB 5.1, 2009	2004
Manti-La Sal, Utah, woodlands	1987 RPA	1978
	FIADB 5.1, 1993	1993
	FIADB 5.1, 2009	2004
Payette, Idaho	1987 RPA	1980
	1997 RPA	1989
	FIADB 5.1, 2011	2008
Salmon-Challis, Idaho	1987 RPA	1977
	1997 RPA	1989
	FIADB 5.1, 2011	2008
Sawtooth, Idaho	1987 RPA	1972
	Westwide, 1991	1982
	1997 RPA	1991
	2002 RPA	1995
	FIADB 5.1, 2011	2007

Sawtooth, Utah, non-woodlands	1987 RPA	1969
	FIADB 5.1, 2009	2001
	FIADB 5.1, 2011	2011
Sawtooth, Utah, woodlands	1987 RPA	1969
	FIADB 5.1, 1993	1992
	FIADB 5.1, 2009	2007
Wasatch-Cache-Uinta, Utah, non-woodlands	1987 RPA	1975
	Westwide, 1993	1993
	FIADB 5.1, 2009	2005
Wasatch-Cache-Uinta, Utah, woodlands	FIADB 5.1, 2009	2004
Wasatch-Cache-Uinta, Wyoming	1987 RPA	1974
	FIADB 5.1, 1984	1992
	FIADB 5.1, 2000	2002
REGION 5		
Angeles, California	1987 RPA	1975
	IDB, 1990s	1996
	FIADB 5.1, 2010	2005
Cleveland, California	FIADB 5.1, 2011	2004
Eldorado, California	1987 RPA	1984
	1997 RPA	1994
	IDB, 1990s	1999
	FIADB 5.1, 2010	2006
Inyo, California	1987 RPA	1979
	IDB, 1990s	1994
	FIADB 5.1, 2010	2006
Inyo, Nevada	1987 RPA	1979
	1997 RPA	1994
	FIADB 5.1, 2005	2005
Klamath, California	1987 RPA	1980
	1997 RPA	1990
	IDB, 1990s	1998
	FIADB 5.1, 2010	2006
Klamath, Oregon	1987 RPA	1980
	1997 RPA	1989
	FIADB 5.1, 2011	2007
Lake Tahoe Basin, California	1987 RPA	1980
	IDB, 1990s	1999
	FIADB 5.1, 2010	2005
Lake Tahoe Basin, Nevada, non-woodlands	1987 RPA	1980
	1997 RPA	1993
	2002 RPA	1999
Lake Tahoe Basin, Nevada, woodlands	1987 RPA	1980
	1997 RPA	1996
Lassen, California	1987 RPA	1981
	IDB, 1990s	1995
	FIADB 5.1, 2010	2005
Los Padres, California	1987 RPA	1975
	IDB, 1990s	1996
	FIADB 5.1, 2010	2006
Mendocino, California	1987 RPA	1981

	IDB, 1990s	1996
	FIADB 5.1, 2010	2006
Modoc, California	1987 RPA	1980
	IDB, 1990s	1994
	FIADB 5.1, 2010	2006
Plumas, California	1987 RPA	1980
	1997 RPA	1993
	IDB, 1990s	2000
	FIADB 5.1, 2010	2006
San Bernardino, California	1987 RPA	1975
	IDB, 1990s	1995
	FIADB 5.1, 2010	2005
Sequoia, California	1987 RPA	1980
	1997 RPA	1990
	IDB, 1990s	1999
	FIADB 5.1, 2010	2006
Shasta-Trinity, California	1987 RPA	1980
	1997 RPA	1983
	IDB, 1990s	1997
	FIADB 5.1, 2010	2006
Sierra, California	1987 RPA	1972
	1997 RPA	1988
	IDB, 1990s	1997
	FIADB 5.1, 2010	2006
Six Rivers, California	1987 RPA	1978
	IDB, 1990s	1997
	FIADB 5.1, 2010	2006
Stanislaus, California	1987 RPA	1981
	1997 RPA	1992
	IDB, 1990s	1999
	FIADB 5.1, 2010	2005
Tahoe, California	1987 RPA	1980
	1997 RPA	1991
	IDB, 1990s	2000
	FIADB 5.1, 2010	2006
REGION 6		
Columbia River Gorge NSA, Washington	FIADB 5.1, 2011	2006
Colville, Washington	1987 RPA	1986
	Westwide, 1991	1993
	IDB, 1990s	1996
	FIADB 5.1, 2011	2006
Crooked River National Grassland, Oregon	FIADB 5.1, 2010	2005
Deschutes, Oregon	1987 RPA	1986
	IDB, 1990s	1995
	FIADB 5.1, 2010	2006
Fremont, Oregon	1987 RPA	1986
	IDB, 1990s	1995
	FIADB 5.1, 2010	2005
Gifford Pinchot, Washington, East	Westwide, 1991	1994
	FIADB 5.1, 2010	2006

Gifford Pinchot, Washington, West	1987 RPA	1986
	IDB, 1990s	1995
	FIADB 5.1, 2011	2007
Malheur, Oregon	1987 RPA	1986
	IDB, 1990s	1994
	FIADB 5.1, 2010	2006
Mt. Baker-Snoqualmie, Washington, East	FIADB 5.1, 2010	2003
Mt. Baker-Snoqualmie, Washington, West	1987 RPA	1986
	IDB, 1990s	1996
	FIADB 5.1, 2011	2007
Mt. Hood, Oregon, East	IDB, 1990s	1994
	FIADB 5.1, 2010	2006
Mt. Hood, Oregon, West	1987 RPA	1986
	IDB, 1990s	1995
	FIADB 5.1, 2010	2005
Ochoco, Oregon	IDB, 1990s	1995
	FIADB 5.1, 2010	2006
Okanogan, Washington, East	1987 RPA	1986
	Westwide, 1991	1991
	IDB, 1990s	1995
	FIADB 5.1, 2011	2007
Okanogan, Washington, West	IDB, 1990s	1994
	FIADB 5.1, 2011	2007
Olympic, Washington	1987 RPA	1986
	IDB, 1990s	1995
	FIADB 5.1, 2011	2007
Rogue River, California	1987 RPA	1986
	1997 RPA	1996
	FIADB 5.1, 2010	2006
Rogue River, Oregon, East	IDB, 1990s	1995
	FIADB 5.1, 2010	2006
Rogue River, Oregon, West	1987 RPA	1986
	IDB, 1990s	1996
	FIADB 5.1, 2010	2006
Siskiyou, California	FIADB 5.1, 2010	2004
Siskiyou, Oregon	1987 RPA	1986
	IDB, 1990s	1995
	FIADB 5.1, 2010	2006
Siuslaw, Oregon	1987 RPA	1986
	IDB, 1990s	1995
	FIADB 5.1, 2010	2006
Umatilla, Oregon	1987 RPA	1986
	IDB, 1990s	1994
	FIADB 5.1, 2010	2006
Umatilla, Washington	1987 RPA	1986
	IDB, 1990s	1995
	FIADB 5.1, 2011	2006
Umpqua, Oregon	1987 RPA	1986
	IDB, 1990s	1996
	FIADB 5.1, 2010	2006

Wallowa-Whitman, Idaho	FIADB 5.1, 2011	2007
Wallowa-Whitman, Oregon	1987 RPA	1986
	IDB, 1990s	1994
	FIADB 5.1, 2010	2006
Wenatchee, Washington	IDB, 1990s	1996
	FIADB 5.1, 2011	2007
Willamette, Oregon, East	FIADB 5.1, 2011	2006
Willamette, Oregon, West	1987 RPA	1986
	IDB, 1990s	1995
	FIADB 5.1, 2010	2006
Winema, Oregon	1987 RPA	1986
	IDB, 1990s	1994
	FIADB 5.1, 2010	2006
REGION 8		
Chattahoochee-Oconee, Georgia	FIADB 5.1, 1972	1972
	FIADB 5.1, 1982	1982
	FIADB 5.1, 1989	1989
	FIADB 5.1, 1997	1997
	FIADB 5.1, 2004	2001
	FIADB 5.1, 2009	2007
Cherokee, Tennessee	FIADB 5.1, 1980	1980
	FIADB 5.1, 1989	1988
	FIADB 5.1, 1999	1999
	FIADB 5.1, 2004	2002
	FIADB 5.1, 2009	2007
Daniel Boone, Kentucky	FIADB 5.1, 1988	1987
	FIADB 5.1, 2004	2002
	FIADB 5.1, 2009	2008
El Yunque, Puerto Rico	FIADB 5.1, 2004	2002
	FIADB 5.1, 2009	2007
Francis Marion-Sumter, South Carolina	FIADB 5.1, 1968	1967
	FIADB 5.1, 1978	1977
	FIADB 5.1, 1986	1986
	FIADB 5.1, 1993	1992
	FIADB 5.1, 2006	2004
	FIADB 5.1, 2011	2009
George Washington, Virginia	FIADB 5.1, 1977	1976
	FIADB 5.1, 1985	1985
	FIADB 5.1, 1992	1991
	FIADB 5.1, 2001	1999
	FIADB 5.1, 2007	2005
	FIADB 5.1, 2011	2009
George Washington, West Virginia	FIADB 5.1, 1989	1987
	FIADB 5.1, 2000	2000
	FIADB 5.1, 2008	2007
Jefferson, Kentucky	FIADB 5.1, 1988	1986
Jefferson, Virginia	FIADB 5.1, 1977	1976
	FIADB 5.1, 1985	1985
	FIADB 5.1, 1992	1991
	FIADB 5.1, 2001	1999

	FIADB 5.1, 2007	2004
	FIADB 5.1, 2011	2009
Jefferson, West Virginia	FIADB 5.1, 1989	1988
	FIADB 5.1, 2011	2009
Kisatchie, Louisiana	FIADB 5.1, 1974	1973
	FIADB 5.1, 1984	1984
	FIADB 5.1, 1991	1991
	FIADB 5.1, 2005	2003
NFS in Alabama	FIADB 5.1, 1972	1971
	FIADB 5.1, 1982	1982
	FIADB 5.1, 1990	1990
	FIADB 5.1, 2000	1999
	FIADB 5.1, 2005	2003
	FIADB 5.1, 2011	2008
NFS in Florida	FIADB 5.1, 1970	1969
	FIADB 5.1, 1980	1979
	FIADB 5.1, 1987	1987
	FIADB 5.1, 1995	1994
	FIADB 5.1, 2007	2004
	FIADB 5.1, 2011	2008
NFS in Mississippi	FIADB 5.1, 1977	1977
	FIADB 5.1, 1987	1986
	FIADB 5.1, 1994	1993
	FIADB 5.1, 2006	2006
NFS in North Carolina	FIADB 5.1, 1974	1974
	FIADB 5.1, 1984	1984
	FIADB 5.1, 1990	1990
	FIADB 5.1, 2002	2001
	FIADB 5.1, 2007	2005
NFS in Texas, Central & West	FIADB 5.1, 2010	2008
NFS in Texas, East	FIADB 5.1, 1975	1975
	FIADB 5.1, 1986	1985
	FIADB 5.1, 1992	1992
	FIADB 5.1, 2003	2002
	FIADB 5.1, 2008	2005
	FIADB 5.1, 2011	2009
Other NFS areas, Kentucky	FIADB 5.1, 2009	2007
Other NFS areas, Oklahoma	FIADB 5.1, 2011	2010
Other NFS areas, South Carolina	FIADB 5.1, 2011	2007
Other NFS areas, Tennessee	FIADB 5.1, 2004	2004
	FIADB 5.1, 2011	2008
Other NFS areas, Texas, Central & West	FIADB 5.1, 2009	2006
Other NFS areas, Texas, East	FIADB 5.1, 2011	2008
Ouachita, Arkansas	FIADB 5.1, 1978	1978
	FIADB 5.1, 1988	1988
	FIADB 5.1, 1995	1995
	FIADB 5.1, 2005	2003
	FIADB 5.1, 2010	2008
Ouachita, Oklahoma	FIADB 5.1, 1976	1976
	FIADB 5.1, 1986	1986

	FIADB 5.1, 1993	1992
	FIADB 5.1, 2008	2008
Ozark and St. Francis, Arkansas	FIADB 5.1, 1978	1978
	FIADB 5.1, 1988	1987
	FIADB 5.1, 1995	1996
	FIADB 5.1, 2005	2003
	FIADB 5.1, 2010	2008
REGION 9		
Allegheny, Pennsylvania	1987 RPA	1986
	FIADB 5.1, 1989	1989
	FIADB 5.1, 2004	2002
	FIADB 5.1, 2009	2007
	FIADB 5.1, 2011	2009
Chequamegon-Nicolet, Wisconsin	FIADB 5.1, 1983	1982
	1987 RPA	1987
	FIADB 5.1, 1996	1994
	FIADB 5.1, 2004	2002
	FIADB 5.1, 2009	2007
Chippewa, Minnesota	FIADB 5.1, 1977	1980
	FIADB 5.1, 1990	1989
	FIADB 5.1, 2003	2001
	FIADB 5.1, 2008	2006
	FIADB 5.1, 2011	2009
Green Mountain, New York	FIADB 5.1, 2009	2006
	FIADB 5.1, 2011	2010
Green Mountain, Vermont	FIADB 5.1, 1983	1982
	FIADB 5.1, 1997	1997
	FIADB 5.1, 2007	2006
	FIADB 5.1, 2011	2009
Hiawatha, Michigan	FIADB 5.1, 1980	1975
	1987 RPA	1987
	FIADB 5.1, 1993	1992
	FIADB 5.1, 2004	2002
	FIADB 5.1, 2009	2007
Hoosier, Indiana	FIADB 5.1, 1986	1985
	FIADB 5.1, 1998	1997
	FIADB 5.1, 2003	2001
	FIADB 5.1, 2008	2006
	FIADB 5.1, 2011	2009
Huron-Manistee, Michigan	FIADB 5.1, 1980	1979
	1987 RPA	1987
	FIADB 5.1, 1993	1993
	FIADB 5.1, 2004	2002
	FIADB 5.1, 2009	2007
	FIADB 5.1, 2011	2009
Mark Twain, Missouri	FIADB 5.1, 1989	1987
	FIADB 5.1, 2003	2001
	FIADB 5.1, 2008	2006
	FIADB 5.1, 2011	2009
Midewin Tallgrass Prairie, Illinois	FIADB 5.1, 2009	2005

	FIADB 5.1, 2011	2009
Monongahela, West Virginia	FIADB 5.1, 1989	1987
	FIADB 5.1, 2000	2000
	FIADB 5.1, 2008	2007
	FIADB 5.1, 2011	2010
Ottawa, Michigan	FIADB 5.1, 1980	1979
	1987 RPA	1987
	FIADB 5.1, 1993	1991
	FIADB 5.1, 2004	2002
	FIADB 5.1, 2009	2007
	FIADB 5.1, 2011	2009
Shawnee, Illinois	FIADB 5.1, 1985	1984
	1987 RPA	1987
	FIADB 5.1, 1998	1997
	FIADB 5.1, 2005	2004
	FIADB 5.1, 2010	2008
Superior, Minnesota	FIADB 5.1, 1977	1978
	FIADB 5.1, 1990	1987
	1997 RPA	1990
	FIADB 5.1, 2003	2001
	FIADB 5.1, 2008	2006
	FIADB 5.1, 2011	2009
Wayne, Ohio	1987 RPA	1986
	FIADB 5.1, 1991	1991
	FIADB 5.1, 2006	2004
	FIADB 5.1, 2011	2010
White Mountain, Maine	Eastwide, 1982	1982
	1987 RPA	1986
	FIADB 5.1, 2003	2001
	FIADB 5.1, 2008	2006
	FIADB 5.1, 2011	2009
White Mountain, New Hampshire	FIADB 5.1, 1983	1983
	FIADB 5.1, 1997	1996
	FIADB 5.1, 2007	2005
	FIADB 5.1, 2011	2010
REGION 10		
Chugach, Alaska, non-reserved	FIADB 5.1, 2003	2000
	FIADB 5.1, 2011	2008
Chugach, Alaska, reserved	FIADB 5.1, 2011	2005
Tongass, Alaska, non-reserved	FIADB 5.1, 2003	1997
	FIADB 5.1, 2011	2008
Tongass, Alaska, reserved	FIADB 5.1, 2011	2006

[a] Substate areas (Smith et al. 2010) include woodlands (forest land dominated by woodland species, such as pinyon and juniper, where stocking cannot be determined (USDA Forest Service 2013c)), 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). National Forests in Oregon and Washington may be divided into eastern and western sections (east or west of the crest of the Cascade Mountains). National Forests in Oklahoma and Texas may be divided into East versus Central & West according to forest inventory survey units (USDA Forest Service 2013d). Alaska is represented by a portion of forest land, in the southcentral and southeast part of the state.
[b] FIADB 5.1 is the current, publicly available, format of FIA inventory data, and these files were downloaded from the Internet January-March 2013 (USDA Forest Service 2013). 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 2013a) 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 January-March 2013. 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 one or two cycles 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 National Forest include new measurements. Table A-1 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 2013b).

Non-FIADB inventories are used where they provide additional information (i.e., they fill in gaps in the time series and are considered to be valid). Gaps of less than 2.5 years are considered to be insignificant. When consecutive surveys indicate greater than a 5% annual change in forest area and/or greater than a 10% annual change in aboveground tree carbon for the area of interest (a highly unlikely occurrence), they are closely examined and one or both may be discarded.

For each pool in each National Forest within each state/substate 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 National Forest 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 National Forest 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.

Table A-22 shows average C density values for forest ecosystem C pools according to NFS 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 January-March 2013 (USDA Forest Service 2013b). 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-2: Average carbon density (Mg C/ha) by carbon pool and forest area (1000 ha) according to NFS Region and forest type, based on the latest inventory survey available for each National Forest as of September 2010 from FIA, corresponding to an average year of 2007

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)
Region 1						
(Northern)						
Douglas-fir	60.9	12.8	13.8	37.1	39	2,408
Ponderosa Pine	44.3	9.2	8.8	24.0	35	388
Fir/Spruce/Mountain Hemlock	58.2	12.3	20.8	37.7	44	2,863
Lodgepole Pine	52.4	11.2	15.4	23.3	37	1,819
Hemlock/Sitka Spruce	114.9	24.3	21.2	37.7	48	272
Western Larch	72.1	15.2	14.9	36.4	34	323
Other Western Softwoods	38.8	8.2	12.7	39.6	31	335
Minor Types and Nonstocked	10.0	1.7	28.8	19.3	45	543
All	55.7	11.7	17.3	32.9	40	8,951

Region 2						
(Rocky Mountain)						
Pinyon/Juniper	18.5	3.7	2.5	21.6	21	155
Douglas-fir	47.3	10.0	11.0	38.9	31	544
Ponderosa Pine	36.8	7.7	6.7	19.7	36	703
Fir/Spruce/Mountain Hemlock	60.4	12.8	18.9	39.1	31	2,120
Lodgepole Pine	51.6	11.0	14.3	23.9	27	995
Other Western Softwoods	40.4	8.5	9.0	39.9	28	191
Aspen/Birch	48.4	9.3	11.1	28.5	59	1,040
Woodland Hardwoods	17.2	3.2	5.3	26.2	26	269
Minor Types and Nonstocked	9.4	1.6	17.0	17.5	32	256
All	47.7	9.9	13.5	30.9	35	6,272
Region 3						
(Southwestern)						
Pinyon/Juniper	16.2	3.2	1.7	21.1	20	2,859
Douglas-fir	63.1	13.3	14.3	37.6	31	331
Ponderosa Pine	38.9	8.1	7.3	23.5	24	1,559
Fir/Spruce/Mountain Hemlock	67.1	14.1	17.3	38.4	31	332
Aspen/Birch	52.5	10.2	13.6	28.6	59	140
Woodland Hardwoods	19.6	3.6	4.9	31.2	26	824
Minor Types and Nonstocked	10.0	1.7	6.8	20.6	25	354
All	27.7	5.6	5.5	24.9	24	6,397
Region 4						
(Intermountain)						
Pinyon/Juniper	17.6	3.5	2.0	21.1	20	1,666
Douglas-fir	50.0	10.5	12.1	38.2	37	1,590
Ponderosa Pine	38.7	8.0	9.1	23.3	32	456
Fir/Spruce/Mountain Hemlock	50.5	10.6	19.9	38.7	37	1,792
Lodgepole Pine	42.5	9.0	15.8	23.7	33	968
Other Western Softwoods	35.4	7.4	12.5	41.0	32	361
Aspen/Birch	30.4	5.7	10.5	27.7	58	798
Woodland Hardwoods	17.1	3.1	5.0	28.1	28	629
Minor Types and Nonstocked	7.3	1.2	22.9	18.0	36	740
All	34.6	7.1	12.3	29.6	34	9,000
Region 5						
(Pacific Southwest)						
Pinyon/Juniper	16.8	3.2	2.8	21.1	26	290
Douglas-fir	173.0	36.0	32.5	39.2	42	142
Ponderosa Pine	53.7	11.1	12.4	22.8	41	562
Fir/Spruce/Mountain Hemlock	114.3	24.1	33.9	38.5	52	622
Lodgepole Pine	69.5	14.6	19.7	27.5	35	256
Other Western Softwoods	23.5	4.4	6.9	38.2	50	390
California Mixed Conifer	116.2	24.3	26.1	38.8	50	2,055
Western Oak	59.9	11.5	7.5	29.7	28	1,065
Tanoak/Laurel	132.7	26.3	13.8	30.8	28	200
Minor Types and Nonstocked	24.0	4.6	19.0	23.2	35	636
All	80.7	16.6	18.9	32.6	41	6,217
Region 6						
(Pacific Northwest)						
Douglas-fir	149.9	31.5	31.9	39.9	95	2,907
Ponderosa Pine	47.5	9.9	11.5	23.8	51	1,531
Fir/Spruce/Mountain Hemlock	102.6	21.6	29.3	39.1	62	2,106
Lodgepole Pine	39.2	8.2	13.4	22.4	52	824
Hemlock/Sitka Spruce	190.4	40.2	45.9	46.7	116	590
Other Western Softwoods	17.8	3.5	8.2	36.9	79	262
Minor Types and Nonstocked	45.2	8.9	21.0	18.5	85	918
All	100.2	21.0	25.4	33.6	76	9,137
Region 8						
(Southern)						
Longleaf/Slash Pine	57.5	11.9	5.3	12.9	82	475
Loblolly/Shortleaf Pine	73.0	15.1	7.6	12.5	50	1,392
Oak/Pine	64.5	12.7	7.5	11.3	49	611
Oak/Hickory	76.4	14.4	9.3	8.0	42	2,585
Oak/Gum/Cypress	64.8	12.4	8.3	7.1	112	224
Minor Types and Nonstocked	72.7	14.1	10.7	9.0	73	234

All	72.0	14.1	8.3	9.9	52	5,521
Region 9						
(Eastern)						
White/Red/Jack Pine	52.1	10.8	8.0	12.8	119	478
Spruce/Fir	34.2	7.2	7.6	33.8	235	644
Oak/Pine	51.2	10.1	7.7	27.4	67	191
Oak/Hickory	67.4	12.7	9.2	8.5	55	1,042
Elm/Ash/Cottonwood	40.3	7.8	5.8	8.2	170	120
Maple/Beech/Birch	79.8	15.2	10.6	28.8	100	1,232
Aspen/Birch	38.6	7.5	8.0	8.9	142	830
Minor Types and Nonstocked	48.7	9.8	9.3	10.8	68	157
All	57.5	11.2	8.9	18.6	117	4,695
Region 10						
(Alaska)						
Fir/Spruce/Mountain Hemlock	65.4	13.7	16.8	43.2	62	1,945
Lodgepole Pine	18.7	3.7	5.6	41.9	52	132
Hemlock/Sitka Spruce	127.5	26.9	30.0	53.5	116	2,085
Minor Types and Nonstocked	31.8	6.1	7.7	11.8	85	108
All	93.4	19.6	22.7	47.4	89	4,270
All NFS (forest land included in Inventory)	**62.3**	**12.8**	**15.2**	**29.3**	**53**	**60,461**

The Inventory is derived primarily from the current FIADB 5.1 data (USDA Forest Service 2013b), 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 2013a, 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 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. (2011a) as the most appropriate non-FIADB sources for these three 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 individual-tree data or even stand-level characteristics such as 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. This approach to filling gaps in older data also extends to timberlands where individual-tree data was not available (e.g., standing dead trees).

Estimating C stocks from forest inventory data

For each inventory summary in each National Forest, data are converted to C units or augmented by other ecological data. Most of the conversion factors and models used for inventory-based forest carbon estimates (Smith et al. 2010, Heath et al. 2011b) were initially developed as an offshoot of the forest carbon simulation model FORCARB (Heath et al. 2010) and are incorporated into a number of applications (Birdsey and Heath 1995, Birdsey and Heath 2001, Heath et al. 2003, Smith et al. 2004, 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

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 above- and below-ground biomass components. If inventory plots include data on individual trees, tree C is based on Woodall et al. (2011), which is also known as the component ratio method (CRM), and is a function of volume, species, and diameter. The value for sound volume provided in the tree table of the FIADB is the principal input to the CRM biomass calculation for each tree. The estimated volumes of wood and bark are converted to biomass based on density of each. Additional components of the trees such as tops, branches, and coarse roots, are estimated according to adjusted component estimates of Jenkins et al. (2003). Live trees with d.b.h of less than 12.7 cm do not have estimates of sound volume in the FIADB, and CRM biomass estimates follow a separate process. An additional component of foliage, which was not explicitly included in Woodall et al. (2011), was added to each tree following the same CRM method. C is calculated by multiplying biomass by 0.5 because biomass is 50 percent of dry weight (IPCC/UNEP/OECD/IEA 1997). Further discussion and example calculations are provided in Woodall et al. 2011.

Some of the older forest inventory data in use for these estimates do not provide measurements of individual trees. Examples of these data include plots with incomplete or missing tree data (e.g., some of the non-timberland plots in older surveys) or the RPA plot-level summaries. The C estimates for these plots are based on average densities (tonnes C per hectare) obtained from plots of more recent surveys with similar stand characteristics and location. This applies to 5 percent of the forest land inventory-plot-to-carbon conversions within the 177 state-level surveys utilized here.

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) according to Jenkins et al. (2003) and expressed 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-3. 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-3. 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 and includes trees of at least 12.7 cm d.b.h. Calculations follow the basic CRM method applied to live trees (Woodall et al. 2011) with additional modifications to account for decay and structural loss. In addition to the lack of foliage, two characteristics of standing dead trees that can significantly affect carbon mass are decay, which affects density and thus specific carbon content (Domke et al. 2011, Harmon et al. 2011), and structural loss such as branches and bark (Domke et al. 2011). Dry weight to C mass conversion is by multiplying by 0.5.

Some of the older forest inventory data in use for these estimates do not provide measurements of individual standing dead trees. In addition to the RPA data, which are plot-level summaries, some of the older surveys that otherwise include individual-tree data may not completely sample dead trees on non-timberlands and in some cases timberlands. The C estimates for these plots are based on average densities (tonnes C per hectare) obtained from plots of more recent surveys with similar stand characteristics and location.

Down dead wood, inclusive of logging residue, are sampled on a subset of FIA plots. Despite a reduced sample intensity, a single down woody material population estimate (Domke et al. 2013, Woodall et al. In Review) per state is now incorporated into these empirical down dead wood estimates. 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-4. 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-5. These amounts are added to explicitly account for down dead wood following harvest. The sum of these two components is then adjusted by the ratio of population totals; that is, the ratio of plot-based to modeled estimates. An example of this 3-part calculation for down dead wood in a 25-year-old naturally regenerated loblolly pine forest with 82.99 Mg C/ha in live trees (Jenkins et al. 2003) in Louisiana is as follows:

First, an initial estimate from live tree C density and Table A-4 (SC, Natural Pine)

C density =82.99 × 0.068 = 5.67 (Mg C/ha)

Second, an average logging residue from age and Table A-5 (SC, softwood)C density = 5.5 × e(−25/17.9) = 1.37 (Mg C/ha)

Third, adjust the sum by the down dead wood ratio plot-to-model for Louisiana, which was 27.6/31.1 = 0.886

C density = (5.67 + 1.37) × 0.886 = 6.24 (Mg C/ha)

Table A-4: 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	Region (cont'd)	Forest type (cont'd)	Ratio (cont'd)
NE	Aspen-Birch	0.078	PWW	Douglas-fir	0.100
	MBB/Other Hardwood	0.071		Fir-Spruce	0.090
	Oak-Hickory	0.068		Other Conifer	0.073
	Oak-Pine	0.061		Other Hardwoods	0.062
	Other Pine	0.065		Red Alder	0.095
	Spruce-Fir	0.092		Western Hemlock	0.099
	White-Red-Jack Pine	0.055		Nonstocked	0.020
	Nonstocked	0.019	RMN	Douglas-fir	0.062
NLS	Aspen-Birch	0.081		Fir-Spruce	0.100
	Lowland Hardwood	0.061		Hardwoods	0.112
	Maple-Beech-Birch	0.076		Lodgepole Pine	0.058
	Oak-Hickory	0.077		Other Conifer	0.060
	Pine	0.072		Pinyon-Juniper	0.030

	Spruce-Fir	0.087		Ponderosa Pine	0.087
	Nonstocked	0.027		Nonstocked	0.018
NPS	Conifer	0.073	RMS	Douglas-fir	0.077
	Lowland Hardwood	0.069		Fir-Spruce	0.079
	Maple-Beech-Birch	0.063		Hardwoods	0.064
	Oak-Hickory	0.068		Lodgepole Pine	0.098
	Oak-Pine	0.069		Other Conifer	0.060
	Nonstocked	0.026		Pinyon-Juniper	0.030
PSW	Douglas-fir	0.091		Ponderosa Pine	0.082
	Fir-Spruce	0.109		Nonstocked	0.020
	Hardwoods	0.042	SC	Bottomland Hardwood	0.063
	Other Conifer	0.100		Misc. Conifer	0.068
	Pinyon-Juniper	0.031		Natural Pine	0.068
	Redwood	0.108		Oak-Pine	0.072
	Nonstocked	0.022		Planted Pine	0.077
PWE	Douglas-fir	0.103		Upland Hardwood	0.067
	Fir-Spruce	0.106		Nonstocked	0.013
	Hardwoods	0.027	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-5: 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

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