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FORCARB2: An Updated Version of the U.S. Forest Carbon Budget Model

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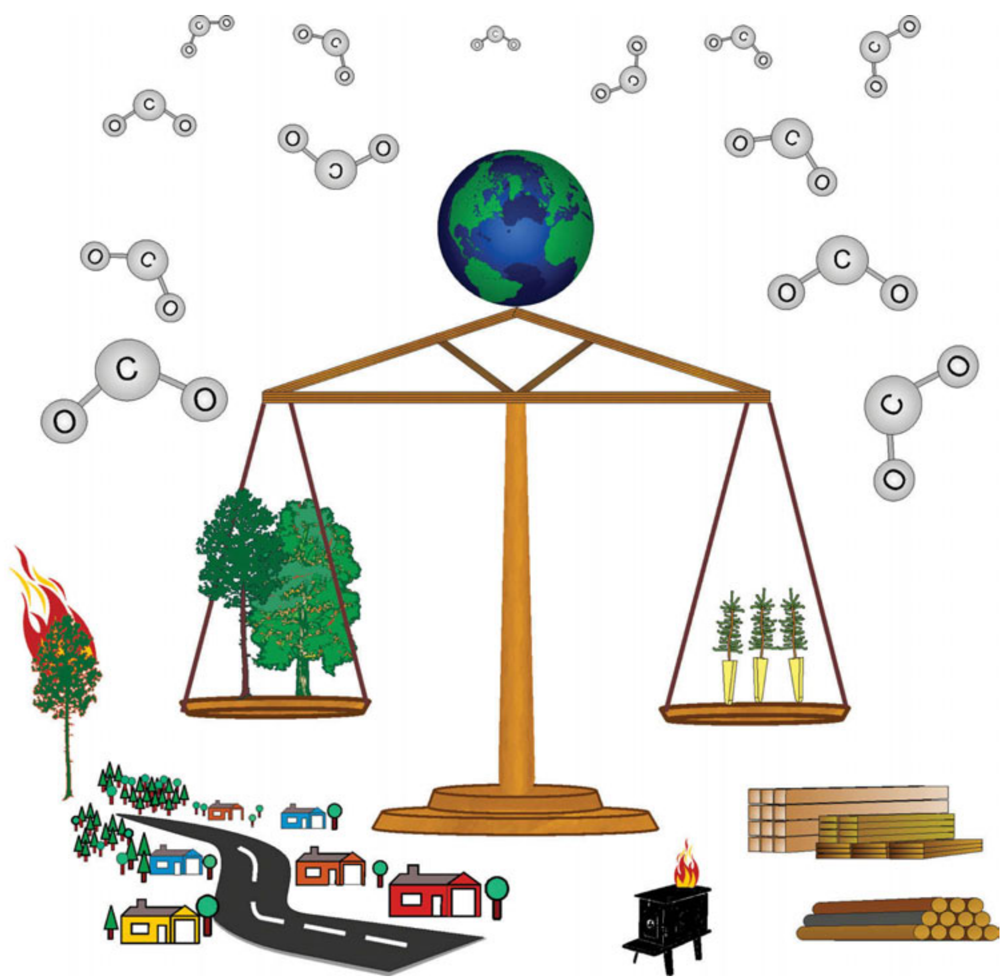

Abstract

FORCARB2, an updated version of the U.S. FORest CARBon Budget Model (FORCARB), produces estimates of carbon stocks and stock changes for forest ecosystems and forest products at 5-year intervals. FORCARB2 includes a new methodology for carbon in harvested wood products, updated initial inventory data, a revised algorithm for dead wood, and now includes public forest land, reserved forest land, and forest land of low productivity. The model has been used to provide estimates and projections for policy-related needs, including the Resources Planning Act timber resource assessment and forest-related greenhouse gas inventories of the United States, and has provided the basis for an analysis of forest carbon for Ontario, Canada. The program is written in FORTRAN and is text based, though virtually every parameter is defined by input text-based files that can be modified or built by the user. We expect users who are fairly advanced in terms of knowledge about computers will be most capable in using this model. Step-by-step instructions for running the program, input and output files, and codes used are included, and input files for public forest lands of the United States are provided as an example. All electronic files for download, including the model source code, executable files, and input and output files are available at http://nrs.fs.fed.us/pubs/35613.

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FORCARB2: An Updated Version of the U.S. Forest Carbon Budget Model

INTRODUCTION

FORCARB2 is an updated version of the U.S. FORest CARBon Budget Model, FORCARB (Plantinga and Birdsey 1993). The model produces carbon stocks and stock change projections for forest ecosystems and forest products at 5-year intervals. Data from the U.S. Forest Service, Forest Inventory and Analysis (FIA) Program (U.S. Forest Service 2009) were used as inputs to the modeling system particularly for initial inventories, in construction of growth-yield curves, and for harvest information such as utilization rates.

FORCARB2 was developed to produce forest carbon projections consistent with the 2005 update of the national timber resource assessment mandated by the Forest and Rangeland Renewable Resources Planning Act (RPA) of 1974 (as amended by the National Forest Management Act of 1976 and the 1990 Food Protection Act). The RPA directs the Secretary of Agriculture to prepare a Renewable Resources Planning Assessment with decadal updates. The 1990 Food Protection Act requires the Forest Service to assess impacts of climate change and identify opportunities to mitigate the buildup of carbon dioxide (Joyce and Birdsey 2000). The assessment includes “an analysis of present and anticipated uses, demand for, and supply of the renewable resources, with consideration of the international resource situation, and an emphasis on pertinent supply, demand and price relationship trends.” In practice, this has meant projecting resource trends for the next 50 years.

FORCARB2 was one of the suite of RPA timber resource assessment (Adams and Haynes 1996; Haynes and others 2007) models used in the 1990s and 2000s that were linked with the Aggregate Timber Assessment (ATLAS) model (Mills and Kincaid 1992). ATLAS provides areas and volumes of inventory and harvests. Harvests were determined economically by the other models in the assessment. ATLAS and FORCARB2 can be used without being linked to the other assessment models, though harvest must be specified. See Birdsey and Heath (1995) and Joyce and others (1995) for FORCARB use in an RPA assessment. FORCARB and FORCARB2 provided estimates for forest greenhouse gas inventories of the United States (U.S. EPA 2002 and others in the series; Woodbury and others 2007), and were the basis for the FORCARB-ON model which provides similar analyses for the province of Ontario (Columbo and others 2007; Chen and others 2008). Heath and Birdsey (1993) used the model to test an hypothesis about the effects of harvest on carbon sequestration, and Smith and Heath (2004) projected carbon on National Forest System and other public lands.

FORCARB2 includes a new methodology for carbon in harvested wood products, updated initial inventory data, a revised algorithm for dead wood, and now covers public forest land, reserved forest land, and forest land of low productivity. It has been further tested and used. This is a legacy model: it is written in FORTRAN and uses text-based input and output files. Knowledgeable computer users will be most capable of using the model.

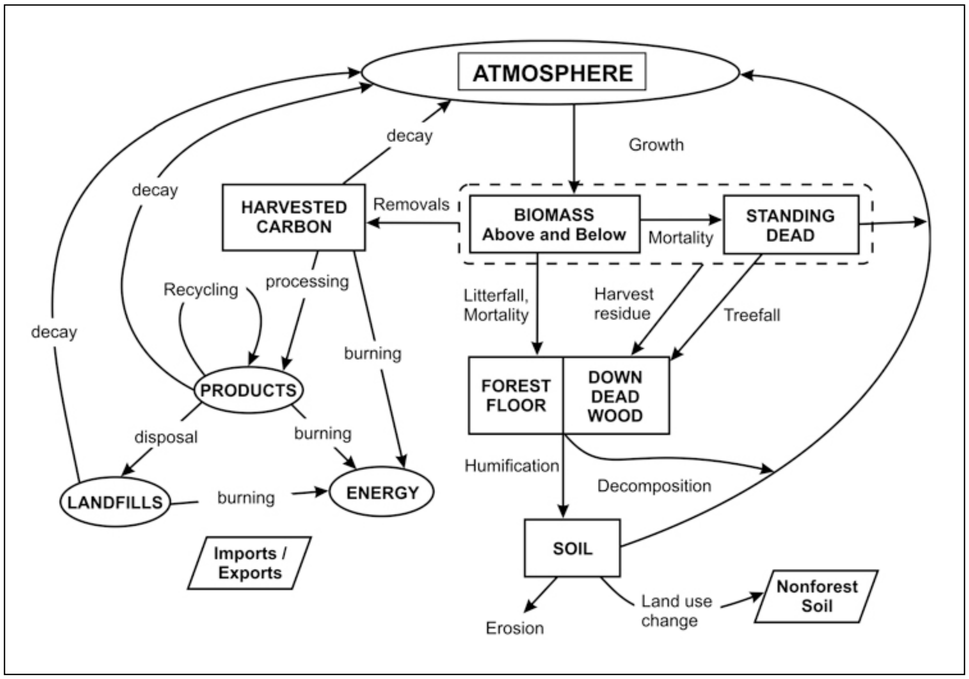
In this user's guide, we discuss facets of the system being modeled, including definitions of important terms, illustrations of the types of information generated by the model, and descriptions of models needed to produce carbon projections. Step-by-step instructions for running FORCARB2, input and output files, and codes used are presented in the appendices. Input data for public forest lands of the United States are provided as an example. These are the data files we have created and used for projecting forest carbon on public forestland for some studies.

DESCRIPTION OF THE SYSTEM

The amount of forest carbon in a changing landscape is determined by two variables: the area of forest and carbon per area. FORCARB2 accounts for changes in both. If forest area is constant, any change in total forest carbon is due to change in the amount of carbon per area, for example from tree growth, mortality, or removal through harvest. There always will be change in the forest on a per-area basis, though the changes in carbon may balance out to zero over a given time period. Vegetation on specific areas of land may change from forest to nonforest such as cropland, or from nonforest to forest. Changes in carbon are common following land cover or land use changes, or due to growing forests on areas that remain forest. A stand-level model focuses on changes on a particular area of land. This inventory system covers the landscape. The projected forest carbon pools are above- and belowground live tree, standing dead tree, down dead wood, forest floor, and soil carbon. Figure 1 shows these forest carbon pools and the processes and relationships between them.

The disposition of carbon in harvested wood products (HWP) is estimated in four categories over time based on Smith and others (2006), following Row and Phelps (1996) and Birdsey (1996): products in use, landfilled carbon, carbon in wood burned for energy, and carbon emitted without energy capture. Products in use include end-use products such as wood used in homes and other buildings, wooden furniture, wooden containers, and paper products. Carbon in landfills is assumed to be deposited for the long term, with slow decay rates. Carbon emitted with energy capture is primarily from recycling of harvested wood byproducts associated with processing at mills, but also includes wood burned in utility plants to produce electricity as well as wood burned directly for heating. Carbon emitted without energy capture includes mill residues or other wood products burned or decayed without capture and use of the heat produced. Because FORCARB2 estimates carbon stocks in forests, carbon in HWP pools should be added to the forest carbon stocks for an estimate of stored carbon.

Figure 1.—Stocks and flows of forest carbon in FORCARB2 (boxes indicate outputs).



Imports and exports of harvested wood from trade can be a significant factor in a forest carbon budget for a region. In this approach, the resulting carbon in harvested wood products includes carbon changes in wood grown in the region that may actually be exported and no longer remains in the region, and does not include carbon in wood products that have been imported into the region. The fate of exported wood is assumed to be similar to that of wood used locally, following the principles of production approach accounting (Penman and others 2003).

FORCARB2 METHODOLOGY FOR CALCULATING CARBON POOLS IN FOREST ECOSYSTEMS

To estimate and project forest carbon, FORCARB2 was linked to the ATLAS model (Mills and Kincaid 1992), which in turn was linked to other parts of the RPA timber assessment modeling system (U.S. EPA 2002). This linked system provided consistent estimates of timber, biomass, carbon, growth and harvest, and area change estimates. Beginning with an initial inventory, ATLAS projects timber inventories by allowing for growth, harvest, land-use change, and changes in management intensity through time. The input files contain information such as starting inventory in terms of area and volume per area by age class, growth-yield relationships, projected areas of forest (accounting for future changes in land use or forest type), harvest requests, and type of harvest. ATLAS is essentially a forest area and volume accounting framework that can be used at a variety of scales based on the stratification of input data. FORCARB2 uses output files from ATLAS containing projections, converts these tree projections to above- and belowground live tree carbon stocks, and estimates carbon in standing dead trees, down dead wood, forest floor, and soil carbon, including carbon in harvested wood products.

Like FORCARB, the backbone of FORCARB2 is made up of sets of equations for estimating stocks for each carbon pool, including live tree, standing dead tree, understory, down dead wood, forest floor, and organic portion of soil, based on forest inventory information from ATLAS combined with data from ecological studies. Definitions for each pool are included in Appendix G. The equations are used to estimate mass density of carbon within each pool. These values are multiplied by the forest area to obtain values for total carbon. With this method, values can be obtained similarly for carbon in inventory (current carbon), carbon in removals (including carbon in harvested areas and carbon in thinned areas), and net carbon from areas that changed land use. Change in carbon stocks is calculated by subtracting consecutive carbon stocks, and dividing by the time interval between stock estimates.

The mass densities of live and standing dead trees are calculated following methods of Smith and others (2003), who described models that estimate aboveground live and standing dead tree carbon as a function of plot-level merchantable growing-stock volume. Models differ by region, forest type, and owner/land-status category. For live trees, models differ only by type of wood (hardwood or softwood). The estimate of mass density of the forest floor is based on equations of Smith and Heath (2002) based on region, forest type, and age. Mass density of soil organic carbon to a depth of 1 meter is estimated for each region and forest type following Amichev and Galbraith (2004). The calculation of mass density of understory carbon is based on models with coefficients specific to region, forest type, and owner/land-status category described in Plantinga and Birdsey (1993). The current approach for estimating the mass of carbon in down dead wood is described in the next section.

Down Dead Wood Carbon Pool

The pool of down dead wood is based on two separate simulations. The first is naturally occurring down dead wood, such as from mortality or nonharvest disturbance, and the second is logging residue. The simulations track existing pools as a series of periodic estimates, each of which is modified according to factors controlling gains and losses. The two sub-pools, mortality and logging residue, are summed for results.

Mortality

The majority of down dead wood is dependent on inputs from fallen live or standing dead trees and large branches. All tree mortality or natural disturbances (which are reflected in mortality statistics) during a simulation interval contribute directly to the pool of standing dead trees, which in turn contributes to the pool of down dead wood. Statistical estimates of mortality determine the increase in standing dead wood over an interval. Similarly, statistics on the relative abundance of standing dead trees limit the size of this pool, with any additional increase in dead wood being allocated to down dead wood. Tree mortality is based on plot-level data from the 1997 Forest Resources database (Smith and others 2001) with region, wood type (softwood and hardwood), and age class as predictors (Table D10). Mortality is expressed in terms of volume in the Forest Resources database; we converted these to carbon density based on inventory data and volume-based biomass equations (Smith and others 2003). Net annual change in standing-dead tree carbon mass is based on periodic inventory estimates.

The annual increment for new accumulation of down dead wood is average annual mortality minus the average annual change in standing dead. The mass of new down dead wood is modified by a factor (0.85) to account for damage to fallen trees that leaves a portion of the carbon mass in the form of small woody debris (and thus forest floor in this model). Minor additional contributions to down dead wood are from fallen large branches of live trees. We model inputs from fallen large branches as a constant proportion of live-tree biomass; this is currently set at 0.01 percent of live carbon mass per year. The loss of carbon mass from down dead wood over time is determined as first-order decay: mass(t=year) = mass(t=0) × exp(–year/K), with decay coefficient K provided in Table D4. Softwood and hardwood carbon mass are modeled separately within each forest type.

Logging Residue

The accumulation of logging residue is through harvest and stand thinning. The difference between tree carbon inventory before harvest and carbon removed during harvest determines logging residue. The logging residue equation is:

Logging residue = initial inventory – mass of removals – remaining inventory

Carbon in inventory is based on Smith and others (2003); carbon in harvested volume mass is based on specific gravities according to forest type (Table D8).

Harvested volumes need two additional modifications to account for all carbon removed during harvest. First, they do not include bark on logs removed: a factor is needed to increase carbon to account for bark. Second, amounts of woody biomass greater than that in merchantable volume usually is removed and sent to mills. A factor is used to increase carbon to account for additional removals such as fuelwood. Currently, carbon in volume removed is multiplied by 1.12 to account for these two effects based on information in Tables 39-41 of Smith and others (2001).

The distinction between above- and belowground logging residue is based on differences between the whole-tree vs. aboveground-only forms of the tree mass equations of Smith and others (2003). Aboveground logging residue includes the aboveground portion of stumps because that portion of the tree is included in the whole-tree equation. Logging residue is also modified by a factor to account for damage during harvest that leaves a portion of the carbon mass in the form of small woody debris. As with down dead wood, the factor 0.85 reduces the carbon mass of aboveground logging residue; this assumes that 15 percent becomes forest floor. The factor 0.9 is applied to belowground logging residue to account for an expected rapid loss in smaller woody roots.

Annual loss of carbon mass from logging residue also is based on decay constants according to wood type as provided in Table D4. The loss of mass over time is determined with the same relationship describing decay as applied to down dead wood. We assume that logging residue does not include a significant amount of large pieces; thus, we use the values for pulpwood to decay all logging residue. We assume decay rates are significantly slower belowground; we assume the belowground logging residue decay rate is equal to three times the pulpwood decay constant.

FORCARB2 METHODOLOGY FOR CALCULATING CARBON IN HWP

FORCARB2 follows the methodology of Smith and others (2006), using the average disposition patterns of carbon in harvested wood from their Table 6. The WOODCARB II model (Skog 2008) is based on similar information. Information such as ratios of industrial roundwood to growing-stock volume is produced by data collected by the FIA program, specifically work on the timber products output such as reported by Johnson (2001). Using average disposition rates means that the current average disposition rates may be less applicable when projections are based on alternative scenarios in which major changes in product mix are expected, such as increased use of recycling. Therefore, some thought should go into interpreting the output from this part of the model.

EXAMPLE DATASET

Input files included with this guide are for all public forest land in the conterminous United States. For purposes of this dataset, U.S. forest land is divided into as many as ten geographical regions (see Figure 2). Some subdivisions and combinations are unique to ATLAS and some to FORCARB2. The regions chosen represent relatively distinct forest environments and generally follow political boundaries. In the example input data included in this study, two public owner groups are included: National Forests and Other Government. The FIA program was a major source of data for initial inventory (volumes and areas by age class), growth-yield curves, harvest information, and forest-type transitions to some extent. In addition to owner group and region, input data are categorized by forest type (or grouping of forest types), and land status (reserved versus not reserved, and productive versus low productivity). Because FIA historically focused on higher productivity lands that produce timber, data often are separated into timberland (productive and not reserved), productive reserved lands (timber harvesting prohibited), and nontimberlands (low-productivity forest land, often designated as “other forest”). Specific file construction techniques with accompanying data sources are described in the following section. Note that variables in input files are in English units whereas results in output files are in metric units.

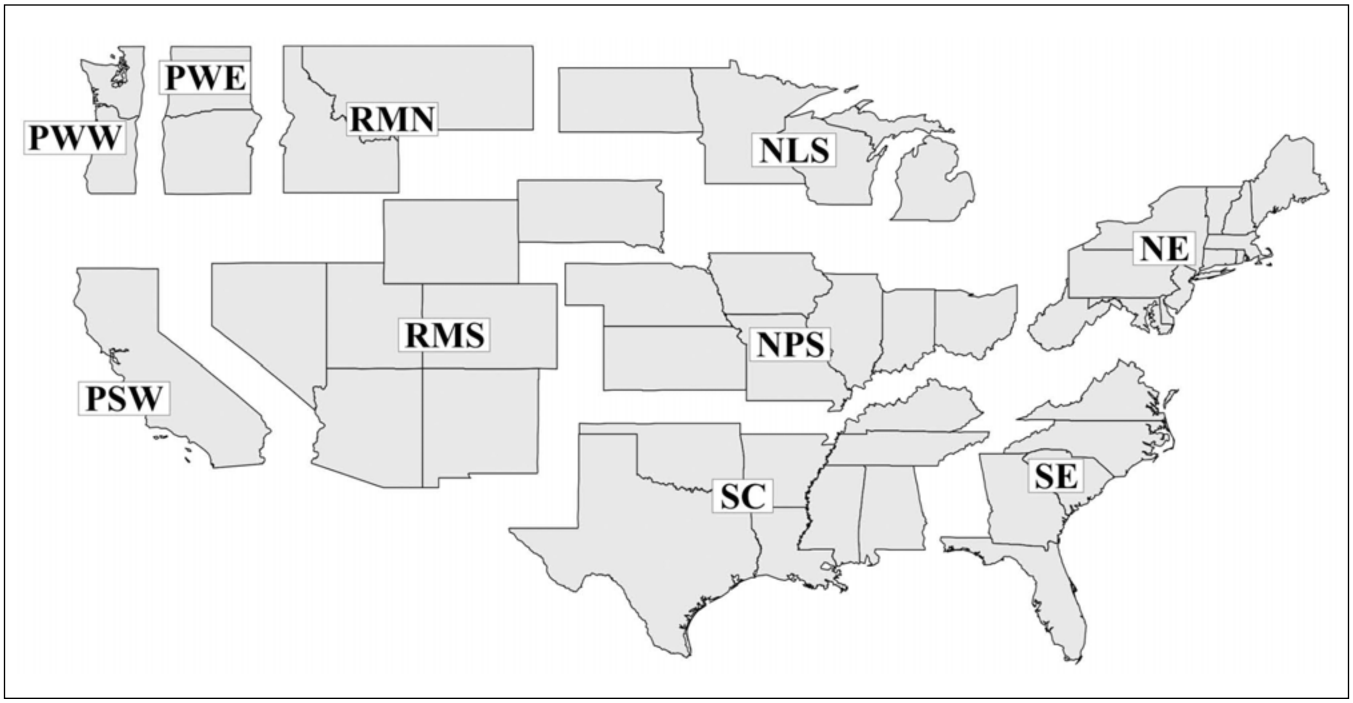


Figure 2.—Definitions of regions for outputs and their name, abbreviation and numerical label: 0, Pacific Northwest, West (PWW—sometimes labeled PNWW); 1, Pacific Northwest, East (PWE—sometimes labeled PNWE); 2, Pacific Southwest (PSW); 3, Rocky Mountain, North (RMN); 4, Rocky Mountain, South (RMS); 5, Northern Prairie States (NPS); 6, Northern Lake States (NLS); 7, Northeast (NE); 8, South Central (SC); and 9, Southeast (SE). Note that regions are merged or subdivided for some input tables, these combinations include: NLS and NPS as North Central; the States of North and South Dakota, Nebraska, and Kansas as the Great Plains (GP); PWW, PWE, and PSW as Pacific Coast; RMN and RMS as Rocky Mountain; SC and SE as South; and RMN, RMS, PWW, PWE, and PSW as West except where stated otherwise. A few states may be included in different regions (i.e., North and South Dakota are sometimes included with the NPS and Ohio is sometimes placed in the NE) (Smith and others 2006).

EXAMPLE GRAPHICS FROM FORCARB2 OUTPUT

Figures 3-9 illustrate graphics that can be produced from FORCARB2 output files. These examples are not meant to be comprehensive. A variety of results featuring many combinations of forest type, grouped by softwood and hardwood, comprising several age classes and over various projection years, is available at the subregional to regional to national level of aggregation. Figure 3 shows carbon in HWP in the four categories. Figure 4 illustrates current projected forest carbon stocks projected by age class. Figure 5 depicts carbon removed by age class due to harvest. Figures 6 and 7 show aggregate forest carbon stocks (Fig. 6) and stock change (Fig. 7) by subregions and regions. The trend in forest areas is shown in Figure 8, and Figure 9 shows carbon removed by age class due to land use change.

Figure 3.—Example output of carbon in harvested wood pools from wood harvested from the North Central Prairie States region, National Forest ownership, oak-hickory forest type (data from output file *bicmur.txt*).

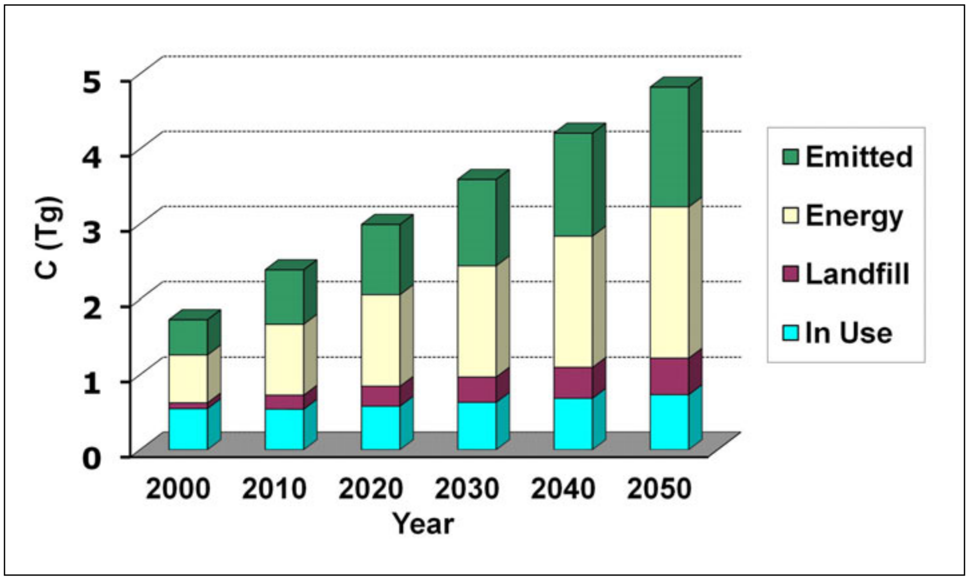


Figure 4.—Example output of total forest carbon by age class, management unit Pacific Northwest—Westside region, Other Government ownership, Douglas-fir forest type, 2000-2050 (data from output file *carbdb.txt*). Each age class represents a stand age range of 10 years, with the last age class containing all stands at least 170 years old.

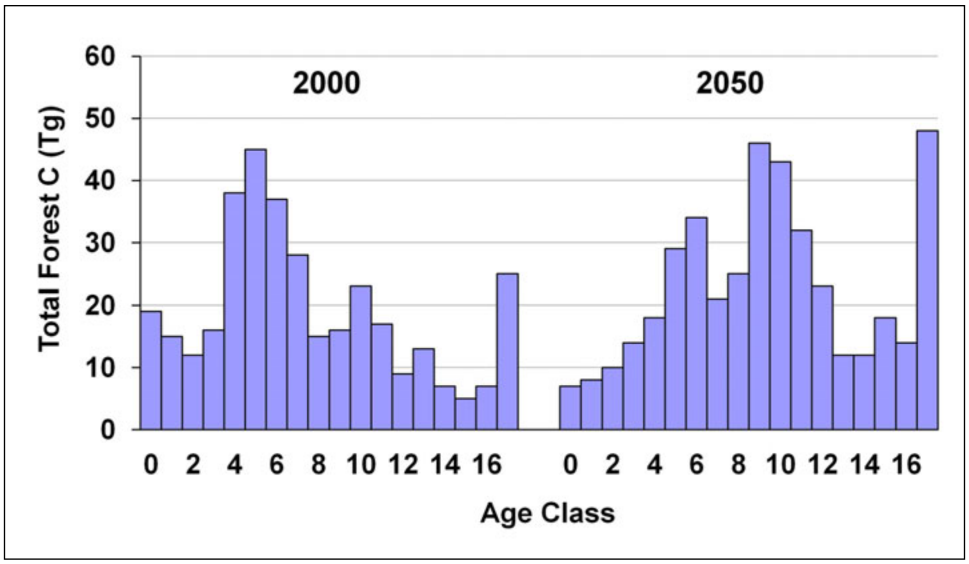


Figure 5.—Example output of carbon in merchantable portion of growing stock harvested by age class by softwoods and hardwoods in the management unit Southeast region, Other Government ownership, oak-pine forest type, 2010 (data from output file *finhar.txt*). Each age class represents a stand age range of 5 years with the last age class containing all stands at least 85 years old. There are no bars at age class less than 25 years old and younger (age classes 0 to 5) because the specified minimum harvest is 25 years in this run.

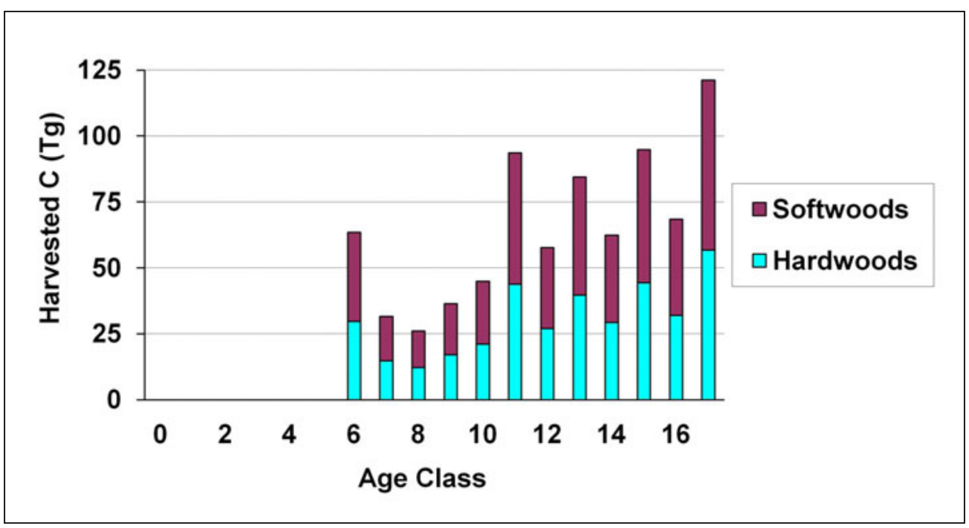


Figure 6.—Example output of forest carbon stocks by region, public timberlands (data from output file *bicreg.txt*).

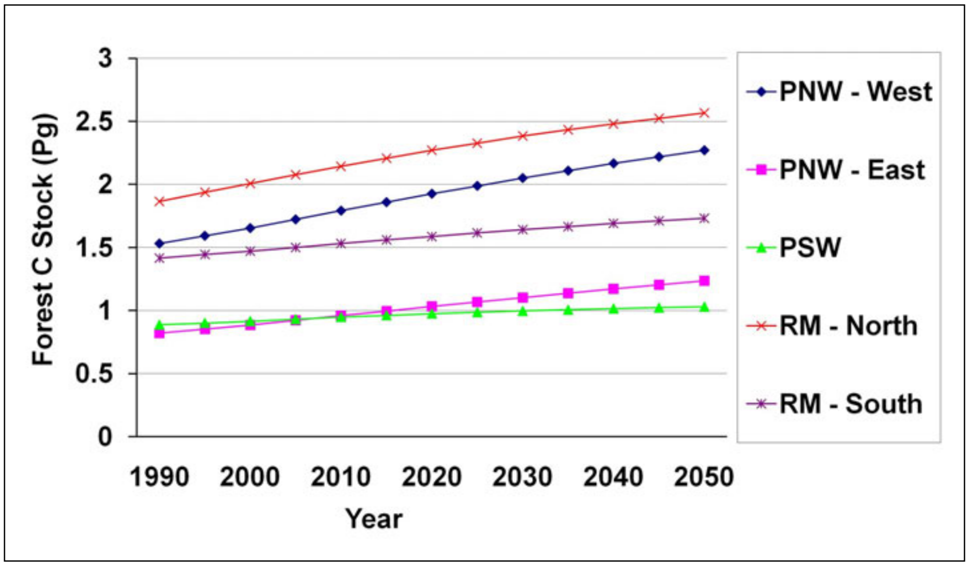


Figure 7.—Example output of changes in forest carbon stock by large region, U.S. public timberlands (data from output file *bicregs_all.txt*).

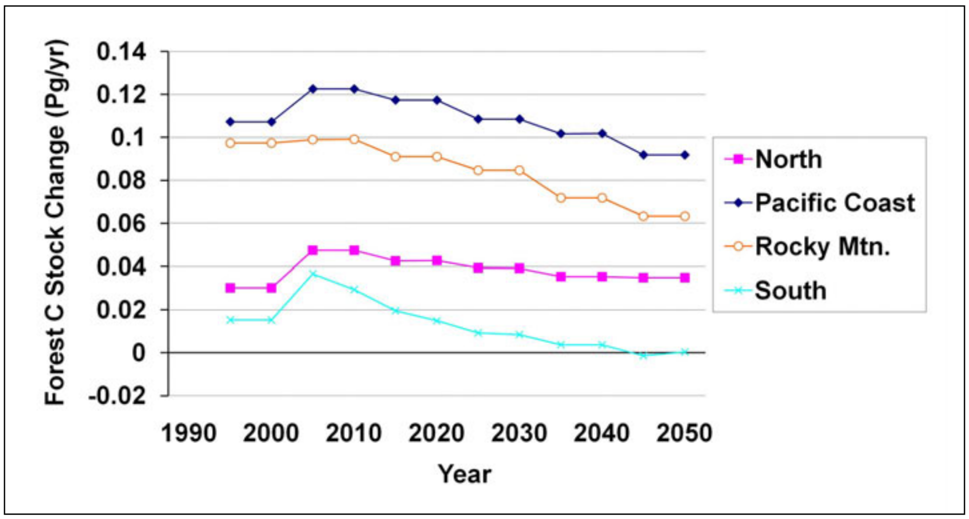
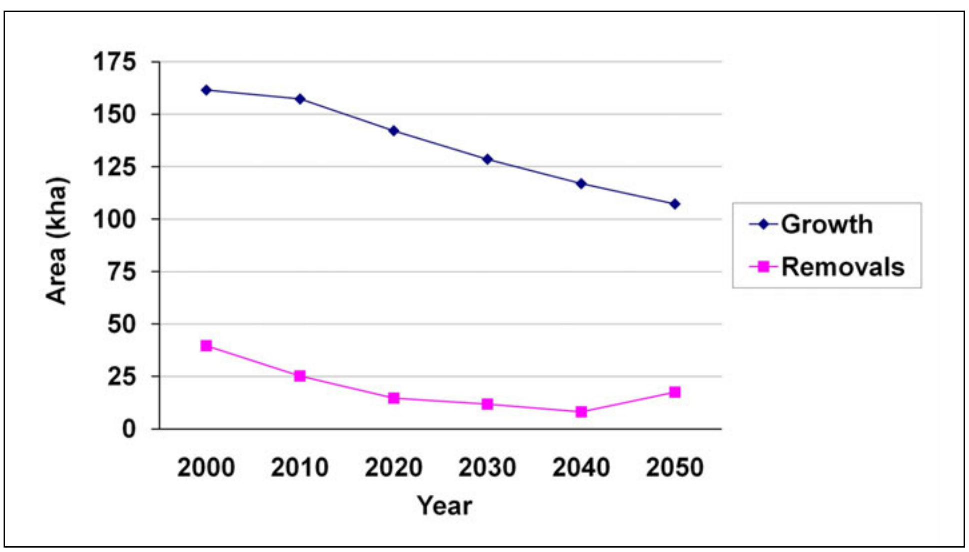


Figure 8.—Example output of area of growth and area of removals, management unit Pacific Southwest region, forest industry ownership, redwood forest type, 2000-2050 (data from output file *findat.txt*).



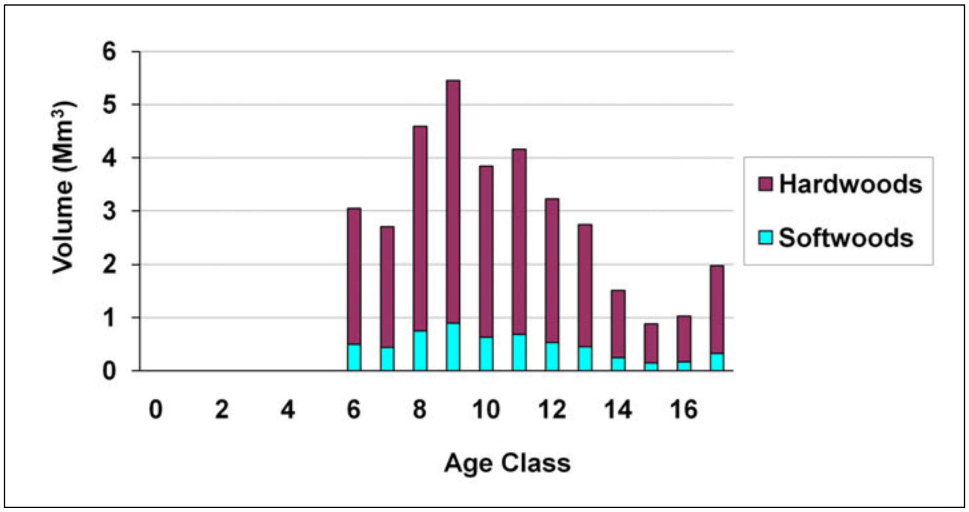


Figure 9.—Example output of volumes removed due to area loss, management unit South Central region, forest industry ownership, upland hardwood forest type, year 2000 (data from output file *volumesac.txt*). Each age class represents a stand age range of 5 years with the last age class containing all stands at least 85 years old. There are no bars at age class less than 25 years of age and younger (age classes 0 to 5) because there is no harvest at this young age by assumption.

INTERPRETATION OF MAIN OUTPUT FROM *bicreg* FILE

Forest Carbon

The *bicreg* files contain the main summary output from FORCARB2. Example output that includes land use change is shown in Table 1. Outputs are in units of thousands of hectares of area and petagrams of carbon. (In the *bicregmu* files, which contain the same summary output by management unit, carbon is given in teragrams.) Within the files, the section on Forest Area Summary (Table 1) provides forest area and the estimated area affected by removals (both harvests and land use change). The Forest Carbon Inventory section lists carbon stocks in the respective pools by year. There are two rows for soil carbon, one labeled Soil and the other Soil w/LUC soil. There are two rows because transferring area into or out of forest transfers a large amount of carbon, but that carbon does not necessarily go into the atmosphere. Rather, it changes categories. For tree-planting scenarios in which management units of millions of hectares appear, the amount of soil carbon transferring in to forests can be misleading if the amount of carbon that transfers in is included in the total. Soil w/LUC soil includes only lands present at the beginning of the projection. In this example, forests are losing area so that Soil is showing a loss over time while Soil w/LUC soil is constant.

The section labeled Tree Carbon Fluxes provides detailed information on the gains and losses of tree carbon in aboveground only or for all tree carbon including roots. “Removals” is used instead of harvests because removals include land-use change. The estimates of flux are total change over the period. The difference between inventories (e.g., 0.00159 for 1990-2000) is the increment (0.01790) minus the removals (0.01556) plus the change in tree carbon due to net area change (–0.00075); it is the same as the difference between the 2000 and 1990 total live-tree stocks (0.10279 – 0.10120). The section Net Area Change (see Table 1) lists the area and carbon changes attributed directly to net area change over the period.

Table 1.—Excerpt from *bicreg.txt*, the summary of projected forest area and carbon data by broad owner/land-status category

** BICREG **						
NC FOREST INDUSTRY			Total Over All Forest Types			
		YEARS				
	1990	2000	2010	…	2040	2050
		Thousand Hectares				
FOREST AREA SUMMARY						
TOTAL FOREST AREA	1536.69	1530.16	1506.81	…	1416.80	1396.13
AREA OF REMOVALS		149.64	86.71	…	10.21	7.48
		Petagrams				
FOREST CARBON INVENTORY						
TOTAL LIVE TREE	0.10120	0.10279	0.10618	…	0.12595	0.13438
TOTAL ABOVEGROUND TREE	0.08450	0.08582	0.08862	…	0.10508	0.11212
TOTAL DEAD TREE	0.01139	0.01107	0.01094	…	0.01123	0.01141
TOTAL ABVEGRD DEAD TREE	0.00952	0.00925	0.00914	…	0.00937	0.00952
TOTAL DOWNED WOOD	0.00854	0.01089	0.01187	…	0.01205	0.01175
ABOVEGROUND DOWN DEAD	0.00636	0.00852	0.00954	…	0.01082	0.01104
BELOWGROUND RESIDUE	0.00219	0.00238	0.00233	…	0.00123	0.00071
SOIL	0.23236	0.23133	0.22742	…	0.21388	0.21111
SOIL w/ LUC SOIL	0.23236	0.23236	0.23236	…	0.23236	0.23236
FOREST FLOOR	0.03233	0.03223	0.03172	…	0.03268	0.03365
UNDERSTORY	0.00265	0.00275	0.00277	…	0.00281	0.00289
TOTAL	0.38847	0.39107	0.39089	…	0.39860	0.40519
TOTAL w/ LUC SOIL	0.38847	0.39210	0.39584	…	0.41708	0.42644
TREE CARBON FLUXES						
TREE CARBON INCREMNT -TOT		0.01790	0.01935	…	0.01448	0.01352
TREE CARBON INCREMENT -AG		0.01495	0.01616	…	0.01209	0.01129
REMOVALS - TOTAL		0.01556	0.01309	…	0.00473	0.00326
REMOVALS - ABOVEGROUND		0.01300	0.01096	…	0.00395	0.00273
DIFF BTWN INVNTORIES -TOT		0.00159	0.00339	…	0.00694	0.00843
DIFF BTWN INVENTORIES -AG		0.00132	0.00280	…	0.00579	0.00704
NET AREA CHANGE						
AREA (1000HA)		-6.53	-23.35	…	-38.04	-20.68
TOTAL TREE		-0.00075	-0.00287	…	-0.00281	-0.00182
ABOVE GROUND		-0.00063	-0.00241	…	-0.00235	-0.00153
SOIL		-0.00103	-0.00391	…	-0.00574	-0.00277
FLOOR		-0.00016	-0.00080	…	-0.00101	-0.00054
UNDER		-0.00001	-0.00003	…	-0.00007	-0.00004
TOTAL		-0.00195	-0.00762	…	-0.00963	-0.00517

In Table 2, a summary of forest carbon is given at the bottom in the Summary block of information total net sequestration and emissions. All forest ecosystem carbon-change pools that show a net increase of carbon into the forest from the atmosphere (sequestration) are summed in the Total carbon sequestration row. Similarly, all forest ecosystem pools that show a net decrease of carbon in the forest are summed into the Total carbon emissions row. So, the variables representing tree carbon increment or removals and changes in inventory for standing dead, down dead wood, aboveground logging residue, belowground logging residue, soil, forest floor, and understory are summed into one of these two categories depending on their value. The total is the difference between sequestration and emissions. These are totals over the period; to obtain annual values, divide by the interval (in this case, 10 years).

Table 2.—Excerpt from *bicreg.txt*, the summary of projected carbon in harvested wood by broad owner/land-status category

** BICREG **							
				YEARS			
		1990	2000	2010	…	2040	2050
				Petagrams			
CUMULATIVE FATES OF REMOVALS CARBON							
IN USE		0	0.00417	0.00352	…	0.00476	0.00510
LANDFILL		0	0.00049	0.00119	…	0.00275	0.00331
ENERGY (EMISSION)		0	0.00339	0.00428	…	0.00791	0.00916
EMITTED (EMISSION)		0	0.00266	0.00350	…	0.00685	0.00804
TOTAL		0	0.01071	0.00862	…	0.01542	0.01774
ALL LOGGING RSD	- ABOVEGD	0.00166	0.00293	0.00238	…	0.00218	0.00201
	- BELOWGD	0.00111	0.00256	0.00211	…	0.00199	0.00188
HARVEST RESIDUE	- ABOVEGD	0	0.00220	0.00257	…	0.00467	0.00537
	- BELOWGD	0	0.00217	0.00253	…	0.00446	0.00511
SUMMARY OF CARBON SEQ. AND EMISSIONS[a]							
TOTAL CARBON SEQUESTERED			0.10481	0.10143	…	0.08326	0.07265
TOTAL CARBON EMITTED			0.01431	0.00336	…	0.00432	0.00450
NET CHANGE IN CARBON			0.09050	0.09807	…	0.07894	0.06814

[a] Summary of carbon sequestration and emissions only includes tree carbon increment or removals and changes in inventory for standing dead, down dead wood, aboveground logging residue, belowground logging residue, soil, forest floor, and understory.

Carbon in Harvested Wood

Table 2 also displays example output from a sample *bicreg.txt* for carbon in harvested wood products. No carbon is displayed in the first year because this is the start of the projection; no wood has been harvested. As the section Cumulative Fates of Removals Carbon indicates, the estimates are cumulative. For changes between years, estimates in the consecutive respective pools would be differenced and divided by the length of the period for an average annual change in carbon. Note that although all values in the fates section are positive, the Energy row (emissions from wood burned with energy capture) are emissions as well as the Emissions row (emissions from wood burned or combusted without energy capture). The Total cumulative fates row adds to the amount of carbon removed from the forest.

The rows labeled All Logging Residue show the amount of carbon in that pool, either aboveground or belowground at the given year. We estimate an existing amount of logging residue in the beginning period. The rows labeled Harvest Residue is a cumulative amount in the pools, including only that amount harvested during the projection period, that is, not accounting for existing amounts on the ground.

DESCRIPTION OF THE PROGRAMS

Three steps are needed to use the FORCARB2 model to produce carbon estimates: 1) running the ATLAS model (including production of input files containing up-to-date timberland data and projections), 2) running the main FORCARB2 model (which converts tree volume to carbon and adds on all other carbon pools), and 3) post-processing of FORCARB2 results. The postprocessors aggregate the results in different ways. Appendix A, a Quick Start Guide, summarizes how to run the programs; Appendix B includes step-by-step instructions that are particularly useful should problems arise in following the Quick Start Guide. A description of the files on the CD is given in Appendix C.

Step 1: ATLAS

There are three main input files to the ATLAS model: the initial inventory; factors including growth and yield, area and area change, and forest type compiled in a file called manage; and harvest requests. The initial inventories are defined by compiling areas together, called inventory units (IUs). The IUs are matched to a management unit (MU) that contains the information used to project growth and yield for that inventory. Several IUs can be assigned to an MU in which case the model aggregates the data to the MU level or most commonly, the inventory is aggregated outside of the MU and the units are matched one-to-one. MUs can be aggregated into larger harvest units (HUs) to allocate inventory among a group of MUs. Several HUs with their associated inventories can be projected in the same simulation. However, the higher-level units cannot be disaggregated. The reason for the aggregation is that MUs often represent groups of related species or forest productivity classes and harvest data often are available only over larger areas, representing multiple species and site conditions. However, with sufficient data all units could be of the same size, with one HU associated with a MU with an IU, each level (harvest, management, inventory) covering the same area.

The current ATLAS version, ATLAS05H, requires the following input files to run: *inven.dat, manage.dat, harvest.dat, gsrsum.txt, sevatlas2.txt, sevatlas2w.txt, period.txt* and *param.dat*. In this data set, multiple versions of several of these are required to run the model for the forest categories used for the coterminous United States. The file *param.dat* specifies folders for input and output files.

There are four separate executable programs that must be run in set order to produce output from the ATLAS model: IUSCAN05, MUSCAN05, HUSCAN05, and ATLAS05H. The example files configured here are in two groups: public timberland in one group and the reserved and lower productivity lands are in the other. Each group is subdivided by geographic region. There is a set of *inven.dat* and *manage.dat* files for each of the larger groupings and these contain the IUs and MUs for all regions within the group. The programs IUSCAN05 and MUSCAN05 read and process these files and need be run only once for each land status category, whereas HUSCAN05 and ATLAS05H must be run on each region/owner-land status category separately. In the example dataset, we include two owner-land status categories, designated by a three-letter file suffix: *pbl* (public timberland), and *rsv* (includes both reserved lands and unreserved low-productivity "other" forest lands). IUSCAN05 is a pre-processor that prepares the IU files; MUSCAN05 is a pre-processor that prepares the MU files.

IUSCAN05

Inven.dat, which contains areas and volumes for each IU stratified by age class (and management intensity where applied) is processed by IUSCAN05. An IU represents a particular forest type or a group of related types within a region. To construct corresponding *Inven* input files for each owner/land-status category, we used inventory datasets that are produced as a part of forest resource statistics developed for the Forest RPA. RPA datasets used were those compiled for 2002. These correspond to published summary statistics (Smith and others 2001, 2004).

MUSCAN05

MUSCAN05 requires an input file named *manage.dat* that identifies MUs used in both ATLAS and FORCARB2. Separate versions of the file were created for each owner/land-status category.[1] Each MU represents a particular forest type within a region and contains numerous stocking and management parameters, including base growth yield table volumes with which to project inventory for each age class. For these examples, custodial management intensity was assumed (intensity ID set to 1), representing average or medium productivity. The yield tables for public timberlands and the Reserved category and the manage file for the Reserved and Other Forest category were developed to match those in Mills and Zhou (2003) and Zhou and others (2007). However, we also assumed that the growth yield table volumes for the Other Forest category were limited to an increase of 15 cubic feet per year. Without this assumption, the volumes increased quickly on Other Forest. Many of the remaining growth and harvest parameters were borrowed from other input data sets and not calibrated for individual MUs.

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[1] These files are example inputs that provide users with a template with which to run the model and examine the input and output structures.

HUSCAN05

HUSCAN05 reads the output files produced by IUSCAN and MUSCAN and links the IUs to the MUs and organizes them by HUs as specified in the file *harvest.dat*. The HU represents the highest level of aggregation and each HU is assigned a set of harvest (removals) to apply to the member MUs for each period of the projection. In our example, within each owner/land-status category, each HU represents a region, an owner, and a wood type (softwood or hardwood). The *harvest.dat* file also contains projection information for each group of MUs, including the number of periods in the projection and the length of a period in years (5 years for the southern regions and 10 years elsewhere).

Currently, we run 18 of these MUs: the two owner/land-status categories and nine regions (Fig. 2; we combine NLS and NPS into one region). This file contains projected removals for each HU. To construct the *harvest* files for the Public category, growing-stock removals by ownerships within the owner/land-status category by softwood (SW) or hardwood (HW) were used from the March 30, 2006 ATLAS RPA base run. Since all inventories in the HUs in ATLAS contain both HW and SW components, it was necessary to apply the following equations to obtain the necessary harvest data. For a particular hardwood HU, harvests = (HW removals + SW removals) / (1 + Ratio of SW to HW for that HU in the 1997 harvest file). For the corresponding SW HU, harvests = those hardwood harvests multiplied by the same ratio. For the Reserved and Unreserved Other category, harvests were set to 0.0.

Other ATLAS05H Input Files

The remaining input files are required by ATLAS05H:

1. ***gsrsum.txt***: contains growing-stock removals by region/owner-land status category and wood type by period. All regions are in a specific order in each file, but there is a separate file for each of the large owner/land-status categories. The *gsrsum* file was constructed using data obtained to create the *harvest* files, as described previously. In the Reserved and Other *gsrsum* file, all removals were set to 0.0.

2. ***sevatlas2.txt*** and ***sevatlas2w.txt***: contain a set of distributions for ATLAS to use when regenerating land among various management intensities within an MU. They are a bridge between a version of ATLAS linked to the TAMM model for the 2005 Timber Assessment Update (Haynes and others 2007) and the stand-alone (portable) version called ATLAS05H. These files were created by the TAMM/ATLAS model in a soil expectation calculation procedure using costs and projected stumpage prices to calculate the best expected returns from a set of investment options in each period of the ATLAS simulation. The stand-alone model reads the files and uses them to substitute for the MU card type 44, which was used previously to distribute regeneration among management intensities. Card type 44 is input for each MU as a predetermined and fixed set of distributions for regenerating harvested or converted land among the model's 12 management intensities. These files allow the distribution to change for each period based on market conditions at the time. Each line starts with the MU identifier followed by 12 columns representing management intensities 1 through 12. These arrays are grouped in large blocks, one block for each projection period. We currently do not apply these shifts in the MUs but we include blank files should there be a need for applying shifts.

3. ***period.txt***: contains the maximum number of periods for which the simulation will run. Generally, it is set to 10 and does not need to be changed. Ten periods are required to project the Southern regions for 50 years. Parameters in the *harvest.dat* file control the actual projection length for each HU, for example, five periods for the PNWW HUs where the period length is 10 years.

Running the suite of ATLAS programs produces output files which are used as input files for the FORCARB2 model.

Step 2: Running FORCARB2

The FORCARB2 model uses two output files generated by ATLAS (*merch.txt* and *coefs_atlas.txt*; see Appendix D). These files provide estimates and projections of areas and tree volume by age class for the specified categories of forest land. The executable program is *forcarb2.exe*. If the input files are available and in the correct folders, running FORCARB2 will produce all summary files for both forest ecosystem carbon and carbon in harvested wood products. The file *flags_output.txt* contains the user's preferences for output; it can be edited before running FORCARB2. FORCARB2 output files, described in Appendix E, are created for each individual region/owner-land status combination run. If running FORCARB2 for multiple regions and/or categories, it is advisable to move the output files to another folder between each run to avoid overwriting previous results.

The parameters for the equations are contained in text files that are read by the FORCARB2 program; these text files must be kept in the same folder as the executable program (*forcarb2.exe*). A detailed list of these files (with example text) is included in Appendix D. In general, the equations estimate carbon for specific region/forest type combinations, with additional details for pools in which there is more information. Because the equation sets were developed separately and depend on different physical parameters, they often have different regional demarcations or different forest type definitions, or both. Therefore, a "cross-table" was set up to relate the ATLAS/FORCARB2 region/forest types (management units) to those used in each parameter file. This cross-table is found in *mu_table.txt*.

Step 3: Post-Processing

Additional utility programs were created for post-processing of FORCARB2 results. Because FORCARB2 is run for specific categories of land, its output files must be processed further to obtain summarized information. The program *total_bicregs_condense* produces summaries of forest carbon on a regional and national basis at various owner/land-status group aggregations. It is found in the FORCARB2 folder of the accompanying electronic files. The output files written by this program are *bicreg_all.txt* and *bicreg_all_condensed.txt*. All of the data values in the bicreg output files from FORCARB2 are summarized at the regional, expanded regional, and national levels. Expanded regions are aggregations of the original regions (Pacific Coast = Pacific Northwest Westside + Pacific Northwest Eastside + Pacific Southwest, Rocky Mountain = Rocky Mountain North + Rocky Mountain South, North = North Central + Northeast, and South = South Central + Southeast).

The original regions and owner/land-status categories are run over different periods and at different scales, for example, southern regions are run at 5-year intervals and 10-year intervals are used elsewhere. To facilitate comparison and allow aggregation, this program uses interpolation and extrapolation procedures to produce data values for each 5-year period from 1990 to 2050 for all possible combinations of region and owner-land status.

FUTURE USE OF FORCARB2

Because the input files to ATLAS and FORCARB2 define the initial volume, growth, harvests, and area change, the model can be used for any size area so long as the input files are modified accordingly. A new forest modeling system is being developed for the 2010 RPA Assessment, so the economically determined harvest forecasts that were used directly in FORCARB2 will no longer be available. However, the programs can forecast carbon stocks when harvests and land use change are prescribed.

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APPENDIX A. QUICK START GUIDE

Output files from FORCARB2 corresponding to the input files are included on the CD. They can be reproduced by the user by running the included programs. “Batch” files have been created that quickly run the entire process from beginning to end. Instructions on how to run these is included here. Users who wish to work their way through the model step by step should refer to the detailed instructions in Appendix B.

1) Insert the disc into the compact disc drive on your PC.
2) This disc should contain two (2) folders, **ATLAS** and **FORCARB2**. Copy these folders to your PC.
3) Right-click each folder and click on *Properties*. Remove the marker that indicates that the folder is “Read-only” by clicking on it. Apply to all subfolders and files.
4) Double-click the **ATLAS** folder to proceed.
5) Double-click the file *ATLAS.bat* to run the ATLAS model. This “batch” file runs all of the model programs and places the output files into appropriate subfolders. The subfolders are labeled by region and owner/land-status category. There are 18 subfolders that comprise nine regions and two owner/land-status categories.

   Regions and abbreviations are as follows:

Abbreviation	Region
NC	North Central[a]
NE	Northeast
PNWE	Pacific Northwest – east side
PNWW	Pacific Northwest – west side
PSW	Pacific Southwest
RMN	Rocky Mountains – North
RMS	Rocky Mountains – South
SC	South Central
SE	Southeast

[a]When running the inputs as provided here, two North Central subregions (NLS and NPS) are combined into one large region (Fig. 2). The output can be split into the separate subregions later.

   Descriptions and abbreviations for owner/land-status categories are as follows:

Abbreviation	Owner/land-status description
pbl	Publicly owned timberlands—includes National Forests and other government-owned (federal, state, or local)
rsv	Reserved timberland (land where harvest is prohibited) and nontimberland (low productivity forest land where it is assumed there is no commercial harvest)

6) A running log is written to the file *atlas_out.txt*. System-related errors (such as the absence of files/folders) are written to this file. A runtime summary of program steps is written to *atlas05_out.txt*. In addition, the ATLAS program keeps a record of program information in *atlog.txt*, which is written to each region/owner/land-status category folder. Processing errors and warnings are found there.

7) To run FORCARB2, navigate to the **FORCARB2** folder.

8) Double-click the file *FORCARB2.bat* to run FORCARB2 and *total_bicregs_condense*. FORCARB2 produces output files for each of the 18 region/owner/land-status combinations and places them in their corresponding subfolders in the **OUTPUT_FILES** folder. The program *total_bicregs_condense* creates two files named *bicreg_all.txt* and *bicreg_all_condensed.txt*, which contain summary information for every category.

9) A running log is written to the file *forcarb2_out.txt*. System-related errors such as the absence of files/folders are written to this file. Runtime summaries of program steps are written to *FORCARB2prog_out.txt* and *total_bicregs_condense_out.txt*. Internal processing errors can be found in *errors.txt*, which is written to the region/owner/land-status subfolders.

APPENDIX B. STEP-BY-STEP INSTRUCTIONS TO RUN THE MODEL

Output files from FORCARB2 corresponding to the input files are included on the CD. They can be reproduced by the user by running the included programs. More experienced users who wish to modify one or more of the input data files to include different or additional data should refer to Mills and Kincaid (1992) for guidance.

1) Insert the disc into the compact disc drive on your PC.
2) This disc should contain two (2) folders, **ATLAS** and **FORCARB2**. Copy these folders to your PC.
3) Right-click each folder and click on *Properties*. Remove the marker that indicates the folder is "Read-only" by clicking on it. Apply to all subfolders and files.
4) If you do not wish to run the programs again but would like to examine the results, skip to step 19. If you do not wish to run ATLAS again, but would like to run FORCARB2, skip to step 14. If running ATLAS, double-click the **ATLAS** folder to proceed.
5) Copy the file *param.dat* from the folder named **REGIONAL_INPUT_FILES** to the main **ATLAS** folder. This file lists the directories to which the output files are written. You can edit the file in a text processor, such as Notepad or one of your choosing. (A warning may be displayed concerning the editing of a *.dat* file; it is safe to ignore it.) Edit the first line (characters 4-11) if you wish to change the file extension that will be given to each of the ATLAS output files; for ease of use, we have assigned an extension of ".txt". You can change the directory locations. They are initially set to the main ATLAS folder. If running multiple regions and/or owner/land-status categories, it is advisable to change the folder to which "Atlas report files" are written between each run to avoid overwriting the output files from the previous run.
6) The **REGIONAL_INPUT_FILES** folder contains two subfolders, one for each of the currently designated owner/land-status categories. Descriptions and abbreviations for owner/land-status categories are as follows:

Abbreviation	Owner/land-status description
pbl	Publicly owned timberlands—includes National Forests and other government-owned (federal, state, or local)
rsv	Reserved timberland (land where harvest is prohibited) and nontimberland (low productivity forest land where it is assumed there is no commercial harvest)

Each owner/land-status category is run separately. Within each of these subfolders are three files (*gsrsum.txt, inven.dat,* and *manage.dat*) and nine subfolders, one for each region of the United States. The three files contain the following data parameters to be used in the model:

inven.dat: For each inventory unit (IU), contains initial acreages and volumes within each age class.

manage.dat: For each management unit (MU), contains growth and yield tables and thinning, stocking, and area-change parameters.

gsrsum.txt: For each MU, contains data on growing-stock removal for each region/owner/land-status combination for each period.

To run a particular owner/land-status category, copy the three files (*gsrsum.txt, inven.dat,* and *manage.dat*) to the main **ATLAS** folder. For example, to run publicly owned timberlands, copy *inven.dat, manage.dat,* and *gsrsum.txt* from the **pbl** folder to the **ATLAS** folder.

7) Run *iuscan05.exe* by double-clicking its filename.
8) Run *muscan05.exe*.
9) Navigate back to the folder from which you copied the files in step 6. Within this folder are nine subfolders, one for each region of the United States. The region abbreviations are as follows:

Abbreviation	Region
NC	North Central[a]
NE	Northeast
PNWE	Pacific Northwest – east side
PNWW	Pacific Northwest – west side
PSW	Pacific Southwest
RMN	Rocky Mountains – North
RMS	Rocky Mountains – South
SC	South Central
SE	Southeast

[a]When running the inputs as provided here, two North Central subregions (NLS and NPS) are combined into one large region (Fig. 2). The output can be split into the separate subregions later.

Each region should be run separately. Within each regional subfolders is a single file named *harvest.dat* that contains data on harvest volume for the particular region/owner/land-status combination. Choose a region to run and copy the *harvest.dat* file for that region to the main **ATLAS** folder. This is the input file for the next program.

10) Run *huscan05.exe*.
11) If running multiple regions and/or owner/land-status categories, you must change the output folder to avoid overwriting the previously produced report files. Edit the file *param.dat* in the **ATLAS** folder if necessary.
12) Run *atlas05h.exe*.

13) Many output files are produced by ATLAS. FORCARB2 requires only two of these: *coefs_atlas.txt* and *merch.txt*. Copy these files to the **FORCARB2** folder and skip to step 16.

14) To run FORCARB2, first navigate to the **FORCARB2** folder.

15) If using the ATLAS output files created by the authors, navigate to the **REGIONAL_INPUT_FILES** subfolder within **FORCARB2** folder. Here, there are 18 subfolders, one for each region/owner/land-status combination. See Steps 6 and 9 for abbreviations. Each combination will require a separate run of FORCARB2. Each subfolder contains two files (*coefs_atlas.txt* and *merch.txt*), output from ATLAS for that particular category. Copy the files for the category you want to run to the **FORCARB2** folder.

16) You can edit *flags_output.txt* should you wish to request particular output files. In this file, each of the FORCARB2 output files is assigned a flag of 0 or 1. A flag assignment of 1 indicates that the file will be produced upon running FORCARB2; output files with an assignment of 0 are not produced. By default, all output files are assigned a flag of 1 and thus are created.

17) Run *forcarb2.exe*.

18) Repeat for additional regions and/or owner/land-status categories. If you want to keep the output files, rename them or move them to other folders so that they will not be overwritten.

19) For a description of FORCARB2 output files, see Appendix E. Output files produced by the authors are found in **FORCARB2\OUTPUT_FILES** (region).(owner/land-status category) by each of the 18 region/owner/land-status combinations discussed previously.

20) Summary FORCARB2 output at the regional and national levels can be produced by running the included program *total_bicregs_condense.exe* (with associated program code in *total_bicregs_condense.for*). This program summarizes data from any *bicreg.txt* files that were produced by FORCARB2 and outputs two files, *bicreg_all.txt* (in the same format as *bicreg.txt*) and *bicreg_all_condensed.txt* (in a condensed tabular format). The program is currently set up to read the *bicreg.txt* files from a region/owner/land-status category directory structure included on the CD; if you set up a different directory structure, you must modify the path in *total_bicregs_condense.for* and recompile.

APPENDIX C. FORCARB2 CD CONTENT

The main directory contains two folders, **ATLAS** and **FORCARB2**, a file with basic information in two formats (*readme.doc* and *readme.txt*), and a copy of the User's Guide.

The folder **ATLAS** contains two "batch" files that run the entire suite of ATLAS programs (*ATLAS.bat* and *ATLAS05H.bat*), executable files used in running the ATLAS model (*iuscan05.exe*; *muscan05.exe*; *huscan05.exe*; *atlas05h.exe*), input files needed by the model which apply to all region/owner-land status categories (*period.txt*; *sevatlas2.txt*; *sevatlas2w.txt*), and three subfolders (**REGIONAL_INPUT_FILES**, **OUTPUT_FILES** and **CODE**).

The subfolder **REGIONAL_INPUT_FILES** within the **ATLAS** folder contains a generic *param.dat* file for use by experienced users, and subfolders for each of the two owner/land-status categories (public[**pbl**], reserved and other[**rsv**]). Within each of these subfolders are three input files needed by the ATLAS model (*gsrsum.txt*, *inven.dat*, and *manage.dat*) and nine subfolders for each region. Each regional subfolder contains a file named *harvest.dat* and a file named *param.dat* which specifies folder locations for all the files input or output from the model programs. Each file must be copied into the folder containing the program files for each region/owner/land-status combination before executing the model programs (this is performed automatically if running the "batch" files).

The subfolder **OUTPUT_FILES** within the **ATLAS** folder contains subfolders for each of the region/owner-land status combinations that contain ATLAS output files. Two of these files, *coefs_atlas.txt* and *merch.txt*, are input files to the FORCARB2 model. Other ATLAS output files may contain data of interest to some (*atacre*; *atavail*; *athar*; *athur*; *athur2*; *atinv*; *atlis2*; *atlist*; *atlog*; *atmur*; *atmurdb*; *avail.txt*; *comdif.txt*; *gainloss*; *invout*; *regen.txt*). Many of these are described in Mills and Kincaid (1992).

The subfolder **CODE** within the **ATLAS** folder contains the FORTRAN source code (*iuscan05.for*; *muscan05.for*; *huscan05.for*; *atlas05h.for*) and several "include" files used by the programs (*atpar.inc*; *atpath.inc*; *atrosum.inc*; *hudet.inc*; *huset.inc*; *husum.inc*; *linkbl.inc*; *mudata.inc*; *mudet.inc*; *parset.inc*; *ttet.inc*). This subfolder is included for the benefit of advanced users who may wish to modify the code and recompile for their own applications.

The folder **FORCARB2** contains three "batch" files that run the FORCARB2 programs (*FORCARB2.bat*, *FORCARB2prog.bat* and *total_bicregs_condense.bat*), executable files used in running the FORCARB2 model (*forcarb2.exe* and *total_bicregs_condense.exe*), text files which contain parameters needed by the programs (*coefs_bark.txt*; *coefs_decay.txt*; *coefs_emitted.txt*; *coefs_ff.txt*; *coefs_gs.txt*; *coefs_gsvol.txt*; *coefs_livetree.txt*; *coefs_mort.txt*; *coefs_owners.txt*; *coefs_pfates.txt*; *coefs_resid.txt*; *coefs_sdeadtree.txt*; *coefs_soil.txt*; *coefs_under.txt*;

coefs_weights.txt; *flags_output.txt*; *mu_table.txt*), and three subfolders (**REGIONAL_INPUT_FILES**, **OUTPUT_FILES** and **CODE**). The text files are described elsewhere in this document.

The subfolder **REGIONAL_INPUT_FILES** within the **FORCARB2** folder contains subfolders for each of the region/owner-land status combinations that contain FORCARB2 input files. These files are output by the ATLAS model. Each subfolder contains files named *coefs_atlas.txt* and *merch.txt* (Appendix D). Each file must be copied into the folder containing the FORCARB2 program files for each region/owner/land-status combination before executing the FORCARB2 program (performed automatically if running "batch" files).

The subfolder **OUTPUT_FILES** within the **FORCARB2** folder contains subfolders for each of the region/owner/land-status combinations. These contain FORCARB2 output files (*bicmur.txt*, *bicreg.txt*, *bicregmu.txt*, *carbdb.txt*, *carbhu.txt*, *errors.txt*, *findat.txt*, *findat0.txt*, *finhar.txt*, *volumes.txt* and *volumesac.txt*). Each of these is described in Appendix E. It also contains the two forest carbon summary files (*bicreg_all.txt* and *bicreg_all_condensed.txt*).

The subfolder **CODE** within the **FORCARB2** folder contains the FORTRAN source code (*forcarb.for* and *total_bicregs_condense.for*) and several "include" files used by the programs (*biccom.inc*, *carbvars.inc*, *coefvars.inc*, *ddwcom.inc*, *forpar.inc*, *lrcom.inc*, and *merch.inc*). This subfolder is included for the benefit of advanced users who may wish to modify the code and recompile for their own applications.

APPENDIX D. FORCARB2 INPUT FILES

Twenty input files are required to run FORCARB2. Two of them, *merch.txt* and *coefs_atlas.txt*, are output files from ATLAS. The file *flags_output.txt* indicates which output files the user would like to produce, and is meant to be edited by the user. *Mu_table.txt* is used to link management units (MUs) with coefficients for equations. All other input files contain coefficients for equations for carbon pools. Each file is described in alphabetical order as follows:

Coefs_atlas.txt

Coefs_atlas.txt contains miscellaneous information produced during the ATLAS run that is needed by FORCARB2. Included on the initial line are start year of model run, number of years in each interval (or period), and number of periods desired. The remainder of the file consists of MU information. Each row contains the elements listed in Table D1. Definitions of the variables are given as follows. An example file is given in Table D2.

Table D1.—Data structure of *coefs_atlas.txt*, an output file of ATLAS used as an input file to FORCARB2

Element	Data Type	Length	Columns
Management Unit[a]	Character – Upper Case	15	1-15
Region Identifier[b]	Integer	2	18-19
Owner-Land Status Identifier[c]	Integer	2	22-23
Forest Type Identifier[d]	Integer	2	26-27
Site Quality Identifier[e]	Integer	2	30-31
Possible Harvesting Types Identifier[f]	Integer	2	34-35
Partial Cutting Occurrence Flag[g]	Integer	1	38

[a] The name of the level of aggregation which includes the growth and yield lookup table, and area change. This is the leftmost column in the *mu_table.txt* file. The sequential order of the MU matches the order of the data in the *merch.txt* file.

[b] The number assigned to the geographic area in which the MU is located. See Figure 2 for a description of regions used in FORCARB2.

[c] Identification of the broad owner/land-status group to which the MU belongs. See the description of *coefs_owners.txt* below for a complete category list.

[d] See Appendix F for a list of the forest types.

[e] If site quality has been assigned to the particular MU, the codes are: 00, no site quality assigned; 01, high (or good) site quality; 02, medium site quality; 03, low (or poor) site quality.

[f] Values are 01, clearcut only; 02, partial cutting only; 03, both clearcut and partial cutting allowed. Note that 02 with a target age class of 0 is the same as clearcutting.

[g] 0=no partial cutting, 1=partial cutting.

Table D2.—Excerpt of *coefs_atlas.txt* file

1990	10	5				
PNWW NF ALDER	0	1	45	0	1	0
PNWW NF HWMIX	0	1	50	0	1	0
PNWW NF DFIR	0	1	50	0	2	0
PNWW NF W.HEM	0	1	50	0	2	0
PNWW NF FR-SP	0	1	25	0	1	0
PNWW NF PINES	0	1	30	0	1	0
PNWW NF SWMIX	0	1	35	0	1	0
PNWW NF NOSTK	0	1	44	0	1	0
PNWW OG ALDER	0	2	45	0	1	0
PNWW OG HWMIX	0	2	50	0	1	0
PNWW TR ALDER	0	6	45	0	1	0
PNWW TR HWMIX	0	6	50	0	1	0
PNWW OG DFIR	0	6	50	0	2	0
…	…	…	…	…	…	…

Coefs_bark.txt

Coefs_bark.txt: see partial listing in Table D3. The file includes factors for estimating the sum of wood plus bark on harvested wood; see Table 5 of Smith and others (2006).

Table D3.—Excerpt of *coefs_bark.txt* listing factors to estimate the sum of wood plus bark on harvested wood (Smith and others 2006)

Region	Wood type	Wood size	Multiplier
Northeast	SW	Saw log	1.182
Northeast	SW	Pulpwood	1.185
Northeast	HW	Saw log	1.199
Northeast	HW	Pulpwood	1.218
North Central	SW	Saw log	1.182
North Central	SW	Pulpwood	1.185
North Central	HW	Saw log	1.199
North Central	HW	Pulpwood	1.218
Pacific Coast	SW	Saw log	1.181
Pacific Coast	SW	Pulpwood	1.185
Pacific Coast	HW	Saw log	1.197
Pacific Coast	HW	Pulpwood	1.219
Rocky Mountain	SW	Saw log	1.181
…	…	…	…

Coefs_decay.txt

Coefs_decay.txt: see partial listing in Table D4. The file contains the decay coefficient (Turner and others 1995) for first-order decay of wood according to region, type (hardwood/softwood) and size of piece (pulpwood, saw log, or large saw logs). These are applied to down dead wood from mortality as well as logging residue from harvest.

Table D4.—Excerpt from *coefs_decay.txt* showing decay coefficients for calculations of dead wood decay

Region	Wood type	Wood size	Decay coefficients
MtWest	HW	Pulpwood	18.13476536
MtWest	HW	Saw log	28.60139984
MtWest	SW	Pulpwood	43.45532048
MtWest	SW	Saw log	58.81511143
MtWest	SW	Large saw	76.88340190
North	HW	Pulpwood	12.11287488
North	HW	Saw log	19.11993958
North	SW	Pulpwood	17.88187843
…	…	…	…

Coefs_emitted.txt

Coefs_emitted.txt: see partial listing in Table D5. These are needed to calculate harvested wood carbon. The file contains coefficients for estimating fractions of emitted carbon associated with energy recapture for industrial roundwood, see Table D7 of Smith and others (2006). Estimates are calculated according to: fraction =A × exp(–((year/B)C)). Fractions differ by region, wood type, and wood size.

Table D5.—Excerpt from *coefs_emitted.txt*, containing coefficients for estimating fractions of emitted carbon associated with energy recapture for industrial roundwood (Smith and others 2006)

Region	Wood type	SL/PW [a]	A	B	C
Northeast	SW	Saw log	0.5582	2594	0.6557
Northeast	SW	Pulpwood	0.6289	3062	0.5432
Northeast	HW	Saw log	0.6143	6812	0.5953
Northeast	HW	Pulpwood	0.5272	3483	0.5364
North Central	SW	Saw log	0.6728	2162	0.6550
North Central	SW	Pulpwood	0.6284	3494	0.5117
North Central	HW	Saw log	0.6097	5144	0.6236
North Central	HW	Pulpwood	0.5243	3399	0.5451
Pacific Northwest; East	SW	All	0.5421	1144	0.7958
…	…	…	…	…	…

[a] SL=sawlog; PW=pulpwood

Coefs_ff.txt

Coefs_ff.txt: see partial listing in Table D6. The file contains coefficients used in FORCARB2 to calculate mass density of the forest floor (Smith and Heath 2002). Coefficients differ by region and forest type. Using these coefficients for A, B, C, and D, forest-floor mass density (Mg/ha) = ((A × YR) / (B+YR)) + (C × exp(–(YR/D))), where YR is the number of years since clearcut harvest. Coefficient A also serves as a flag; if A equals 0, C is the estimate for forest-floor carbon.

Table D6.—Excerpt from *coefs_ff.txt*, showing a sample of coefficients used in FORCARB2 to calculate forest floor mass density (Smith and Heath 2002)

Region/Forest type	A	B	C	D
N pine	19.1	25.6	13.8	8.4
N spruce, fir, hemlock	62.9	57.8	33.7	8.4
N mixed conifer-hardwood	65.0	79.5	29.7	8.4
N aspen-birch	18.4	53.7	10.2	9.2
N maple-beech-birch	50.4	54.7	27.7	9.2
N mixed hardwood, oak	24.9	134.2	8.2	9.2
N nonstocked	0.0	1.0	4.8	9999.9
S pine	20.4	27.1	12.2	3.8
S mixed conifer-hardwood	15.4	20.1	10.3	3.8
…	…	…	…	…

Coefs_gs.txt

Coefs_gs.txt: See partial listing in Table D7. These are needed to calculate carbon in harvested wood. File contains factors applied to estimate carbon in harvested wood based on growing-stock volume; see Table 5 of Smith and others (2006). These include the ratio of industrial roundwood to growing-stock removals as roundwood (IndRwd/GSRwd), the ratio of carbon in bark to carbon in wood (Bark/Wood), the fraction of growing-stock volume removed as roundwood (GSRwd/AllRwd), and the ratio of fuelwood to growing-stock removals as roundwood (FW/GSRwd). Ratios are included for each region/wood type/wood size combination.

Table D7.—Excerpt from *coefs_gs.txt*, showing various factors applied to estimate carbon in harvested wood based on growing-stock volume

Region	Wood type[a]	Wood size	IndRwd/ GSRwd	Bark/ wood	GSRwd/ AllRwd	FW/ GSRwd
NE	SW	Saw log	0.991	0.182	0.948	0.136
NE	SW	Pulpwood	3.079	0.185	0.948	0.136
NE	HW	Saw log	0.927	0.199	0.879	0.547
NE	HW	Pulpwood	2.177	0.218	0.879	0.547
NC	SW	Saw log	0.985	0.182	0.931	0.066
NC	SW	Pulpwood	1.285	0.185	0.931	0.066
NC	HW	Saw log	0.960	0.199	0.831	0.348
NC	HW	Pulpwood	1.387	0.218	0.831	0.348
PC	SW	Saw log	0.965	0.181	0.929	0.096
…	…	…	…	…	…	…

[a] SW = softwood; HW = hardwood

Coefs_gsvol.txt

Coefs_gsvol.txt: see partial listing in Table D8. These are needed to calculate carbon in harvested wood. The file contains factors for calculating carbon in growing-stock volume; see Table 4 of Smith and others (2006). These include the fraction that is softwood, fractions that are of sawtimber size, and average specific gravity. These are given for each region/forest type combination.

Table D8.—Excerpt from file *coefs_gsvol.txt* containing factors to calculate carbon in growing-stock volume (Smith and others 2006)

Region	Forest-type group	Softwood fraction	Softwood sawtimber fraction	Hardwood sawtimber fraction	Softwood specific gravity	Hardwood specific gravity
Northeast	Aspen-birch	0.247	0.439	0.330	0.353	0.428
Northeast	Elm-ash-cottonwood	0.047	0.471	0.586	0.358	0.470
Northeast	Maple-beech-birch	0.132	0.604	0.526	0.369	0.518
Northeast	Oak-hickory	0.039	0.706	0.667	0.388	0.534
Northeast	Oak-pine	0.511	0.777	0.545	0.371	0.516
Northeast	Spruce-fir	0.870	0.508	0.301	0.353	0.481
Northeast	White-red-jack pine	0.794	0.720	0.429	0.361	0.510
Northern Lake States	Aspen-birch	0.157	0.514	0.336	0.351	0.397
…	…	…	…	…	…	…

Coefs_livetree.txt

Coefs_livetree.txt: see partial listing in Table D9. The file contains coefficients used in FORCARB2 to calculate mass density of live trees following methods of Smith and others (2003). Coefficients differ by region, forest type, owner/land-status category, and type of wood. Values are given for both full tree (above- and belowground) and aboveground portion of tree only. Using these coefficients for F, G, and H, live mass density (Mg/ha) = $F \times (G+(1-\exp(-\text{volume}/H)))$. When the coefficient for H equals 0, the coefficient for F is the predicted value for live mass density. The mass density is then multiplied by the forest area to estimate total live-tree carbon.

Table D9.—Excerpt from *coefs_livetree.txt*, coefficients used in FORCARB2 to calculate mass density of live trees (Smith and others 2003)

Region	Forest type	Owner	Wood type[a]	Tree part[b]	F	G	H
NE	Aspen- Birch	All	all	ag	438.47703	0.034680	410.705746
NE	Aspen- Birch	All	all	full	508.51010	0.036143	397.427168
NE	Aspen- Birch	All	HW	ag	581.27948	0.023864	574.944090
NE	Aspen- Birch	All	HW	full	683.59185	0.024465	566.852986
NE	Aspen- Birch	All	SW	ag	60.339938	0.018041	38.4255956
NE	Aspen- Birch	All	SW	full	73.331860	0.018273	38.2625320
NE	MBB/ Other HW	Priv	all	ag	357.40011	0.046993	255.054236
NE	MBB/ Other HW	Priv	all	full	425.25821	0.047576	254.727135
…	…	…	…	…	…	…	…

[a] HW = hardwood, SW = softwood, all = based on both hardwood and softwood.

[b] ag = aboveground; full = above- and belowground (roots).

Coefs_mort.txt

Coefs_mort.txt: see partial listing in Table D10. The file contains annual estimated mortality percentages derived from the 1997 RPA plot level dataset used for estimating carbon in down dead wood. The particular set of numbers to use in the FORCARB2 run depends on the region, the type of dominant wood (hardwood or softwood) in the forest type, and the age class group. The applicable percentage is multiplied by the live-tree carbon mass density to obtain the annual mortality in carbon density. To calculate mortality over an interval of p years, mortality is calculated for each end of the interval (year and year+p) and these are averaged to give the mean annual mortality. See text for detailed information on the calculations.

Table D10.—Example of annual estimated mortality percentages derived from the 1997 RPA plot level dataset from *coefs_mort.txt*

Region	Wood type[a]	ACGRP[b]	Percent
NE	HW	AC1_3	2.3
NE	HW	AC4_plus	0.8
NE	SW	AC1_3	12.6
NE	SW	AC4_plus	1.0
NLS	HW	AC1_3	2.2
NLS	HW	AC4_plus	1.1
NLS	SW	AC1_3	1.5
NLS	SW	AC4_plus	1.2
NPS	HW	AC1_3	1.1
NPS	HW	AC4_plus	1.0
pjW	SW	AC4_plus	0.5
…	…	…	…

[a] HW = hardwood, SW = softwood.

[b] ACGRP = included age-class groups. AC1_3 includes age classes 1 through 3; AC4_plus includes all age classes 4 and greater.

Coefs_owners.txt

Coefs_owners.txt: see partial listing in Table D11. The file is a list of the broad owner/land-status groups used for FORCARB2 output. The order of the groups must match the numbers assigned to the corresponding MUs in the manage files used by MUSCAN in the ATLAS model. (Note: Several of the groups listed in this file are not discussed in this guide.)

Table D11.—Broad owner/land-status groups used in FORCARB2 output from *coefs_owners.txt*

National Forest
Other Government
Forest Industry
Other Private (including Farm)
Miscellaneous Corporate
Tribal Lands
Reserved
Other Forest

Coefs_pfates.txt

Coefs_pfates.txt: see partial listing in Table D12. These are needed to calculate harvested wood carbon. The file contains estimates of disposition patterns of carbon as fractions from industrial roundwood over time from 0 to 100 years after harvest (see Table 6 of Smith and others 2006). Fractions vary by region, wood type, and wood size. Possible product fates include continued use as products, stored in landfills, consumed for the production of energy or emitted without energy recapture.

Table D12.—Excerpt of the *coefs_pfates.txt* file, containing disposition patterns of carbon as fraction of industrial roundwood over time (Smith and others 2006)

Region	Wood type	Wood size	Number of years since harvest[a]	In Use	Landfills	Energy	Emitted
NC	Softwood	Saw log	0	0.630	0.000	0.249	0.121
NC	Softwood	Saw log	1	0.599	0.016	0.257	0.127
NC	Softwood	Saw log	2	0.570	0.032	0.265	0.133
NC	Softwood	Saw log	3	0.544	0.045	0.272	0.138
NC	Softwood	Saw log	4	0.520	0.058	0.279	0.143
NC	Softwood	Saw log	5	0.499	0.069	0.285	0.147
NC	Softwood	Saw log	10	0.410	0.115	0.310	0.165
NC	Softwood	Saw log	15	0.349	0.145	0.327	0.178
NC	Softwood	Saw log	20	0.306	0.166	0.339	0.189
NC	Softwood	Saw log	25	0.272	0.181	0.348	0.198
NC	Softwood	Saw log	30	0.245	0.193	0.356	0.206
NC	Softwood	Saw log	40	0.203	0.210	0.367	0.220
NC	Softwood	Saw log	50	0.173	0.221	0.374	0.231
NC	Softwood	Saw log	60	0.151	0.229	0.379	0.241
NC	Softwood	Saw log	70	0.133	0.236	0.382	0.249
NC	Softwood	Saw log	80	0.118	0.241	0.384	0.257
NC	Softwood	Saw log	90	0.106	0.246	0.385	0.263
NC	Softwood	Saw log	100	0.096	0.250	0.385	0.269
NC	Softwood	Pulpwood	0	0.514	0.000	0.305	0.180
NC	Softwood	Pulpwood	50	0.014	0.091	0.504	0.391
NC	Softwood	Pulpwood	100	0.008	0.084	0.504	0.403
…	…	…	…	…	…	…	…

[a] Data is annual; only select years are shown for illustration.

Coefs_resid.txt

Coefs_resid.txt: see partial listing in Table D13. The file contains the average ratios of types of woody residue biomass to live-tree biomass for each region/forest type/owner/land-status combination. The types of woody residue are down wood due to mortality, and logging residue, which is split into aboveground and belowground. See text for additional information on the algorithm.

Table D13.—Excerpt from file *coefs_resid.txt*

Mu_id	Owner group	ddwood2tree[a]	aglres2tree[b]	bglres2tree[c]
NC FI CS	private	0.0206	0.0000	0.0000
NC FI CS-LH	private	0.0371	0.0095	0.0089
NC FI CS-MB	private	0.0369	0.0000	0.0011
NC FI CS-OH	private	0.0392	0.0213	0.0194
NC FI CS-OP	private	0.0357	0.0098	0.0095
NC FI CS-PN	private	0.0274	0.0248	0.0243
NC FI LS-AB	private	0.0402	0.0245	0.0245
…	…	…	…	…

[a] Ratio of down dead wood to live tree.
[b] Ratio of aboveground logging residue to live tree.
[c] Ratio of belowground logging residue to live tree.

Coefs_sdeadtree.txt

Coefs_sdeadtree.txt: see partial listing in Table D14. The file contains coefficients used in FORCARB2 to calculate mass density of standing dead trees (Smith and others 2003). Coefficients differ by region, forest type and owner/land-status category. Values are given for both full tree (above- and belowground) and aboveground portion of tree only. Using these coefficients for A, B, and C, standing-dead mass density (Mg/ha) = (predicted live-tree mass density) × A × exp(–((volume/B)C)). If the coefficient for C equals 0, A is the predicted value.

Table D14.—Excerpt from *coefs_sdeadtree.txt* (Smith and Heath 2003)

Region	Forest type	Owner group	Forest[a]	Tree part[b]	A	B	C
NE	Aspen-Birch	all	all	ag	0.0438829	697.1841396	3.4784987
NE	Aspen-Birch	all	all	full	0.0436075	704.7826187	3.5064502
NE	MBB/Other HW	Priv	all	ag	0.1193884	240.2169916	2.3834805
NE	MBB/Other HW	Priv	all	full	0.1189334	240.3618154	2.3909855
NE	MBB/Other HW	Publ	all	ag	0.1193884	240.2169916	2.3834805
NE	MBB/Other HW	Publ	all	full	0.1189334	240.3618154	2.3909855
NE	Oak-Hickory	all	all	ag	0.0614742	459.1132221	1.6087507
…	…	…	…	…	…	…	…

[a] All = all forests versus productive forests or low-productivity forests.
[b] ag = aboveground; full = above- and belowground (roots).

Coefs_soil.txt

Coefs_soil.txt: see partial listing in Table D15. The file contains estimates of mass density of soil organic carbon for each region-forest type combination in tons per hectare. This includes all fine organic material in the soil to a depth of 1 meter but excludes coarse roots larger than 2 mm in diameter (which are included in other pools). These estimates were derived from the national STATSGO spatial database (USDA Soil Conserv. Serv. 1991) using the general approach of Amichev and Galbraith (2004).

Table D15.—Excerpt from *coefs_soil.txt* with estimates of mass density of soil organic carbon (Mg/ha) for each region-forest type combination

Region/Forest type	soilC1m_tph[a]
GP Spruce/Fir	48.024310
GP Pinyon / Juniper	59.470494
GP Ponderosa Pine	48.509203
GP Exotic softwoods	123.313204
GP Oak / Pine	67.809404
GP Oak / Hickory	85.503725
GP Elm / Ash / Cottonwood	79.014500
GP Maple / Beech / Birch	97.145771
GP Aspen / Birch	68.320741
GP Non stocked	48.458307
NE White / Red / Jack Pine	78.127857
NE Spruce / Fir	97.985485
…	…

[a] Soil carbon (Mg/ha) to a depth of 1 meter.

Coefs_under.txt

Coefs_under.txt: see partial listing in Table D16. The file contains coefficients used in FORCARB2 to calculate mass density of the understory developed by Plantinga and Birdsey (1993). Coefficients differ by region, forest type, and owner/land-status category. The equation used in FORCARB2 depends on whether stand age has reached the age in variable INTYR. If younger, the understory mass density = $A0Y+(B1Y \times YR)+(B2Y \times YR^2)$, where YR is the number of years since afforestation. If older, then understory mass density = $A0V+(B1V \times VOLAC)+(B2V \times VOLAC^2)$, where VOLAC is volume per area.

Table D16.—Excerpt of file *coefs_under.txt* showing coefficients to calculate understory mass density (Plantinga and Birdsey 1993)

Region/owner/ forest type	A0Y	B1Y	B2Y	INTYR	A0V	B1V	B2V
NC FI LS-OH	1849.	-8.40	0.0	15.	1920.	-0.81885	0.000428
NC FI LS-LH	1817.	-2.00	0.0	15.	1671.	-0.05883	0.000109
NC FI LS-MB	1889.	-16.48	0.0	15.	1506.	-0.51967	0.000247
NC FI LS-AB	1805.	0.50	0.0	15.	2078.	-0.48959	0.000165
NC FI NONSTOCK	1889.	-16.48	0.0	15.	1506.	-0.51967	0.000247
NC FI CS-OH	1849.	-8.40	0.0	15.	1920.	-0.81885	0.000428
NC FI CS-LH	1833.	-5.20	0.0	15.	2281.	-1.09687	0.000448
NC FI CS-MB	1889.	-16.48	0.0	15.	1506.	-0.51967	0.000247
NC FI CS NONSTO	1849.	-8.40	0.0	15.	1920.	-0.81885	0.000428
…	…	…	…	…	…	…	…

Coefs_weights.txt

Coefs_weights.txt: see partial listing in Table D17. The file contains factors used to convert growing-stock volume of wood to mass of carbon. Factors differ by region, forest type, and species within forest type (based on Table 4 of Smith and others 2006).

Table D17.—Excerpt from *coefs_weights.txt* containing factors used to convert growing-stock volume of wood to mass of carbon (Smith and others 2006)

Region/forest type	Specific gravity	v2c_lbs (ft^3-lbs)[a]	v2c_tons (m^3- tonnes)[b]	Wood Type[c]
NE Aspen-Birch	0.428554187	13.37089064	0.214277094	HW
NE Aspen-Birch	0.355927137	11.10492668	0.177963569	SW
NE MBB/Other HW	0.515042451	16.06932446	0.257521225	HW
NE MBB/Other HW	0.366181708	11.42486929	0.183090854	SW
NE Oak-Hickory	0.538236597	16.79298183	0.269118299	HW
NE Oak-Hickory	0.391929346	12.22819561	0.195964673	SW
…	…	…	…	…

[a] v2c_lbs(ft^3-lbs) = factor to convert volume in cubic feet to carbon in pounds.

[b] v2c_tons (m^3-tonne) = factor to convert volume in cubic meters to carbon in tonnes.

[c] HW = hardwood, SW = softwood.

Flags_output.txt

Flags_output.txt: see partial listing in Table D18. The file contains flags indicating which output files you want FORCARB2 to produce. Available output files include *carbdb.txt*, *carbhu.txt*, *findat.txt*, *finhar.txt*, *bicmur.txt*, *bicreg.txt*, *bicregmu.txt*, *volumes.txt*, and *volumesac.txt*. (See Output Files section for description of each.) A value of 1 indicates the file (or files) will be produced; if a 0 is present, the file(s) will not be created.

Table D18.—Example *flags_output.txt*

	CARBs	FINDAT	FINHAR	BICMUR	BICREG	BICREGMU	VOLUMES	VOLUMESAC
Select output (0,1)	1	1	1	1	1	1	1	1

Merch.txt

Merch.txt: see partial listing in Table D19. The file contains MU-level values of merchantable inventory, growth, and removals, and net area-change volumes. These are reported for each age class and period. There are 18 age classes (numbered 0 to 17); each represents a stand age span of 10 years (5 in the south). This corresponds with the period length specified in *coefs_atlas.txt*. Following a clearcut, a stand would be placed in age class 0. After the specified time interval, it would move to age-class 1, and so on. If a stand reaches the maximum age class, it would remain at that level until harvested.

Each group of 18 rows contains estimates for a particular MU for a particular period. Data for each period are grouped together. The order of the MUs matches the order found in *coefs_atlas.txt*. The final period's MU block contains three additional rows (a total of 21). The contents of each row are as follows:

ROW	TYPE OF DATA
1	Age class
2	Inventory area
3	Softwood inventory volume
4	Hardwood inventory volume
5	Volume of softwood growth
6	Volume of hardwood growth
7	Area harvested
8	Volume of softwood removed
9	Volume of hardwood removed
10	Thinning area
11	Softwood volume thinned
12	Hardwood volume thinned
13	Net area change
14	Net change in softwood volume due to change in area
15	Net change in hardwood volume due to change in area
16	Area loss
17	Softwood volume on lost area recovered by harvest
18	Hardwood volume on lost area recovered by harvest

The additional three rows in the final period's MU block are as follows:

ROW	TYPE OF DATA
19	Final inventory area
20	Final softwood inventory volume
21	Final hardwood inventory volume

Areas are in thousands of acres; volumes are in millions of cubic feet. Each data value has a maximum length of 10, with resolution to the nearest thousandth.

Table D19.—Excerpt of several lines of *merch.txt*, an input file to FORCARB2 that contains MU level estimates of merchantable inventory, growth, and removals, and net area-change volumes for each age class and period

0	1	2	3	4	…	13	14	15	16	17
95.287	75.429	93.155	87.996	175.234	…	5.220	1.410	0.000	0.000	0.000
0.724	0.743	1.393	1.958	3.757	…	0.161	0.030	0.000	0.000	0.000
31.330	32.114	60.238	84.700	162.470	…	6.946	1.284	0.000	0.000	0.000
0.000	0.135	0.374	0.443	0.320	…	0.066	0.027	0.000	0.000	0.000
0.000	5.852	16.169	19.155	13.859	…	2.869	1.158	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	…	1.483	0.400	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	…	0.054	0.010	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	…	2.334	0.432	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	…	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	…	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	…	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	…	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	…	0.000	0.000	0.000	0.000	0.000
…	…	…	…	…	…	…	…	…	…	…

Mu_table.txt

Mu_table.txt: see partial listing in Table D20. The file contains references linking MUs to the region/forest type/owner/land-status combinations in the various "*coef_*" files listed previously. The more data underlying a carbon pool, likely the more categories in a "*coef_*" file.

Table D20.—Several sample abbreviated lines from *mu_table.txt*, which links the ATLAS/FORCARB MUs with their corresponding region-forest type from each of the *coef* files

Management unit	TREES/(WEIGHTS-1:25)	Forest floor	…
PNWW FI DFIR—H	PWW Douglas-fir Priv	PNWW Douglas-fir, western hemlock	…
PNWW FI DFIR—M	PWW Douglas-fir Priv	PNWW Douglas-fir, western hemlock	…
PNWW FI DFIR—L	PWW Douglas-fir Priv	PNWW Douglas-fir, western hemlock	…
PNWW FI W.HEM-H	PWW Western Hemlock all	PNWW Douglas-fir, western hemlock	…
PNWW FI W.HEM-M	PWW Western Hemlock all	PNWW Douglas-fir, western hemlock	…
…	…	…	…

APPENDIX E. FORCARB 2 OUTPUT FILES

The user has a choice of output files from FORCARB2. These may be specified in the file flags_output.txt by turning the flags on (=1) or off (=0). Each of the optional output files is described as follows:

Bicmur.txt

Bicmur.txt: see partial listing in Table E1. The file contains projections of carbon flows resulting from the harvesting and use of wood and wood products. Estimates are made of the amounts in use (as wood products), in landfills, burned for energy as a substitute for for fossil fuel, or emitted or left as logging residue for each MU. Values are given in teragrams of carbon and are tracked from time of harvest to the last period in the model. Each row indicates how much of a year's removals remain in that category over time. Each column indicates the total amounts of carbon in that category for each year in the model.

Table E1.—Example of *bicmur.txt* file, which contains projections of carbon flows resulting from the harvesting and use of wood and wood products

** BICMUR **

		POST REMOVALS CARBON FLOWS						
	NC NF CS-OH							
		PERIOD						
		1990	2000	2010	2020	2030	2040	2050
		Teragrams						
PERIOD	REMOVALS	----	------	------	--IN USE-	------	------	------
1990	0	0	0	0	0	0	0	0
2000	1.1243		0.5474	0.3322	0.2631	0.2253	0.1978	0.1759
2010	0.4265			0.2076	0.126	0.0998	0.0855	0.075
2020	0.3921				0.1909	0.1159	0.0918	0.0786
2030	0.3901					0.1899	0.1153	0.0913
2040	0.4002						0.1948	0.1182
2050	0.3982							0.1938
TOTAL		0	0.5474	0.5398	0.58	0.6309	0.6852	0.7329
PERIOD	REMOVALS	----	------	------	-LANDFILL	------	------	------
1990	0	0	0	0	0	0	0	0
2000	1.1243		0.077	0.1579	0.1786	0.1883	0.1956	0.2019
…	…	…	…	…	…	…	…	…

Bicreg.txt

Bicreg.txt: see partial listing in Table E2. The file contains a summary of projected forest area and carbon data by broad owner/land-status category. Areas are given in thousands of hectares and carbon is reported in petagrams.

Table E2.—Excerpt from *bicreg.txt*, the summary of projected forest area and carbon data by broad owner-land status category

** BICREG **

B I C A R B
REGIONAL CARBON SEQUESTRATION AND EMISSIONS

PNWW NATIONAL FOREST — Total Over All Forest Types

	YEARS					
	1990	2000	2010	…	2040	2050
	Thousand Hectares					
FOREST AREA SUMMARY						
TOTAL FOREST AREA	2878.2	2878.2	2878.2	…	2878.2	2878.2
AREA OF REMOVALS		52.39	7.92	…	11.63	10.94
	Petagrams					
FOREST CARBON INVENTORY						
TOTAL LIVE TREE	0.54362	0.61592	0.69734	…	0.90528	0.96231
TOTAL ABOVEGROUND TREE	0.44875	0.50847	0.57572	…	0.74748	0.79459
TOTAL DEAD TREE	0.06073	0.0661	0.07166	…	0.08359	0.08633
TOTAL ABVEGRD DEAD TREE	0.03956	0.04284	0.04618	…	0.05324	0.05483
TOTAL DOWNED WOOD	0.01844	0.02882	0.03593	…	0.06023	0.064
ABOVEGROUND DOWN DEAD	0.01733	0.02625	0.03381	…	0.05824	0.06212
BELOWGROUND RESIDUE	0.00111	0.00256	0.00211	…	0.00199	0.00188
SOIL	0.25896	0.25896	0.25896	…	0.25896	0.25896
SOIL w/ LUC SOIL	0.25896	0.25896	0.25896	…	0.25896	0.25896
FOREST FLOOR	0.10609	0.10789	0.1108	…	0.11909	0.12139
UNDERSTORY	0.00866	0.00933	0.0104	…	0.01586	0.01816
TOTAL	0.99651	1.08702	1.18509	…	1.44301	1.51115
TOTAL w/ LUC SOIL	0.99651	1.08702	1.18509	…	1.44301	1.51115
TREE CARBON FLUXES						
TREE CARBON INCREMNT -TOT		0.08661	0.08378	…	0.06704	0.06125
TREE CARBON INCREMENT -AG		0.07153	0.0692	…	0.05538	0.05059
REMOVALS - TOTAL		0.01431	0.00236	…	0.00427	0.00422
REMOVALS - ABOVEGROUND		0.01181	0.00195	…	0.00353	0.00349
DIFF BTWN INVNTORIES -TOT		0.0723	0.08142	…	0.06277	0.05703
DIFF BTWN INVENTORIES -AG		0.05972	0.06725	…	0.05185	0.04711
NET AREA CHANGE						
AREA (1000HA)		0	0	…	0	0
TOTAL TREE		0	0	…	0	0
ABOVE GROUND		0	0	…	0	0
SOIL		0	0	…	0	0
FLOOR		0	0	…	0	0
UNDER		0	0	…	0	0
TOTAL		0	0	…	0	0

(Table E2 continued on next page)

(Table E2 continued)

** BICREG **

	YEARS					
	1990	2000	2010	…	2040	2050
	Petagrams					
CUMULATIVE FATES OF REMOVALS CARBON						
IN USE	0	0.00417	0.00352	…	0.00476	0.0051
LANDFILL	0	0.00049	0.00119	…	0.00275	0.00331
ENERGY	0	0.00339	0.00428	…	0.00791	0.00916
EMITTED	0	0.00266	0.0035	…	0.00685	0.00804
TOTAL	0	0.01071	0.00862	…	0.01542	0.01774
LOGGING RESIDUE - ABOVEGD	0.00166	0.00293	0.00238	…	0.00218	0.00201
BELOWGD	0.00111	0.00256	0.00211	…	0.00199	0.00188
ALL LOGGING RSD - ABOVEGD	0	0.0022	0.00257	…	0.00467	0.00537
BELOWGD	0	0.00217	0.00253	…	0.00446	0.00511
SUMMARY OF CARBON SEQUESTRATION AND EMISSIONS						
TOTAL CARBON SEQUESTERED		0.10481	0.10143	…	0.08326	0.07265
TOTAL CARBON EMITTED		0.01431	0.00336	…	0.00432	0.0045
NET CHANGE IN CARBON		0.0905	0.09807	…	0.07894	0.06814
…	…	…	…	…	…	…

Bicregmu.txt

Bicregmu.txt contains a summary of projected forest area and carbon data by MU. Areas are given in thousands of hectares and carbon is reported in teragrams. The file structure is similar to *bicreg.txt*; see Table E2 for example.

Carbdb.txt

Carbdb.txt contains carbon estimates for the age classes of each MU for each year in the simulation. Values are given for total carbon in hardwood types, total carbon in softwood types, total carbon in all types not broken up by pool, total nonsoil carbon and forest area. The total includes live tree, standing dead, forest floor, soil (where applicable), understory, and down dead wood. Output is comma-separated to facilitate its use in other analytical software. The table format is as follows:

Element	**Data Type**	**Length** [a]	**Columns**
Region	Character – Upper Case	4	2-5
Year	Integer	4	7-10
Harvest Unit	Character	55	12-66
Management Unit	Character – Upper Case	15	68-82
Age Class	Integer	2	84-85
Softwood Total Carbon	Integer	10	87-96
Hardwood Total Carbon	Integer	10	98-107
Total Carbon	Integer	10	109-118
Total Nonsoil carbon	Real	10(5)	120-129
Forest Area	Real	12(5)	131-142

[a] For elements of Data Type *Real*, the number in parentheses indicates the number of digits after the decimal point, while the other number indicates the total number of characters including the decimal point. For example, a length of 10(5) would be of the format 0000.00000.

Carbhu.txt

Carbhu.txt contains carbon estimates for the age classes of each harvest unit (HU) for each year in the simulation. The table format is as follows:

Element	Data Type	Length	Columns
Region	Character – Upper Case	4	2-5
Year	Integer	4	7-10
Harvest Unit	Character	55	12-66
Age Class	Integer	2	68-69
Softwood Tree Carbon	Integer	10	71-80
Hardwood Tree Carbon	Integer	10	82-91
Total Carbon	Integer	10	93-102

Errors.txt

Errors.txt contains information describing errors should any be detected. This may be useful in diagnosing and correcting of data problems.

Findat.txt

Findat.txt contains carbon amounts for inventory, growth, removals, and net area change for each period for each MU. Values are included for the various components of the forest ecosystem, including soils, forest floor, and understory. For trees, both hardwood and softwood values are given as well as both total and aboveground only. Area is in thousands of hectares; carbon is given in teragrams. The table format is given in Table E3.

Table E3.—Data structure of *findat.txt*, an output file of FORCARB2

Heading	Element	Data Type	Length[a]	Columns
P	Period Number[b]	Integer	2	1-2
R	Region Identifier[c]	Integer	2	3-4
O	Owner-Land Status Identifier[d]	Integer	1	6
F	Forest Type Identifier[e]	Integer	2	7-8
S	Site Quality Identifier[f]	Integer	1	10
I	Management Intensity Identifier[g]	Integer	1	12
INAREA	Inventory Area	Real	11(5)	14-24
SWMRCH	Carbon in Merchantable Portion of Tree - Softwood	Real	11(5)	26-36
HWMRCH	Carbon in Merchantable Portion of Tree - Hardwood	Real	11(5)	38-48
SWTOTL	Total Live Tree Carbon – Softwood	Real	11(5)	50-60
HWTOTL	Total Live Tree Carbon – Hardwood	Real	11(5)	62-72
SWABGR	Above Ground Live Tree Carbon – Softwood	Real	11(5)	74-84
HWABGR	Above Ground Live Tree Carbon – Hardwood	Real	11(5)	86-96
SDTOTL	Total Standing Dead Tree Carbon	Real	11(5)	98-108
SDABGR	Above Ground Standing Dead Tree Carbon	Real	11(5)	110-120
SWLRAG	Above Ground Logging Residue Carbon – Softwood	Real	11(5)	122-132
HWLRAG	Above Ground Logging Residue Carbon – Hardwood	Real	11(5)	134-144
SWLRBG	Below Ground Logging Residue Carbon – Softwood	Real	11(5)	146-156
HWLRBG	Below Ground Logging Residue Carbon – Hardwood	Real	11(5)	158-168
SWALRAG	Above Ground Undecayed Logging Residue Carbon – Softwood	Real	11(5)	170-180
HWALRAG	Above Ground Undecayed Logging Residue Carbon – Hardwood	Real	11(5)	182-192

(Table E3 continued on next page)

(Table E3 continued)

SWALRBG	Below Ground Undecayed Logging Residue Carbon – Softwood	Real	11(5)	194-204
HWALRBG	Below Ground Undecayed Logging Residue Carbon – Hardwood	Real	11(5)	206-216
SWDDW	Down Dead Wood Carbon – Softwood	Real	11(5)	218-228
HWDDW	Down Dead Wood Carbon – Hardwood	Real	11(5)	230-240
SOIL	Soil Carbon	Real	11(5)	242-252
FLOOR	Forest Floor Carbon	Real	11(5)	254-264
UNDER	Understory Carbon	Real	11(5)	266-276
TOTAL	Total Inventory Carbon	Real	11(5)	278-288
TOTAG	Total Above Ground Carbon	Real	11(5)	290-300
GTAREA	Area of Growth	Real	11(5)	302-312
GTSWMRCH	Growth of Carbon in Merchantable Portion of Tree - Softwood	Real	11(5)	314-324
GTHWMRCH	Growth of Carbon in Merchantable Portion of Tree – Hardwood	Real	11(5)	326-336
GTSWTOTL	Growth of Total Live Tree Carbon – Softwood	Real	11(5)	338-348
GTHWTOTL	Growth of Total Live Tree Carbon – Hardwood	Real	11(5)	350-360
GTSWABGR	Growth of Above Ground Live Tree Carbon – Softwood	Real	11(5)	362-372
GTHWABGR	Growth of Above Ground Live Tree Carbon – Hardwood	Real	11(5)	374-384
RMAREA	Area of Removals	Real	11(5)	386-396
RMSWMRCH	Removals of Carbon in Merchantable Portion of Tree – Softwood	Real	11(5)	398-408
RMHWMRCH	Removals of Carbon in Merchantable Portion of Tree – Hardwood	Real	11(5)	410-420
RMSWTOTL	Removals of Total Live Tree Carbon – Softwood	Real	11(5)	422-432
RMHWTOTL	Removals of Total Live Tree Carbon – Hardwood	Real	11(5)	434-444
RMSWABGR	Removals of Above Ground Live Tree Carbon – Softwood	Real	11(5)	446-456
RMHWABGR	Removals of Above Ground Live Tree Carbon – Hardwood	Real	11(5)	458-468
NCAREA	Net Area Change	Real	11(5)	470-480
NCSWMRCH	Net Change in Carbon of Merchantable Portion of Tree Due to Area Change – Softwood	Real	11(5)	482-492
NCHWMRCH	Net Change of Carbon in Merchantable Portion of Tree Due to Area Change – Hardwood	Real	11(5)	494-504
NCSWTOTL	Net Change of Live Tree Carbon Due to Area Change – Softwood	Real	11(5)	506-516
NCHWTOTL	Net Change of Live Tree Carbon Due to Area Change – Hardwood	Real	11(5)	518-528
NCSWABGR	Net Change of Above Ground Live Tree Carbon Due to Area Change – Softwood	Real	11(5)	530-540
NCHWABGR	Net Change of Above Ground Live Tree Carbon Due to Area Change – Hardwood	Real	11(5)	542-552
NCSOIL	Net Change of Soil Carbon Due to Area Change	Real	11(5)	554-564
NCFLOOR	Net Change of Forest Floor Carbon Due to Area Change	Real	11(5)	566-576
NCUNDER	Net Change of Understory Carbon Due to Area Change	Real	11(5)	578-588
NCTOTAL	Net Change of Total Carbon Due to Area Change	Real	11(5)	590-600
NCTOTAG	Net Change of Total Above Ground Carbon Due to Area Change	Real	11(5)	602-612

[a] For elements of Data Type *Real*, the number in parentheses indicates the number of digits after the decimal point, while the other number indicates the total number of characters including the decimal point. For example, a length of 10(5) would be of the format 0000.00000.
[b] The number of the time period (or interval) for which the data has been calculated, beginning with 0. Typically, each period represents 10 years (5 years in the southern regions).
[c] The number assigned to the geographic area in which the MU is located. In this table, results are given by subregions for the NC region. See Figure 2 for a description of regions used in FORCARB2.

[d] See the description of *coefs_owners.txt* above for a complete group list.

[e] See Appendix F for a list of the forest types used in FORCARB2.

[f] If site quality has been assigned to the particular MU, the codes are: 00, no site quality assigned; 01, high (or good) site quality; 02, medium site quality; 03, low (or poor) site quality.

[g] This identifier is used to label a user-defined level of forest management to be applied to stands in the specific MU. In the RPA Assessment, only the private timberlands in the PNWW, SC, and SE regions made use of more than one management intensity. The meaning of a particular identifier differs by region and owner/land-status category; discussion of their structure are found in Mills and Kincaid (1992) and their implementation in Adams and others (2003).

Findat0.txt

Findat0.txt contains carbon estimates for logging residue and down dead wood present at the beginning of the model run (initial conditions) for each MU. Structure is similar to *findat.txt*, except that only the MU identifiers and those data elements pertaining to logging residue and down dead wood are present. Carbon is given in teragrams. The table format is as follows:

Heading	Element	Data Type	Length[a]	Columns
P	Period Number	Integer	2	1-2
R	Region Identifier	Integer	2	3-4
O	Owner-Land Status Identifier	Integer	1	6
F	Forest Type Identifier	Integer	2	7-8
S	Site Quality Identifier	Integer	1	10
I	Management Intensity Identifier	Integer	1	12
SWLRAG	Above Ground Logging Residue Carbon – Softwood	Real	11(5)	14-24
HWLRAG	Above Ground Logging Residue Carbon – Hardwood	Real	11(5)	26-36
SWLRBG	Below Ground Logging Residue Carbon – Softwood	Real	11(5)	38-48
HWLRBG	Below Ground Logging Residue Carbon – Hardwood	Real	11(5)	50-60
SWALRAG	Above Ground Undecayed Logging Residue Carbon – Softwood	Real	11(5)	62-72
HWALRAG	Above Ground Undecayed Logging Residue Carbon – Hardwood	Real	11(5)	74-84
SWALRBG	Below Ground Undecayed Logging Residue Carbon – Softwood	Real	11(5)	86-96
HWALRBG	Below Ground Undecayed Logging Residue Carbon – Hardwood	Real	11(5)	98-108
SWDDW	Down Dead Wood Carbon – Softwood	Real	11(5)	110-120
HWDDW	Down Dead Wood Carbon – Hardwood	Real	11(5)	122-132

[a] For elements of Data Type *Real*, the number in parentheses indicates the number of digits after the decimal point, while the other number indicates the total number of characters including the decimal point. For example, a length of 10(5) would be of the format 0000.00000.

Finhar.txt

Finhar.txt contains harvest information for each MU by age class and period. Each group of 13 rows contains output for a particular MU for a particular period. Data for each period are grouped together. The order of the MUs matches the order in *coefs_atlas.txt*.

Each column corresponds to an age class. There are 18 age classes (numbered 0 to 17); each represents a stand age span of 10 years (5 in the south). This corresponds with the period length specified in *coefs_atlas.txt*. The final column (age class 17) contains all subsequent stand ages. Carbon is given in tens of tonnes. The row variables are as follows:

Row	Type of Data
1	Age class
2	Carbon in merchantable portion of growing stock harvested – softwood
3	Carbon in merchantable portion of growing stock harvested – hardwood
4	Carbon in merchantable portion of growing stock thinned – softwood
5	Carbon in merchantable portion of growing stock thinned – hardwood
6	Total carbon in live trees harvested – softwood
7	Total carbon in live trees harvested – hardwood
8	Above ground carbon in live trees harvested – softwood
9	Above ground carbon in live trees harvested – hardwood
10	Total carbon in live trees thinned – softwood
11	Total carbon in live trees thinned – hardwood
12	Above ground carbon in live trees thinned – softwood
13	Above ground carbon in live trees thinned – hardwood

Volumes.txt

Volumes.txt contains timber volume data for each MU for each period. Values are given for softwood, hardwood, and totals for inventory, harvest, thinning, removals, area loss, and net area change. Data are reported in millions of cubic meters. The format is as follows:

Element	Data Type	Length[a]	Columns
Management Unit Name	Text	15	1-15
Year	Integer	4	18-21
Softwood Inventory	Real	10(4)	24-33
Hardwood Inventory	Real	10(4)	36-45
Total Inventory	Real	10(4)	48-57
Softwood Harvest	Real	10(4)	60-69
Hardwood Harvest	Real	10(4)	72-81
Total Harvest	Real	10(4)	84-93
Softwood Thinned	Real	10(4)	96-105
Hardwood Thinned	Real	10(4)	108-117
Total Thinned	Real	10(4)	120-129
Softwood Removals	Real	10(4)	132-141
Hardwood Removals	Real	10(4)	144-153
Total Removals	Real	10(4)	156-165
Loss in Softwood Inventory Due to Area Loss	Real	10(4)	168-177
Loss in Hardwood Inventory Due to Area Loss	Real	10(4)	180-189
Loss in Total Inventory Due to Area Loss	Real	10(4)	192-201
Net Change in Softwood Inventory Due to Area Change	Real	10(4)	204-213
Net Change in Hardwood Inventory Due to Area Change	Real	10(4)	216-225
Net Change in Total Inventory Due to Area Change	Real	10(4)	228-237

[a] For elements of Data Type *Real*, the number in parentheses indicates the number of digits after the decimal point, while the other number indicates the total number of characters including the decimal point. For example, a length of 10(5) would be of the format 0000.00000.

Volumesac.txt

Volumesac.txt contains timber-volume data for each MU for each period for each age class. There are 18 age classes (numbered 0 to 17); each represents a stand age span of 10 years (5 in the south). Values are given for softwood, hardwood, and totals for inventory, harvest, thinning, removals, area loss, and net area change. Data are reported in millions of cubic meters. The format is as follows:

Element	Data Type	Length[a]	Columns
Management Unit Name	Text	15	1-15
Year	Integer	4	18-21
Age Class	Integer	2	23-24
Softwood Inventory	Real	10(4)	27-36
Hardwood Inventory	Real	10(4)	39-48
Total Inventory	Real	10(4)	51-60
Softwood Harvest	Real	10(4)	63-72
Hardwood Harvest	Real	10(4)	75-84
Total Harvest	Real	10(4)	87-96
Softwood Thinned	Real	10(4)	99-108
Hardwood Thinned	Real	10(4)	111-120
Total Thinned	Real	10(4)	123-132
Softwood Removals	Real	10(4)	135-144
Hardwood Removals	Real	10(4)	147-156
Total Removals	Real	10(4)	159-168
Loss in Softwood Inventory Due to Area Loss	Real	10(4)	171-180
Loss in Hardwood Inventory Due to Area Loss	Real	10(4)	183-192
Loss in Total Inventory Due to Area Loss	Real	10(4)	195-204
Net Change in Softwood Inventory Due to Area Change	Real	10(4)	207-216
Net Change in Hardwood Inventory Due to Area Change	Real	10(4)	219-228
Net Change in Total Inventory Due to Area Change	Real	10(4)	231-240

[a] For elements of Data Type *Real*, the number in parentheses indicates the number of digits after the decimal point, while the other number indicates the total number of characters including the decimal point. For example, a length of 10(5) would be of the format 0000.00000.

APPENDIX F. FOREST TYPES USED IN FORCARB2

There is a management unit in the dataset for each forest type per region. The numeric codes are based on the ATLAS model (Mills and Kincaid 1992).

```
0, PACIFIC NORTHWEST – WESTSIDE
10    Douglas-Fir
20    Western Hemlock
25    Fir-Spruce
30    Pines
35    Mixed Softwoods
44    Nonstocked
45    Alder
50    Mixed Hardwoods
77    Other Softwood Forest
88    Other Hardwood Forest

1, PACIFIC NORTHWEST - EASTSIDE
07    Pinyon-Juniper
21    Ponderosa Pine
40    Douglas-Fir
43    True Fir
44    Nonstocked
46    Lodgepole Pine
50    Hardwoods
77    Other Softwood Forest
88    Other Hardwood Forest

2, PACIFIC SOUTHWEST
07    Pinyon-Juniper
23    True Fir
27    Redwood
28    Hardwoods
40    Douglas-Fir
41    Ponderosa Pine
44    Nonstocked
49    Mixed Conifers
77    Other Softwood Forest
88    Other Hardwood Forest

ROCKY MOUNTAINS
  (NORTH-3 and SOUTH-4)
01    Douglas-Fir
02    Ponderosa Pine
03    Fir-Spruce
04    Lodgepole Pine
05    Hardwoods
06    Nonstocked
07    Pinyon-Juniper
08    High Elevation
77    Other Softwood Forest
88    Other Hardwood Forest

5, NORTH CENTRAL - PLAINS STATES
01    Pines
02    Oak-Pine
03    Oak-Hickory
04    Lowland Hardwoods
05    Maple-Beech-Birch
09    Nonstocked
88    Other Hardwood Forest

6, NORTH CENTRAL – LAKE STATES
01    Jack Pine
02    Red Pine
03    White Pine
04    Spruce-Fir
05    Swamp Conifer
06    Oak-Hickory
07    Lowland Hardwoods
08    Maple-Beech-Birch
09    Aspen-Birch
10    Nonstocked
77    Other Softwood Forest
88    Other Hardwood Forest

7, NORTHEAST
01    White-Red-Jack Pines
02    Spruce-Fir
03    Loblolly Pine-Shortleaf-
        Pine-Oak-Gum-Cypress
04    Oak-Pine
05    Oak-Hickory
06    Elm-Ash-Red Maple
07    Maple-Beech-Birch
08    Aspen-Birch
09    Nonstocked
77    Other Softwood Forest
88    Other Hardwood Forest

SOUTH
  (SOUTH CENTRAL-8 and SOUTHEAST-9)
01    Planted Pine
02    Natural Pine
03    Oak-Pine
04    Upland Hardwoods
05    Bottomland Hardwoods
09    Nonstocked
77    Other Softwood Forest
88    Other Hardwood Forest
```

APPENDIX G. GLOSSARY

Age class – Age range assigned to a forest stand based on the number of years since establishment or the average age of dominant trees. Each class spans 10 years (5 years in the south). There are 18 age classes beginning with age-class 0 representing stands aged 0 to 9 years (0 to 4 years in the south). All stands older than age class 17 are assigned to it.

Area loss – Loss of acreage in a management unit (MU) since the previous period; may be due to land moving to a nonforest use/cover or to another MU (representing a change in forest type or kind of management).

ATLAS – The Aggregate Timberland Assessment System, a timber projection model developed by the USDA Forest Service.

Biomass – All organic material, either from living or formerly living sources, present in an ecosystem or ecosystem component.

Carbon density – The amount of carbon per area, such as in tonnes per hectare.

Carbon stock change – The difference between carbon stocks at two points in time. When the movement of carbon into or out of an ecosystem or ecosystem component is measured directly, such as when using an eddy covariance tower, the change in carbon is called flux.

Carbon sequestration – Increasing carbon within an ecosystem; by atmospheric scientists' convention, often expressed as a negative value indicating that carbon is being reduced in the atmosphere and carbon in forest components is increasing.

Clear cut – A method of timber harvesting by which all the trees are removed from a stand. This is the most commonly assumed method modeled in FORCARB2.

Coarse tree roots – Roots with a diameter greater than a particular threshold, generally in the range of 0.2 to 0.5 cm depending on the source.

d.b.h. – Diameter of a tree measured at breast height (4.5 feet above the ground). This is the standard height at which diameter is measured.

Down dead wood – Woody material on the ground larger than 3 inches (about 7.5 cm) in diameter, consisting of the sum of the two subpools of logging residue including stumps and the coarse roots of stumps, and fallen trees and branches from mortality.

Emitted – A category of disposition of carbon from harvested wood in which either combustion or decay of the harvested wood occurs without concomitant energy capture. Emissions are from decay of logging residue; they do not include emissions from machinery to harvest, transport, or process the wood.

Energy – A category of disposition of carbon from harvested wood in which emissions occur during combustion and resulting energy is captured.

Fine tree roots – Roots with a diameter smaller than a particular threshold, generally in the range of 0.2 to 0.5 cm depending on the source.

FORCARB2 – An updated version of the U.S. Forest Carbon Budget Model, which estimates carbon stocks and stock change within and between the various components of an ecosystem, including live tree, standing dead tree, understory, forest floor, soil, and woody residue.

Forest floor – A forest-carbon pool that includes all organic material in the layer of the forest directly above the mineral soil, including fine woody debris less than 3 inches (7.5 cm) in diameter, tree litter, humus, and fine roots.

Forest products – The various end uses for which harvested wood may be used, including residential and nonresidential construction, wooden containers, paper and paper products, and fuelwood.

Growing-stock removals – Removals of trees from the growing-stock inventory through harvesting, cultural operations, or land-use change.

Growing-stock volume – Total volume of trees within an area that are classified as growing stock includes all live trees of commercial species that meet minimum merchantability standards. In general, these trees have at least one solid 8-foot section, are reasonably free of form defect on the merchantable bole, and at least 34 percent of the volume is merchantable (may be less in some locations).

Growth – In ATLAS, this is most often net growth on growing stock, which refers to addition of tree volume through natural development over a period of years. The net change has the loss from mortality subtracted.

Harvest – The cutting of trees from a stand which may result in the regeneration of a new stand.

Harvest unit (HU) – The area to which harvest volumes are applied. The coarsest level of aggregation in ATLAS; typically identified by geographic region, ownership class, and fiber type (hardwood or softwood), as many as 65 MUs can be assigned to one HU.

Inventory – A systematic sampling of trees in a given area to determine the basic composition and/or characteristics of the surrounding forest.

Inventory unit (IU) – A relatively homogenous area for which inventory data are compiled. The finest level of aggregation used in ATLAS, usually stratified by geographic region, owner/land-status category, forest type, and site class. Within an IU, the inventory area and volume per unit area (often acres and cubic foot volumes per acre) are stratified by age class.

Landfill – A waste management area in which discarded wood and paper (and its associated carbon) may be stored for a long period and undergo a slow rate of decay.

Large sawtimber – A size class of harvested timber meeting minimum standards of length and defect and generally having a minimum diameter of 15 inches.

Logging residue – The unused portions of growing-stock and nongrowing-stock trees cut or killed by logging activities and which remain on site. FORCARB2 considers both above- and belowground amounts.

Management intensity – In ATLAS, a further level of stratification within an IU that may represent specific silvicultural treatments or unusual stand composition such that the growth and harvesting parameters in the MU are distinct.

Management unit (MU) – A level of aggregation in ATLAS developed to represent a group of stands having similar management objectives and growth characteristics; as many as 10 IUs can be assigned to one MU. MU parameters used in ATLAS include growth, yield, area change, and harvest rules.

Merchantable volume – See Growing-stock volume

Net area change – Area gained minus area loss. As used here, generally refers to the difference between timberland or forest land removed from productive forest and converted to other uses vs. cropland or other lands reverting or planted to forest.

Owner/land-status category – The grouping of land of a particular IU according to ownership (such as National Forest and Other Government) or land status (such as Reserved and low-productivity forest land [Other]). See the description of *coefs_owners.txt* above for an owner/land-status category list.

Partial cutting – A method of accounting for harvest in the ATLAS model where only part of the forest area in an age class is harvested.

Period – The time interval between model estimations of inventory, growth, acreage, and harvest. It is specified by the user, though the generally accepted convention is 10 years (5 years in the Southern United States).

Pulpwood – A size class of harvested timber that does not meet the requirements for saw logs; generally used in the production of wood pulp, paper, or other lower grade wood products. In FORCARB2, we emulate pulpwood by defining it as age class 4 and younger (40 years and younger; 20 years and younger in the south).

Region – An aggregation of U.S. States over which model estimations are produced. See Figure 2 for the regions used in FORCARB2 and their constituent States.

Removals – Net volume of growing-stock trees removed from the inventory by harvesting, cultural operations, or inventory lost due to land-use change.

Saw log – A log meeting minimum standards of diameter, length, and defect specified by regional standards. Includes logs at least 8 feet long, straight and sound, with minimum diameters of 6 inches inside bark for softwoods and 8 inches for hardwoods.

Sawtimber – A size class of harvested timber meeting minimum standards of length and defect and generally having a minimum diameter at breast height of 9 inches (11 inches for hardwoods). Sawtimber often is used to indicate size of trees rather than logs.

Soil organic carbon – Carbon in the organic portion of soil to a depth of 1 meter (not including coarse roots).

Standing dead tree – All nonliving woody vegetation at least 1 inch in d.b.h., including coarse nonliving roots.

TAMM – Timber Assessment Market Model, a timber sector model that provides annual projections of volumes and prices in the solid-wood products and sawtimber stumpage markets, and estimates of total timber harvest and inventory by geographic region for periods up to 50 years.

Thinning – The harvesting of trees within a stand generally to improve stand composition or spacing.

Understory – All live herbaceous vegetation and woody vegetation less than 1 inch d.b.h.

Heath, Linda S.; Nichols, Michael C.; Smith, James E.; Mills, John R. 2010. **FORCARB2: An updated version of the U.S. Forest Carbon Budget Model.** Gen. Tech. Rep. NRS-67. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 52 p. [CD-ROM].

FORCARB2, an updated version of the U.S. FORest CARBon Budget Model (FORCARB), produces carbon stocks and stock change projections for forest ecosystems and forest products at 5-year intervals. FORCARB2 includes a new methodology for carbon in harvested wood products, updated initial inventory data, a revised algorithm for dead wood, and now covers public forest land, reserved forest land and forest land of low productivity. The program is written in FORTRAN and is text based, though virtually every parameter is defined by input text-based files that can be modified or built by the user. Instructions for running the program, input and output files, and codes used are included, and input files for public forest lands of the United States are provided as an example.

KEY WORDS: carbon sequestration; forest inventory; RPA Assessment; carbon model; FIA

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