CRITERION 3—

Chapter 7. Down Woody Materials as an Indicator of Wildlife Habitat, Fuels, and Carbon Stocks of the United States

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Why Are Down Woody Materials Important?

The down woody materials (DWM) indicator is used to estimate the quantity of dead organic material (resulting from plant mortality and leaf turnover) in forest ecosystems of the United States. The DWM indicator, coupled with other components of the enhanced Forest Inventory and Analysis (FIA) program, can indicate the current status of fuels, carbon pools, and wildlife habitat of our nation's forest ecosystems. The fine and coarse woody components of the DWM indicator are specifically designed to match the components defined by the National Fire Danger Rating System. Use of the DWM indicator may increase the precision of carbon pool estimates across the United States. Additionally, the coarse woody debris (CWD) component of DWM may indicate the condition of habitat critical for numerous plants and animals.

Methods

The diversity of ecosystem attributes estimated using data from the DWM indicator requires a variety of plot-based sampling protocols: line-intersect sampling for fine woody debris (FWD) and CWD; simple random sampling for duff, litter, and fuel-bed depths; and shape and packing ratio estimation for slash piles. Briefly, CWD was sampled on each of three 24-foot horizontal distance transects radiating from each FIA subplot center at 30, 150, and 270 degrees. Down woody pieces with an intersecting transect diameter of at least 3 inches and a length of at least 3 feet were considered CWD. Data collected for every CWD piece were transect diameter, length, small-end diameter, large-end diameter, decay class, species (if it could be determined), evidence of fire, and presence of cavities. FWD (1-, 10-, and 100-hour fuels) were sampled on the 150-degree transect on each subplot. FWD pieces with transect diameters of 0.01 to 0.24 and 0.25 to 0.99 inches (1- and 10-hour fuels, respectively) were tallied separately along a 6-foot (slope distance) segment of the 150-degree transect. Pieces of FWD with transect diameters of 1.00 to 2.99 inches (100-hour fuels) were tallied on a 10-foot (slope distance) segment of the 150-degree transect (Woodall and Williams 2005).

Slight differences between the 2001 and 2002-03 DWM sample protocols are detailed in Woodall and Williams (2005). Unit-area estimates (tons per acre) for the fuel-hour classes followed Brown's (1974) estimation procedures, while CWD volume and pieces per acre estimates were based on DeVries's line-intercept estimators (DeVries 1986). Conversion of tonnage estimates (fuel loads) to carbon estimates was based on work detailed by Waddell (2002). For more background and details regarding the sampling and estimation of DWM components, see Woodall and Williams (2005). In order to produce national maps of DWM estimates, each plot was assigned to an Environmental Monitoring and Assessment Program (EMAP) hexagon (Overton and others 1990, White and others 1992). The EMAP grid, produced by the U.S. Environmental Protection Agency, is a hexagonal grid superimposed on the map of the United States.

What Data Are Available?

The national DWM inventory began in 2001, primarily in States for which the FIA annual inventory system (U.S. Department of Agriculture Forest Service 2002) had been implemented. Since 2001, as annual inventories have started in each State, so have the DWM inventories, with 41 States having an annual DWM inventory in 2003 for a total of 3,535 plots nationwide (table 7.1). As annual inventories are implemented in remaining States and as more years of DWM data are collected in current annual inventory States, the nationwide sample size will increase substantially. Because the database management and estimation algorithms are currently being developed, the current analyses for the DWM indicator should be considered preliminary until data have been thoroughly vetted and appropriately linked with the standing tree inventory (phase 2). Although 3,535 plots were sampled as of 2003, only 3,167 were included in these analyses. The data from the remaining 368 plots require further editing and validation. These data editing and management efforts are ongoing.

What Do the Data Show?

FWD are down dead woody materials with a diameter < 3 inches and can usually be attributed to branch-fall or wind-felled

Table 7.1—Preliminary number of down woody materials indicator inventory plots as of 2003

State	Number of plots	State	Number of plots
Alabama	139	Nebraska	12
Arizona	164	Nevada	21
Arkansas	109	New Hampshire	16
California	214	New Jersey	13
Colorado	167	New York	118
Connecticut	6	North Carolina	102
Florida	78	North Dakota	4
Georgia	160	Ohio	66
Idaho	44	Oklahoma	2
Illinois	44	Oregon	167
Indiana	30	Pennsylvania	225
Iowa	21	South Carolina	84
Kansas	20	South Dakota	13
Kentucky	68	Tennessee	103
Louisiana	67	Texas	73
Maine	123	Utah	181
Massachusetts	6	Vermont	8
Michigan	128	Virginia	108
Minnesota	192	Washington	140
Missouri	105	Wisconsin	92
Montana	102		

tree crowns. There are no obvious areas of exceedingly high FWD fuel loadings (> 20 tons per acre) across the nation (fig. 7.1). Upon visual inspection, the distribution of FWD fuel loadings across the nation appears to be random. The accumulation of FWD may be partly dependent on the growth form of trees, stochastic wind disturbances, and individual tree mortality in the context of stand development. Local areas of unusually high FWD accumulations may indicate blowdown events or locally limited tree mortality.

CWD are down dead woody materials with a diameter $\geq$ 3 inches and are usually detached large tree limbs or dead and down shrub or tree boles. There is a definite pattern of CWD fuels across the nation (fig. 7.2). The forest ecosystems of the West Coast, together with more isolated areas of the northern Great Lakes region and northern New England, have some of the highest accumulations of CWD in terms of fuel loadings (tons per acre). There are areas of very high CWD accumulations in other regions. However, they occur in patches indicating the possible effects of local-scale

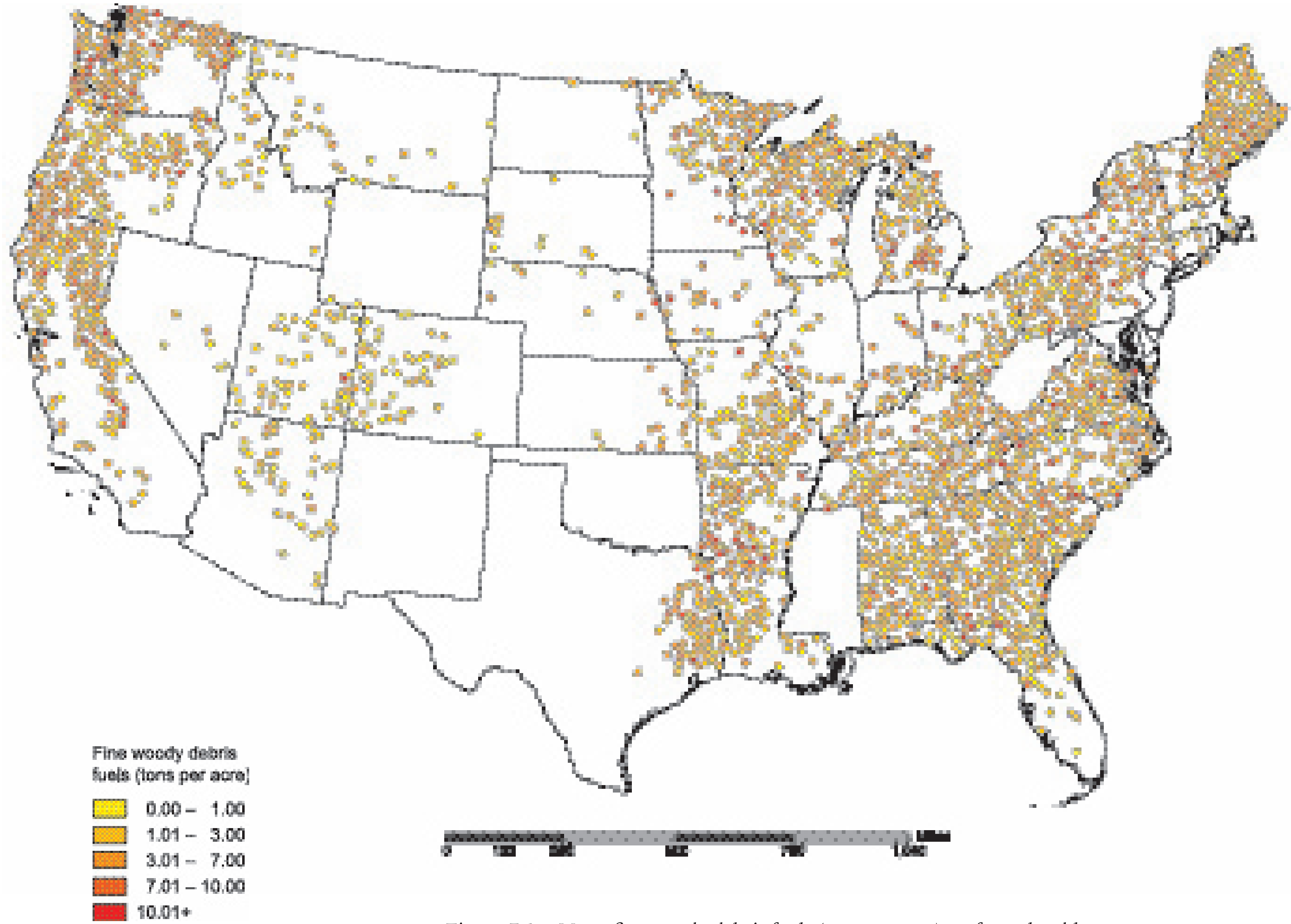

Figure 7.1—Mean fine woody debris fuels (tons per acre) on forest land by Environmental Monitoring and Assessment Program (EMAP) hexagon (Overton and others 1990, White and others 1992) based on the down woody materials indicator of the Forest Inventory and Analysis program, 2001–03. (Data source: U.S. Department of Agriculture Forest Service, Forest Inventory and Analysis program.)

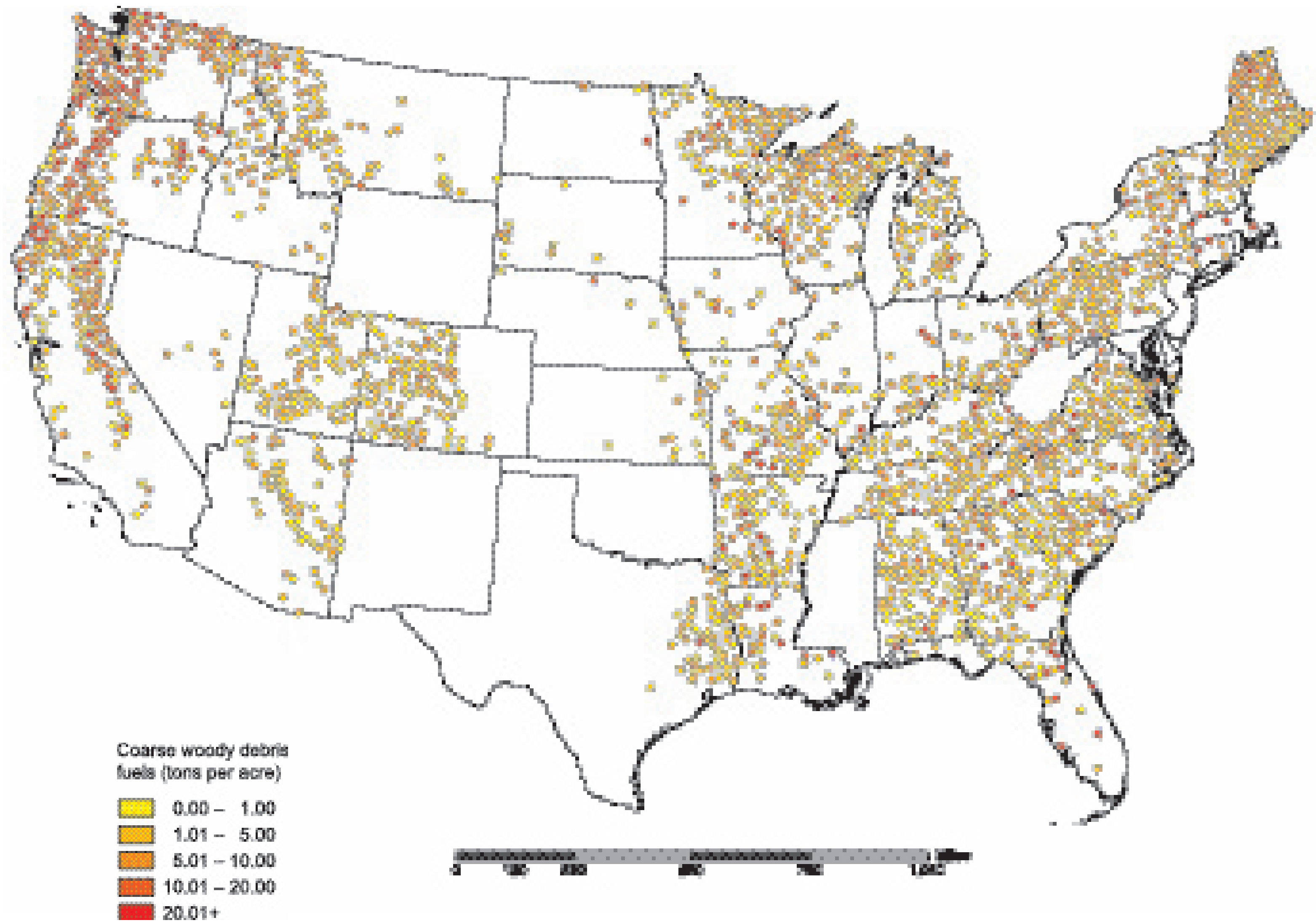

Figure 7.2—Mean coarse woody debris fuels (tons per acre) on forest land by Environmental Monitoring and Assessment Program (EMAP) hexagon (Overton and others 1990, White and others 1992) based on the down woody materials indicator of the Forest Inventory and Analysis program, 2001–03. (Data source: U.S. Department of Agriculture Forest Service, Forest Inventory and Analysis program.)

wind events (i.e., tornadoes), mortality events (i.e., root diseases or pine beetle outbreaks), or microtopography (e.g., watershed drainages or mountaintops). These results indicate that the cool and rather moist regions of the United States (e.g., Maine, Oregon, and Washington) feature forests producing substantial amounts of forest biomass that eventually become down dead debris with slow decay rates. Forests in other regions have less CWD accumulation, possibly because the average site quality is lower and less biomass is produced in these regions, and possibly because decay rates are higher in areas with warmer climates.

The volume and condition of CWD can indicate the quantity and quality of wildlife habitat or of stand structural diversity across large scales. The condition of CWD habitat may be indicated by decay and size distributions. A uniform distribution of decay class proportions indicates sustainable recruitment of new CWD pieces. A size class distribution dominated by large CWD pieces indicates a more decay-resistant CWD habitat optimal for larger wildlife. CWD volume estimates, like the estimates of CWD weight, are highest in the Pacific Northwest (fig. 7.3). The distribution of CWD piece sizes varies by region of the United States, with the Pacific Northwest States having the highest mean number of CWD pieces in the largest CWD size classes (table 7.2). Forests in States in the Great Lakes region and in New England have substantially more CWD pieces in the smaller CWD size classes than do forests in the Pacific Northwest. The Rocky Mountain

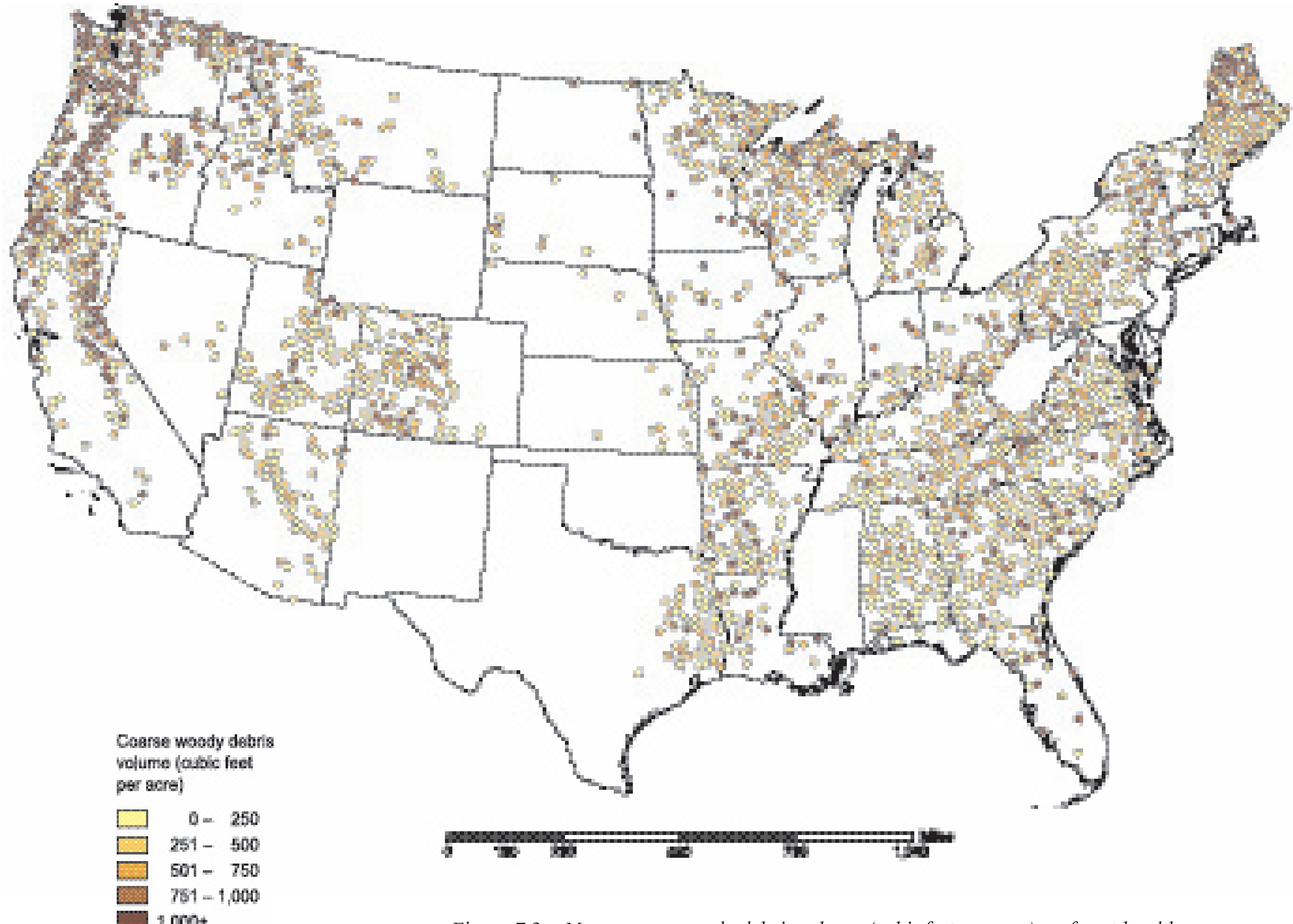

Figure 7.3—Mean coarse woody debris volume (cubic feet per acre) on forest land by Environmental Monitoring and Assessment Program (EMAP) hexagon (Overton and others 1990, White and others 1992) based on the down woody materials indicator of the Forest Inventory and Analysis program, 2001–03. (Data source: U.S. Department of Agriculture Forest Service, Forest Inventory and Analysis program.)

and Southeastern forests have fewer CWD pieces per acre in all size classes. The distribution of CWD pieces by decay class is nearly Gaussian in most regions, with only minor differences by region (table 7.3). The Great Lakes and Pacific Northwest regions have higher proportions of freshly fallen CWD compared to New England, which has a higher proportion of very decayed pieces. Overall, these CWD analyses indicate substantial amounts of CWD habitat across the United States, primarily concentrated in Pacific Northwest States. Trends in the condition and recruitment of CWD pieces across the United States are less distinct, with certain regions appearing to have larger and more recently recruited pieces.

The carbon pools of CWD and FWD pieces are a substantial portion (approaching 10 percent) of the carbon sequestered in forests of the United States (O'Neill and others 2004, Smith and others 2004) (table 7.4). Climate may play an important role in the accumulation of this carbon, especially in the soil and DWM carbon pools (FWD and CWD). When all DWM inventory plots are stratified by 4-degree latitude classes, there are obvious trends in CWD and

Table 7.2—Mean number of coarse woody debris (CWD) pieces per acre by CWD diameter class for representative States of different regions of the United States (Pacific Northwest, Great Lake States, northern New England, southern Rocky Mountains, and Southeast)

State group	Number of plots	CWD transect diameter class (inches)				
		3.0 – 7.9	8.0 – 12.9	13.0 – 17.9	18.0+	Total
		pieces per acre				
OR, WA	299	191	45	18	14	268
MI, MN, WI	327	156	27	2	1	186
ME, NH, VT	147	220	27	3	1	251
AZ, CO, UT	478	57	10	2	1	70
GA, NC, SC, TN	430	73	9	2	2	86

Table 7.3—Mean number of coarse woody debris pieces per acre by decay class for representative States of different regions of the United States (Pacific Northwest, Great Lake States, northern New England, southern Rocky Mountains, and Southeast)

State group	Number of plots	Decay class[a]				
		1	2	3	4	5
		pieces per acre				
OR, WA	299	16	55	112	67	17
MI, MN, WI	327	15	49	64	40	19
ME, NH, VT	147	4	28	75	85	57
AZ, CO, UT	478	2	8	26	25	9
GA, NC, SC, TN	430	4	19	33	25	6

[a] Class 1 = least decayed; class 5 = most decayed.

FWD carbon pools (table 7.4). As latitude increases, so does the mean mass of CWD carbon per hectare in forested landscapes. Between the lowest and highest latitude classes there is a nearly 140-percent increase in CWD carbon. For FWD, there is less of a trend, with only a 23-percent increase between the lowest and highest latitude classes. Although no stronger conclusions can be drawn from a preliminary dataset and without more rigorous statistical testing, the data suggest that colder forests at more northern latitudes may have slower decay rates and sequester more DWM carbon.

Conclusions

Since 2001, the DWM inventory has been progressively accumulating data about an important indicator of fuel loadings, wildlife habitat, and carbon pools. The inventory is a work in progress with preliminary data indicating numerous forest ecosystem attributes across the nation. First, fuel loadings of larger down woody pieces, CWD, are highest in the Pacific Northwest and are also high in the Great Lake States and northern New England. Remaining areas of the United States have large amounts of CWD only at local scales, and these concentrations are most likely due to isolated windfall events. Second, the fuel loadings of smaller down woody pieces, FWD, are more randomly distributed across the United States. Third, both size class and decay class distributions of the CWD resource vary across the nation, indicating a variation in the quantity and quality of wildlife habitat. Fourth, a substantial amount of the carbon in forest ecosystems is in CWD and FWD. This carbon contribution to the overall forest carbon equation may be partially dependent on the climate of the region, i.e., whether cool temperatures and lack of moisture slow the decomposition of DWM.

Table 7.4—Mean carbon pools of coarse woody debris and fine woody debris in megagrams per hectare (Mg/ha) by latitude class for the United States

Latitude class	Number of observations	CWD	CWD std. error	FWD	FWD std. error
degrees		- - - - - - - *Carbon pools (Mg/ha)* - - - - - - -			
< 33	408	4.56	1.02	2.99	0.19
≥ 33 and < 37	706	4.70	0.71	3.21	0.15
≥ 37 and < 41	860	4.75	0.47	2.63	0.15
≥ 41 and < 45	600	8.05	1.14	4.06	0.18
≥ 45	593	10.45	1.40	3.69	0.20

CWD = Coarse woody debris; FWD = Fine woody debris.

Literature Cited

Brown, J.K. 1974. Handbook for inventorying downed woody material. Gen. Tech. Rep. INT-16. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 24 p.

DeVries, P.G. 1986. Sampling theory for forest inventory: a teach-yourself course. In: Line-intersect sampling. Berlin: Springer-Verlag: 242-279. Chapter 13.

O'Neill, K.C.; Woodall, C.W.; Amacher, M.C. 2004. Cross-indicator analysis: combining inventories of soil and down woody material to assess carbon storage at the regional scale. In: Forest Science in Practice: Proceedings of the 2003 Society of American Foresters National Convention. Bethesda, MD: Society of American Foresters: 102-110.

Overton, W.S.; White, D.; Stevens, D.L. 1990. Design report for EMAP: Environmental Monitoring and Assessment Program. EPA/600/3-91/053. Washington, DC: U.S. Environmental Protection Agency, Office of Research and Development. 43 p.

Smith, J. E.; Woodbury, P.B.; Heath, L.S. 2004. Forest carbon sequestration and products storage, and Appendix C-1. In: U.S. Agriculture and Forestry greenhouse gas inventory: 1990-2001. Tech. Bull. 197. Washington, DC: U.S. Department of Agriculture: 80-93.

U.S. Department of Agriculture, Forest Service. 2002. Forest Inventory and Analysis fiscal year 2001 business report. FS-747. Washington, DC: U.S. Department of Agriculture, Forest Service. 31 p.

Waddell, K.L. 2002. Sampling coarse woody debris for multiple attributes in extensive resource inventories. Ecological Indicators. 1: 139-153.

White, D.; Kimerling, A.J.; Overton, W.S. 1992. Cartographic and geometric components of a global sampling design for environmental monitoring. Cartography and Geographic Information Systems. 19:5-22.

Woodall, C.W.; Williams, M.S. 2005. The sampling protocol, estimation, and analysis procedures for the Down Woody Materials Indicator of the FIA program. Gen. Tech. Rep. NC-256. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station. 47 p.