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Status of Hardwood Forest Resources in the Appalachian Region Including Estimates of Growth and Removals

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Front cover:
Scenic beauty typical of the Appalachian Hardwood Region.

All photos taken by Christopher M. Oswalt, U.S. Forest Service.

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Abstract

The Appalachian Hardwood Region (AHR) is an important wood producing area of the Eastern United States and is near a large portion of the U.S. population that is growing considerably. Combined, these two forces create the need for assessments of the hardwood forest resources in the region. Here we present results from an investigation into the forest resources of the AHR with particular emphasis on the growth and removals of hardwood timber volume in the region. Total timberland acreage in the AHR remained relatively unchanged from the late 1980s and early 1990s (time 1 estimate) to the most recent estimate (time 2). However, the hardwood forests of the AHR continue to mature and a concomitant decline in early successional hardwood forests is being realized. Moreover, shifts in species composition may be occurring in the region. According to estimates of growth-to-removals ratios, while removals are increasing, growth continues to outpace removals at almost 2 to 1. This study provides an important assessment of the current status and recent utilization of hardwood species in the Appalachians. In addition, it provides a framework in which to continue to monitor the resources of the AHR.

Keywords: Appalachian Region, FIA, forest resources, growth-to-removals ratio, hardwood, timber removal.

Introduction

The Appalachian Mountains, extending from northeast Alabama to southern New York State, are highly coveted for their beauty, biodiversity, and the natural resources that Americans have long relied on (Delcourt and Delcourt 1997, Lorimer 2001, Smith and others 2004). These mountains and the surrounding landscape are dominated by hardwood forests such as the oak-hickory forest type. Here, we refer to this area as the Appalachian Hardwood Region (AHR). The AHR contains forest resources that are valued for their ecological significance and economic production. Therefore, assessments of the hardwood forest resources in the region are necessary. Regular assessments can help inform citizens, advocacy groups, forest land managers, and policymakers of the current status of the resource and recent trends in resource utilization to better guide land use decisionmaking.

Here we present results from an investigation into the growth and removals of hardwood timber volume in the AHR along with current and past estimates of the status of forest resources in the region. Historical and current estimates of timberland area, stand-size class distributions, diameter distributions, and species-group specific populations are presented. In addition, historical and current estimates of growth and removals volume are presented for the areas of each of the 12 States that comprise the AHR.

Methods

Geographical Coverage

The AHR was delineated using county boundaries according to a definition similar to that used by one of the more prominent trade associations operating in the Appalachian Region. The use of this definition allowed for greater consistency in comparing the estimates of growth and removals from this study within the broader AHR to timber product output statistics from industries in the same region.

The AHR was defined by individual counties with an average elevation of > 1,000 feet within the Appalachian Mountains and surrounding area. The result was 344 counties stretching from northeast Alabama to southern New York State. The AHR as defined here, includes major portions of the Interior Plateau, Southwestern Appalachians, Central Appalachians, Blue Ridge, Ridge and Valley, Western Allegheny Plateau, North Central Appalachians and the Northern Appalachian Plateau and Uplands ecoregions (Omernik 1987) (fig. 1).

Available Data

Data for each of the counties within the AHR were obtained from the Forest Service, U.S. Department of Agriculture, Forest Inventory and Analysis (FIA) Program. Current timberland area estimates (table 1) were derived from data collected according to the annualized inventory design (Bechtold and Patterson 2005) in all States, with the exception of Maryland, which was collected as a periodic inventory (Northeastern Research Station 2002). Because data collection was variable among States and crossed multiple years, a specific date was not applied, rather time 1 and time 2 were used as monikers for data collected in the late 1980s and early 1990s and data collected in the early 2000s, respectively. Data for time 2 were collected between 1999 and 2005, and represented the most current inventory for each State at the time of this study. Historical timberland area estimates for all counties within the AHR were obtained from

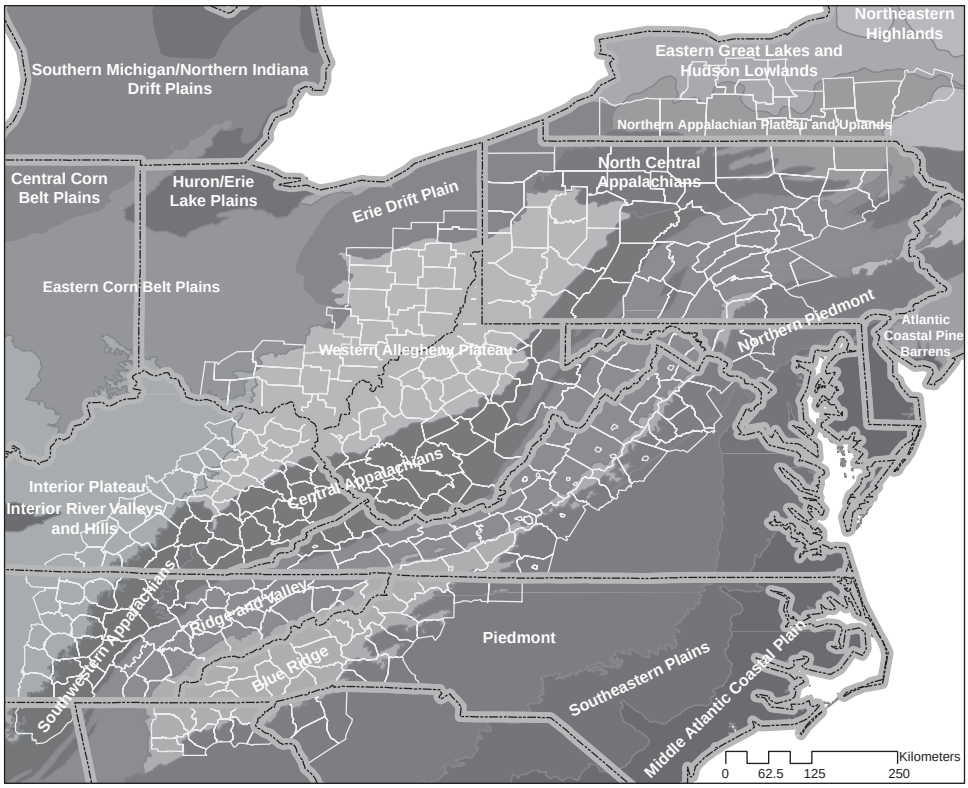

Figure 1—Map of 344 counties that comprise the Appalachian Hardwood Region (AHR) along the associated Level III Ecoregions (Omernik 1987). Source files: State boundaries–ESRI; EcoRegions–USA EPA Level III Ecoregions; County boundaries–ESRI-USA.

estimates generated between 1986 and 1993 and labeled time 1. All historical estimates were derived from periodic inventories in each State. Growth and removals estimates for each State were obtained from inventory data collected between 1984 and 2005 (table 2). Due to differences in inventory methods and the periodic nature of past inventories, a common year for growth and removals estimates among States was not possible and no specific label was applied.

Tables 1 and 2 contain the number of plots used to derive estimates of timberland area, growth volume, and removal volume according to State and year of data. Data were collected from a total of 12,403 FIA plots for estimating timberland area in the AHR for time 2 and 13,352 plots for time 1 (table 1). A total of 7,918 plots were remeasured for the most recent estimates of growth and removals (Alabama, 2005; Georgia, 2004; Kentucky, 2004; Maryland, 1999; New York, 1993; North Carolina, 2005; Ohio, 1991; Pennsylvania, 1989; South Carolina, 2005; Tennessee, 2004; Virginia, 2005; West Virginia, 2000) (table 2).

Estimation Procedures

Components of change (i.e., growth or removals) are estimated using the Beers-Miller approach (Beers and Miller 1964) for the remeasured plots (table 2).

$$G_s = s_2 - s_1$$

where

G_s = change for component s
s_2 = tree size at time t+1 weighted on the basis of plot size at time t
s_1 = tree size at time t weighted on the basis of plot size at time t

Error estimates used here are calculated as a percentage of the estimate, *S.E.%* (percent sampling error) by dividing the estimate $\hat{Y}_s$ into the square root of its variance $v(\hat{Y}_s)$:

$$S.E.\% = 100 \frac{\sqrt{v(\hat{Y}_s)}}{\hat{Y}_s}$$

Table 1—Area of timberland, number of plots, and associated standard error for counties within the Appalachian Hardwood Region by State and data year, time 1 and 2

Time	State	Data	Plots	Timberland	Standard error
		year	*number*	*acres*	
1	Alabama	1990	78	430,482	7,749
	Georgia	1989	346	1,528,504	18,189
	Kentucky	1988	1,165	7,262,887	71,903
	Maryland	1986	218	829,281	36,405
	New York	1993	704	3,626,540	95,015
	North Carolina	1990	1,155	4,953,616	38,638
	Ohio	1991	1,098	4,796,992	84,427
	Pennsylvania	1989	2,570	13,673,880	159,984
	South Carolina	1993	251	938,772	9,294
	Tennessee	1989	1,276	7,222,903	38,281
	Virginia	1992	1,946	7,964,881	38,231
	West Virginia	1989	2,545	11,900,346	92,823
	Total		13,352	65,129,084	260,516
2	Alabama	2005	86	443,130	45,598
	Georgia	2004	304	1,454,319	62,390
	Kentucky	2004	1,936	7,135,598	57,798
	Maryland	1999	149	769,166	39,151
	New York	2004	296	3,830,215	115,672
	North Carolina	2002	977	4,695,045	40,377
	Ohio	2004	588	5,039,467	134,050
	Pennsylvania	2004	2,631	13,851,351	109,426
	South Carolina	2005	145	918,932	64,509
	Tennessee	2004	1,371	7,395,516	99,100
	Virginia	2005	1,767	8,087,047	106,749
	West Virginia	2000	2,153	11,796,966	335,034
	Total		12,403	65,416,752	327,084

where

$S.E.\%$ = percent sampling error
$\hat{Y}_s$ = estimate
$v(\hat{Y}_s)$ = square root of its variance

See Scott and others (2005) for a detailed treatment of the sample-based estimators used by FIA.

Analysis

State level aggregate timberland area was calculated for each group of counties in the AHR for time 1 and 2. Average annual net growth and removals were calculated for each group of AHR counties within each State for each of the remeasurement periods associated with that State. Components of change are generally reported by FIA as annualized estimates. Average annual net growth G_N is calculated as:

Table 2—Number of remeasured plots used to derive estimates of growth and removals for each State and inventory year

State	Data available	Remeasured plots
	inventory year	
Alabama	1990	78
	2000	78
	2005	73
Georgia	1989	315
	1997	289
	2004	239
Kentucky	1988	514
	2004	609
Maryland	1986	106
	1999	77
New York	1993	615
North Carolina	1984	1,075
	1990	1,090
	2002	717
	2005	496
Ohio	1991	1,065
Pennsylvania	1989	1,732
South Carolina	1986	245
	1993	241
	2001	185
	2005	109
Tennessee	1989	1,275
	1999	1,286
	2004	1,229
Virginia	1984	1,875
	1992	1,863
	2001	1,334
	2005	680
West Virginia	1989	1,282
	2000	994

$$G_N = \frac{G_g - M}{RP_p}$$

where

G_g = gross growth
M = mortality
RP_p = period (years) between plot measurement for plot p

Periodic mean annual net growth across the 21-year period (1984–2005) was calculated by taking the mean of all available estimates for each State. In other words, a grand mean was calculated for each State *sensu* (Blaikie 2003) by:

$$\bar{\chi}_w = \frac{\sum(\bar{\chi} \cdot n)}{\sum n}$$

where

$\bar{\chi}_w$ = the weighted mean (periodic mean)
$\bar{\chi}$ = individual estimate of mean annual growth/removals
n = remeasurement sample size

Current mean annual growth $G_N CUR$ was calculated using only the most current available estimate of growth (table 2) for each State. Current mean annual growth acre^{-1} $G_N Acre$ was calculated by:

$$G_N Acre = \frac{G_N CUR}{TL_{ST}}$$

where

TL_{ST} = timberland (acres) for the group of AHR counties in State *ST*
$G_N CUR$ = current mean annual growth
$G_N Acre$ = current mean annual growth acre^{-1}

Periodic mean annual removals, current mean annual removals, and current mean annual removals acre^{-1} were calculated in the same manner as the growth estimates above. FIA estimates of removals include both removals due to timber harvesting and removals associated with land clearing. Because growth and removals vary temporally, mean annual growth and mean annual removals estimates were also calculated for four different periods (1984–89, 1990–94, 1995–99, 2000–2005). A growth-to-removals ratio (G:R) was calculated for each period in each State by dividing the growth estimate by the removals estimate. In addition, a composite G:R was calculated for the entire AHR by dividing the sum of all growth by the sum of all removals for both periodic and current growth and removals. The periodic G:R and current G:R were calculated similarly to the growth and removal statistics. The current G:R represents the most recent estimates of both growth and removals available. The periodic G:R represents growth and removals estimates averaged over the 21-year period of this study. A G:R of 1 indicates that equal volumes of wood are being grown (net) and removed (timber harvests and land clearing). A G:R ratio of < 1 indicates that more wood is being removed than is being grown and a G:R of > 1 indicates more wood volume is being added to standing inventory than is being removed through harvesting and land clearing.

Key Findings

- The area of timberland in the AHR has remained stable over the period of time represented by this study.

According to FIA estimates, there were approximately 65.13 million acres (table 1) of timberland within the AHR counties during time 1. According to estimates from the time 2 dataset, timberland acreage increased by about 288,000 acres to 65.42 million acres. However, upon examining the error associated with each group of AHR counties within each State and the overall error rate, there did not appear to be any statistically significant changes (fig. 2). Thus, timberland acreage has remained stable in the AHR over the period of this study. Of course, some timberland has been lost to development and agriculture, but the losses have approximately equaled gains from planting activities and agricultural abandonment. During time 2, about 91 percent of the AHR timberland was comprised of acreage covered by hardwood dominated forest types.

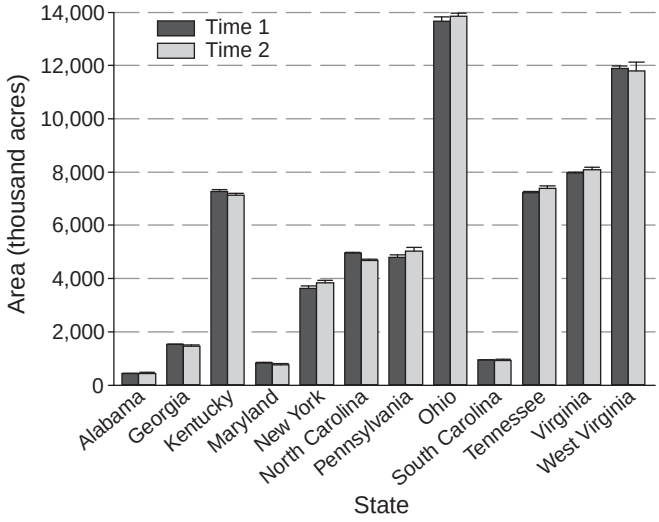

Figure 2—Area of timberland for time 1 and time 2 for all counties within the Appalachian Hardwood Region according to State. Error bars represent one standard error.

- Mature or late-successional stands in the AHR are increasing, while young or early successional stands are declining.

While overall timberland area has remained stable, sawtimber-size stands have increased from accounting for 57 percent of all acres during time 1 to 64 percent of all acres during time 2 (table 3). Proportional increases in mature sawtimber-size stands were also noted for private lands only (56 to 63 percent) and public lands only (65 to 70 percent).

Table 3—Area of timberland within each stand-size class for counties within the Appalachian Hardwood Region, time 1 and 2

Time	Stand-size class	All	Standard error	Private	Standard error	Public	Standard error
				acres			
1	Sawtimber	37,356,340	197,301	30,550,717	178,426	6,805,623	84,213
	Poletimber	18,126,580	137,438	15,449,199	126,882	2,677,381	52,821
	Sapling-seedling	9,563,837	99,831	8,500,962	94,120	1,062,875	33,280
	Nonstocked	82,327	9,262	77,474	8,985	4,853	2,249
	Total	65,129,084	260,516	54,578,352	238,483	10,550,732	104,855
2	Sawtimber	42,175,358	262,630	33,578,638	234,340	8,596,720	118,572
	Poletimber	15,690,406	160,189	13,071,201	146,208	2,619,205	65,448
	Sapling-seedling	7,243,962	108,844	6,241,438	101,032	1,002,523	40,491
	Nonstocked	307,025	22,408	279,323	21,373	27,702	6,731
	Total	65,416,752	327,084	53,170,601	294,883	12,246,151	141,519

Declines in early successional (sapling-seedling) stands over the period between time 1 and time 2 were observed for public lands only, private lands only, and all timberland. The largest proportional declines in early successional stands occurred on private lands (16 to 12 percent) and all timberland (15 to 11 percent). On all timberland, there was a significant decline from 9.56 (± 0.10) million acres during time 1 to 7.24 (± 0.11) million acres during time 2 (table 3).

- Diameter distribution of hardwood trees has shifted to larger diameter classes.

The diameter distribution for all live hardwood trees within the AHR has shifted to larger diameter classes from the time 1 estimate to time 2 (fig. 3). Specifically, a shift from declining number of trees to increasing number of trees appears to occur between the 8-inch and the 10-inch diameter classes (table 4).

- Shifts in species composition may be occurring in the AHR.

Across all timberland, common species such as oaks and hickories have declined between time 1 and time 2, while species such as American beech and yellow-poplar have increased in numbers over the same period (table 5). All oak species accounted for about 14 percent of all live trees during time 1 and 13 percent during time 2. Surprisingly, the estimates of maple populations did not reflect large increases over the period of this study. The greatest change occurred as a reduction in the other eastern hardwoods category. However, due to changes in the category definition, this reduction could be due to changes in the species included in the category, rather than an actual loss.

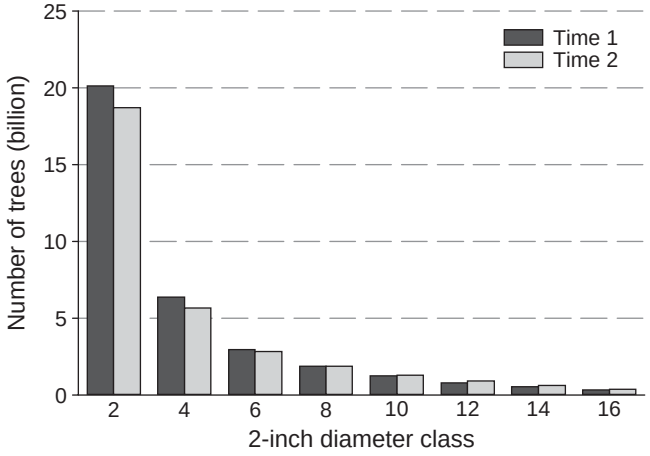

Figure 3—Number of all live hardwood trees on timberland for counties within the Appalachian Hardwood Region by 2-inch diameter class for time 1 and time 2.

- All live tree hardwood volume within the AHR has increased considerably.

All live tree hardwood volume increased about 20.5 billion cubic feet from time 1 to time 2 (table 6). At time 1 there was an estimated 94.7 billion cubic feet of hardwood standing volume. By time 2 there was an estimated 115.2 billion cubic feet of standing hardwood volume within the AHR, an increase of about 22 percent. The increase was more considerable on public lands. Standing hardwood volume increased 36 percent on public lands within the AHR, whereas standing volume increased by only 18 percent on private lands. During time 2, the 12- and 14-inch diameter classes contained the largest amount of standing hardwood

Table 4—Number of all live hardwood trees on timberland for counties within the Appalachian Hardwood Region for each 2-inch diameter class, time 1 and 2

Time	Diameter class	All	Standard error	Private	Standard error	Public	Standard error
	inches			*thousand trees*			
1	2	20,130,686	211,446	16,979,775	194,194	3,150,911	83,654
	4	6,382,679	119,061	5,367,864	109,187	1,014,815	47,475
	6	2,957,542	81,047	2,446,553	73,714	510,989	33,688
	8	1,896,916	64,907	1,556,921	58,803	339,996	27,479
	10	1,249,485	52,679	1,021,917	47,641	227,568	22,481
	12	808,287	42,369	665,705	38,451	142,582	17,795
	14	530,592	34,328	434,534	31,066	96,058	14,606
	16	323,213	26,793	264,608	24,242	58,605	11,409
	18	185,901	20,319	149,074	18,196	36,827	9,044
	20	105,644	15,318	83,594	13,626	22,049	6,998
	22	56,472	11,199	44,441	9,935	12,031	5,169
	24	32,441	8,488	25,721	7,558	6,719	3,863
	26	18,124	6,344	14,209	5,618	3,915	2,949
	28	9,779	4,660	7,611	4,111	2,168	2,194
	30	6,218	3,716	5,100	3,366	1,118	1,576
	32	3,318	2,714	2,645	2,424	673	1,222
	34	1,925	2,067	1,595	1,882	330	856
	36	1,343	1,727	1,074	1,544	269	772
	38	735	1,278	572	1,127	163	602
	40	478	1,030	417	962	61	369
	42+	630	1,183	555	1,110	76	410
	Total	34,702,408	277,619	29,074,486	254,112	5,627,922	111,801
2	2	18,732,318	223,271	15,431,429	202,647	3,300,889	93,724
	4	5,658,569	122,713	4,563,915	110,206	1,094,654	53,973
	6	2,823,184	86,678	2,268,543	77,698	554,641	38,419
	8	1,868,310	70,512	1,504,428	63,274	363,882	31,118
	10	1,304,874	58,928	1,044,311	52,717	260,563	26,333
	12	906,240	49,109	725,896	43,952	180,344	21,907
	14	619,448	40,601	499,245	36,450	120,203	17,885
	16	397,727	32,533	315,833	28,991	81,894	14,763
	18	239,252	25,233	183,083	22,073	56,169	12,226
	20	133,226	18,829	100,529	16,356	32,698	9,328
	22	74,581	14,088	55,894	12,196	18,687	7,052
	24	41,786	10,545	31,198	9,112	10,588	5,308
	26	22,848	7,798	16,808	6,688	6,040	4,009
	28	14,215	6,151	11,112	5,438	3,103	2,873
	30	7,556	4,484	5,663	3,882	1,893	2,245
	32	4,042	3,280	2,963	2,808	1,079	1,695
	34	2,792	2,726	2,026	2,322	766	1,428
	36	1,310	1,867	1,033	1,658	277	859
	38	759	1,421	497	1,150	262	834
	40	308	905	289	877	19	225
	42+	706	1,371	605	1,269	101	519
	Total	32,854,052	295,686	26,765,302	266,884	6,088,750	127,292

Table 5—Number of all live hardwood trees on timberland for counties within the Appalachian Hardwood Region for each species group, time 1 and 2

Time	Species group	All	Standard error	Private	Standard error	Public	Standard error
				thousand trees			
1	Select white oaks	1,390,016	55,562	1,184,781	51,297	205,235	21,350
	Select red oaks	884,065	44,311	713,501	39,808	170,565	19,463
	Other white oaks	1,472,112	57,179	1,112,832	49,715	359,280	28,248
	Other red oaks	1,243,740	52,557	1,015,491	47,491	228,249	22,515
	Hickory	1,673,716	60,969	1,468,507	57,109	205,209	21,349
	Yellow birch	197,114	20,923	137,601	17,482	59,513	11,497
	Hard maple	2,457,564	73,879	2,169,562	69,415	288,002	25,291
	Soft maple	5,785,907	113,359	4,604,372	101,124	1,181,535	51,226
	Beech	1,342,684	54,608	1,042,238	48,112	300,446	25,832
	Sweetgum	152,059	18,377	133,832	17,240	18,227	6,363
	Tupelo and blackgum	1,599,866	59,609	1,192,910	51,472	406,956	30,064
	Ash	1,095,683	49,330	1,018,679	47,565	77,005	13,078
	Cottonwood and aspen	299,920	25,809	269,232	24,453	30,689	8,256
	Basswood	208,261	21,507	178,413	19,906	29,848	8,142
	Yellow-poplar	1,462,871	57,000	1,290,261	53,531	172,610	19,580
	Black walnut	100,122	14,912	95,028	14,528	5,094	3,364
	Other eastern soft hardwoods	3,515,337	88,360	3,125,457	83,316	389,880	29,426
	Other eastern hard hardwoods	4,883,742	104,147	4,133,858	95,818	749,884	40,810
	Eastern noncommercial hardwoods	4,937,628	104,720	4,187,932	96,443	749,695	40,805
	Total	34,702,408	277,619	29,074,486	254,112	5,627,922	111,801
2	Select white oaks	1,117,478	54,533	942,444	50,080	175,034	21,582
	Select red oaks	773,598	45,373	572,968	39,048	200,629	23,107
	Other white oaks	1,280,746	58,381	894,776	48,797	385,971	32,049
	Other red oaks	1,064,039	53,213	851,778	47,610	212,261	23,767
	Hickory	1,402,772	61,099	1,214,396	56,848	188,377	22,390
	Yellow birch	180,447	21,913	108,082	16,960	72,365	13,877
	Hard maple	2,576,019	82,796	2,250,511	77,389	325,508	29,432
	Soft maple	5,771,466	123,931	4,457,794	108,917	1,313,672	59,126
	Beech	1,574,665	64,734	1,213,628	56,830	361,037	30,997
	Sweetgum	219,684	24,179	195,892	22,832	23,792	7,957
	Tupelo and blackgum	1,594,967	65,150	1,144,485	55,188	450,482	34,624
	Ash	1,148,432	55,283	1,052,557	52,925	95,875	15,973
	Cottonwood and aspen	226,835	24,569	193,100	22,669	33,735	9,475
	Basswood	212,553	23,783	174,345	21,540	38,208	10,084
	Yellow-poplar	1,759,964	68,437	1,549,994	64,225	209,970	23,638
	Black walnut	117,032	17,648	110,664	17,161	6,368	4,117
	Other eastern soft hardwoods	3,706,865	99,321	3,168,621	91,827	538,244	37,847
	Other eastern hard hardwoods	3,174,033	91,906	2,568,600	82,677	605,433	40,139
	Eastern noncommercial hardwoods	4,952,456	114,801	4,100,667	104,463	851,789	47,611
	Total	32,854,052	295,686	26,765,302	266,884	6,088,750	127,292

Table 6—Volume of all live hardwood trees on timberland for counties within the Appalachian Hardwood Region for each 2-inch diameter class, time 1 and 2

Time	Diameter class	All	Standard error	Private	Standard error	Public	Standard error
	inches			*cubic feet*			
1	6	7,330,945,952	184,477,661	6,012,042,570	167,060,893	1,318,903,382	78,247,463
	8	11,407,590,487	230,123,376	9,309,231,871	207,883,825	2,098,358,616	98,696,927
	10	13,837,269,683	253,448,064	11,265,642,068	228,687,144	2,571,627,615	109,261,665
	12	13,938,278,647	254,371,439	11,446,101,173	230,511,484	2,492,177,474	107,560,611
	14	13,143,623,052	247,013,861	10,715,063,892	223,028,908	2,428,559,160	106,178,875
	16	10,876,313,555	224,700,809	8,874,632,393	202,973,323	2,001,681,162	96,396,491
	18	8,052,078,037	193,338,241	6,412,949,586	172,541,150	1,639,128,451	87,230,883
	20	5,716,890,567	162,908,489	4,475,463,367	144,139,423	1,241,427,200	75,914,442
	22	3,665,996,657	130,454,723	2,842,688,656	114,875,767	823,308,001	61,822,269
	24	2,410,505,968	105,783,488	1,885,888,393	93,566,798	524,617,575	49,349,777
	26	1,573,205,336	85,458,739	1,200,189,894	74,642,944	373,015,442	41,612,823
	28	959,941,024	66,755,346	726,348,171	58,067,911	233,592,852	32,930,138
	30	696,173,103	56,848,943	563,593,336	51,150,125	132,579,767	24,808,608
	32	387,858,413	42,432,672	299,630,992	37,295,561	88,227,421	20,237,906
	34	231,819,483	32,804,902	186,269,413	29,405,905	45,550,070	14,541,470
	36	188,854,616	29,609,262	146,871,807	26,111,571	41,982,809	13,960,453
	38	109,845,782	22,581,639	78,913,802	19,139,926	30,931,980	11,983,057
	40	80,470,575	19,327,796	67,924,904	17,757,356	12,545,671	7,631,514
	42+	131,922,607	24,747,047	112,197,293	22,822,066	19,725,313	9,569,202
	Total	94,739,583,545	663,177,085	76,621,643,583	596,402,572	18,117,939,962	290,013,479
2	6	7,319,593,600	184,334,769	5,874,503,517	165,138,889	1,445,090,083	81,905,155
	8	11,565,034,808	231,705,983	9,289,483,128	207,663,204	2,275,551,680	102,779,648
	10	14,946,615,464	263,411,788	11,943,830,848	235,470,008	3,002,784,616	118,066,276
	12	16,456,792,488	276,398,939	13,169,706,625	247,258,839	3,287,085,863	123,529,106
	14	16,385,349,322	275,798,327	13,217,180,158	247,704,092	3,168,169,164	121,274,071
	16	14,309,245,601	257,734,256	11,387,850,936	229,924,189	2,921,394,665	116,455,202
	18	11,184,052,717	227,857,526	8,572,156,579	199,484,347	2,611,896,138	110,113,794
	20	7,874,476,601	191,194,161	5,894,638,356	165,421,654	1,979,838,245	95,869,096
	22	5,309,471,583	156,996,303	3,961,517,768	135,610,894	1,347,953,815	79,104,517
	24	3,571,726,611	128,766,497	2,639,181,279	110,687,451	932,545,332	65,795,888
	26	2,204,790,839	101,169,004	1,573,645,944	85,470,706	631,144,895	54,128,789
	28	1,579,673,483	85,634,238	1,229,598,088	75,551,896	350,075,394	40,312,949
	30	943,481,224	66,180,555	670,326,248	55,783,645	273,154,976	35,609,702
	32	539,497,870	50,044,764	395,873,411	42,868,861	143,624,460	25,821,293
	34	447,324,923	45,569,611	323,205,782	38,734,980	124,119,142	24,003,975
	36	217,393,857	31,767,820	165,525,043	27,720,153	51,868,814	15,517,328
	38	136,972,119	25,216,213	89,961,498	20,435,822	47,010,621	14,772,764
	40	55,564,572	16,060,637	48,451,577	14,997,461	7,112,996	5,746,323
	42+	184,269,636	29,247,629	150,247,736	26,409,960	34,021,899	12,567,331
	Total	115,231,327,319	731,390,067	90,596,884,520	705,182,144	24,634,442,799	338,170,054

volume (table 6). During time 1, 10- and 12-inch diameter classes contained the largest amount of standing hardwood volume.

- AHR periodic mean annual hardwood removals were less than one-half of periodic mean annual hardwood net growth.

Periodic mean annual removals of hardwood volume were about 44 percent of periodic mean annual growth for the same period (tables 7 and 8). Periodic mean annual removals represented a range from about 30 percent of growth in the New York AHR counties to an estimated 70 percent of growth in the Maryland AHR counties.

- AHR current mean annual hardwood removals are less than one-half of the current mean annual hardwood net growth.

Current mean annual removals, which represent the most recent estimate of removals (unlike periodic mean annual removals that averages all estimates over the study period), represent about 47 percent of the current annual growth within the AHR (tables 7 and 8). Current mean annual removals represented a range from about 13 percent of growth in the Georgia AHR counties to an estimated 102 percent of growth in the Maryland AHR counties.

- The region-wide hardwood G:R suggests that more than 2 times more wood on average has been grown in the AHR than has been removed on an annual basis for the period of this study.

Both the periodic G:R and current G:R indicate that more wood volume is being grown in the AHR than removed on an annual basis for the period of this study (table 9). The periodic G:R and the current G:R for the AHR are 2.31 and 2.12, respectively. In other words, the amount of wood volume being added to the standing inventory in the AHR every year is more than twice the amount that is being removed annually. Estimates indicate that between 1984 and 2005, the periodic G:R has been >1 for all groups of AHR counties within each State. Thus, on average, more wood is being grown than removed. However, the current G:R indicates that in the AHR counties in the State of Maryland, the most recent estimates suggest that there is almost a 1-to-1 ratio, meaning that the amount of wood being removed is equivalent to the volume of wood being grown annually.

- Current mean annual hardwood removals account for a small proportion of standing hardwood volume in the AHR.

Table 7—Periodic mean annual growth and current mean annual growth of hardwood growing stock on timberland for the counties within the Appalachian Hardwood Region for each State

State	Periodic mean annual growth[a]	Current mean annual growth	Standard error (current growth)	Proportion of AHR growth	Data available[b]
	cubic feet			*percent*	*inventory year*
Alabama	17,120,507	21,204,474	2,841,399	1	1990, 2000, 2005
Georgia	47,111,895	51,687,654	9,148,715	2	1989, 1997, 2004
Kentucky	250,738,065	266,231,814	9,051,882	10	1988, 2004
Maryland	40,868,254	34,560,514	6,362,591	1	1986, 1999
New York	120,239,861	120,239,861	3,835,652	4	1993
North Carolina	215,595,038	395,336,916	30,401,409	15	1984, 1990, 2002, 2005
Ohio	157,767,288	157,767,288	4,480,591	6	1991
Pennsylvania	471,379,980	471,379,980	39,265,952	17	1989
South Carolina	30,958,339	32,279,831	5,713,530	1	1986, 1993, 2001, 2005
Tennessee	338,792,298	443,130,926	35,007,343	16	1989, 1999, 2004
Virginia	298,429,230	286,513,777	16,932,964	11	1984, 1992, 2001, 2005
West Virginia	460,103,701	423,064,241	67,267,214	16	1989, 2000
Total	2,449,104,456	2,703,397,277			

AHR = Appalachian Hardwood Region.

[a] Grand mean – each available estimate weighted according to sample size *sensu* (Blaikie 2003).

[b] Data available indicate the date associated with each estimate of growth used in the study.

Table 8—Periodic mean annual removals and current mean annual removals of hardwood growing stock on timberland for the counties within the Appalachian Hardwood Region for each State

State	Periodic mean annual removals[a]	Current mean annual removals	Standard error (current removals)	Proportion of AHR removals	Data available[b]
	cubic feet			*percent*	*inventory year*
Alabama	7,471,418	13,185,397	7,590,833	1	1990, 2000, 2005
Georgia	22,164,182	6,812,815	2,616,121	1	1989, 1997, 2004
Kentucky	123,468,232	156,041,738	12,873,443	12	1988, 2004
Maryland	26,771,344	35,178,956	9,347,049	3	1986, 1999
New York	35,214,913	35,214,913	3,282,030	3	1993
North Carolina	80,244,161	104,921,746	26,964,889	8	1984, 1990, 2002, 2005
Ohio	76,088,518	76,088,518	5,021,842	6	1991
Pennsylvania	235,132,987	235,132,987	34,752,655	18	1989
South Carolina	18,189,623	15,139,609	5,474,483	1	1986, 1993, 2001, 2005
Tennessee	128,154,219	190,479,908	24,724,292	15	1989, 1999, 2004
Virginia	128,433,622	168,369,411	26,636,041	13	1984, 1992, 2001, 2005
West Virginia	178,832,328	239,279,135	39,959,616	19	1989, 2000
Total	1,060,165,548	1,275,845,133			

AHR = Appalachian Hardwood Region.

[a] Grand mean – each available estimate weighted according to sample size *sensu* (Blaikie 2003).

[b] Data available indicate the date associated with each estimate of removals used in the study.

Table 9—Periodic G:R ratio, current G:R and the G:R for 5-year periods between 1984 and 2005 of hardwood growing stock on timberland for the counties within the Appalachian Hardwood Region for each State

State	Periodic G:R[a]	Current G:R	Mean G:R 1984–1989	Mean G:R 1990–1994	Mean G:R 1995–1999	Mean G:R 2000–2005
	ratio					
Alabama	2.29	1.61	—	2.41	—	2.23
Georgia	2.13	7.59	1.51	—	1.72	7.59
Kentucky	2.03	1.71	2.74	—	—	1.71
Maryland	1.53	0.98	2.20	—	0.98	—
New York	3.41	3.41	—	3.41	—	—
North Carolina	2.69	3.77	3.05	1.87	—	3.29
Ohio	2.07	2.07	—	2.07	—	—
Pennsylvania	2.00	2.00	2.00	—	—	—
South Carolina	1.70	2.13	1.67	1.19	—	2.32
Tennessee	2.64	2.33	3.23	—	2.73	2.33
Virginia	2.32	1.70	3.66	1.95	—	1.90
West Virginia	2.57	1.77	3.70	—	—	1.77
Average	2.31	2.12	—	—	—	—

G:R = growth-to-removals ratio; — = no estimate for the survey period.

[a] Associated error has not been calculated for the estimates of growth to removals. Therefore, readers are cautioned to not make comparisons among States or time periods.

Estimated current mean annual hardwood removals account for about 1 percent of the current total hardwood inventory in the AHR. That is, about 1 percent of the standing hardwood volume (time 2) is being removed each year, based on past removals.

Discussion and Implications

Total timberland acreage in the AHR remained relatively unchanged from the late 1980s and early 1990s (time 1 estimate) to the most recent estimate (time 2). The addition of about 288,000 acres since the time 1 estimate equates to an increase of only 0.44 percent. Although statistically insignificant, the increase is important in that it indicates that no apparent region-wide loss of timberland acreage is occurring. While some lands were being converted from forest to nonforest uses, more acreage reverted from nonforest to forest uses over the study period resulting in the relatively stable timberland base. Much of this stability can be attributed to the continued natural reversion of abandoned agricultural lands across many parts of the South and East (Prestemon and Abt 2002) offsetting the loss of acreage to agricultural and urban uses.

The maturation of the AHR along with the concomitant loss of early successional habitat poses interesting challenges for the future. Using stand size as a proxy for developmental or successional stage, early successional forests of the AHR are becoming increasingly rare on the landscape. Moreover, the shift of the region-wide diameter distribution of hardwood stems supports the position that young stands are not as prevalent as they once were. This is not unlike the trend observed in numerous Eastern States (Turner and others 2008). As large acreages of the oak-dominated forests within the AHR mature, the probability of significant landscape level changes increases. A large number of AHR forests, with a large component of red oaks in particular, will be reaching biological maturity simultaneously. As a result, the AHR could experience major shifts similar to that which is occurring in the oak-dominated forests of Arkansas (Spetich and He 2008) and Missouri (Kabrick and others 2007). Furthermore, compositional shifts underway may be expedited or additional shifts mediated by the widespread senescence possible in these forests.

The standing volume of hardwood trees in the AHR has been increasing considerably. Not surprisingly, as many of the stems in the region continue to grow in diameter (as seen by the shift in the AHR diameter distribution), the volume contained within the stems increases. Assuming the current annual rate of removals in the AHR, it would take around 90 years to harvest this standing inventory if no additional growth occurred. However, according to the results in this study, additional hardwood volume is being added to the AHR standing inventory each year.

The current mean annual rate of removals for hardwood species in the AHR is about 1.3 million cubic feet per year. It is important to note that the removals estimates provided by FIA include land clearing and land use changes. FIA estimates of removals do not represent only harvesting. Compared to the periodic mean annual removals, the current rate is slightly higher. This suggests an increasing rate of removals over the period of this study. In fact, similar increases were observed for 7 of the 9 groups of AHR counties (represented by the respective State name) with multiple estimates over the study period. At the time of this analysis, only one estimate of removals was available for the AHR counties in New York, Ohio, and Pennsylvania. The current rate of removals is still below that of the current rate of growth in the AHR.

The current mean annual growth for hardwood species in the AHR is 2.7 million cubic feet per year. This results in a current G:R that indicates substantial growth over removals within the region. However, comparing the current G:R with the periodic G:R suggests that the AHR G:R is declining, which indicates increased removals in relation to growth. Of course, such a trend needs to be regularly monitored. At this time, however, more hardwood volume is being added to the standing inventory each year than is being removed. In addition, the current G:R of 2.12, which represents the most recent data available at the time of this analysis, is much greater than the 1-to-1 ratio that represents equivalent growth and removals. That is to say that there is ample room to allow removals to fluctuate and not reach the point where yearly removals are greater than yearly growth in the region.

While the results of this study provide an interesting view of the AHR hardwood resource and its utilization, some data quality concerns do exist. For instance, the estimates of growth and removals from many of the Northern States are dated and at times considerably older than the recent estimates from the Southern States. Updated information, when available, needs to be incorporated into a similar analysis. In addition, comparison of periodic inventory estimates with that of annual inventory estimates can introduce an unknown amount of uncertainty in the comparison. Therefore, specific increases and/or declines should be viewed with a complete understanding of the methodological changes that have occurred (Bechtold and Patterson 2005). However, this study provides an important assessment of the current status and recent utilization of hardwood species in the Appalachians. In addition, it provides a framework in which to continue to monitor the resources of the AHR.

Conclusions

Considerable attention has been given to the Appalachian Region in the Eastern United States because of its scenic beauty, rich biodiversity, and abundance of natural resources. Of particular importance are the hardwood forests that dominate the Appalachian landscape. Questions surrounding the sustainability of the Appalachian hardwood resource are repeatedly being asked. While growth and removals of hardwood volume are not the only indicators of the sustainability of Appalachian hardwood forests, understanding how much wood is being grown and removed in the AHR is a key component in assessing the sustainability of the resource. It is apparent from the results of this analysis that overharvesting is not occurring at the landscape scale of the AHR. Volume from annual growth is estimated to be twice that of annual removals volume. The positive growth to removals relationship bodes well for the future of this important hardwood region. However, a clear understanding of the sustainability of the AHR resource requires a much more comprehensive approach than provided here and calls for future monitoring of the resource.

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Appendix

A productive hardwood forest in the Appalachian Region of the United States.

Statistical Reliability

A measure of reliability of inventory statistics is provided by sampling errors. These sampling errors mean that the chances are two out of three that this confidence interval covers the true population value. Sampling errors (in percent) and associated confidence intervals around the sample estimates for timberland area, number of all live trees; and growth and removals volume are presented in the following table (table A.1).

FIA inventories, supported by the full complement of sample plots, are designed to achieve reliable statistics at the survey unit area and State area levels. Sampling error increases as the area or volume considered decreases in magnitude. Sampling errors and associated confidence intervals are often unacceptably high for small components of the total resource. Statistical confidence may be computed for any subdivision of State totals using the following formula.

$$SE_s = SE_t \left(\frac{\sqrt{X_t}}{X_s} \right)$$

Sampling errors obtained from this method are only approximations of reliability because this process assumes constant variance across all subdivisions of total.

For example, the number of acres of timberland in the sawtimber-size stands in 2004 is estimated at 42,175 acres. The estimate of sampling error for this example is computed as:

$$SE_s = 0.5 \left(\frac{\sqrt{65,417}}{\sqrt{42,175}} \right) = 0.62$$

Thus, the sampling error is 0.62 percent, and the resulting confidence interval of one standard error (two times out of three) for area of timberland classified as sawtimber is 42,175 ± 261.5 thousand acres. To achieve the 95 percent confidence interval, the standard error is multiplied by 1.96 resulting in 42,175 acres ± 512.5 thousand acres (261.5 thousand acres * 1.96 = 512.5).

Traditional users of FIA data are accustomed to the highly variable accuracy of small subsets of population totals. All FIA published reports include a brief explanation of sampling errors and provide precautions about the reliability of subpopulations such as county-level statistics. Therefore, when summarizing statistics from the FIA database, it is strongly recommended that users beware of any subdivisions below the survey unit level (e.g., county level data will experience higher and more variable standard errors). Users should familiarize themselves with the procedures to compute sampling errors as outlined above.

Item	Sample estimate and confidence interval[a]	Sampling error
		percent
Timberland (1,000 acres)		
Time 1	65,129 ± 261	0.4
Time 2	65,417 ± 327	0.5
All live trees (1,000 trees)		
Time 1	34,702,408 ± 277,619	0.8
Time 2	32,854,052 ± 295,686	0.9
All live volume (thousand cubic feet)		
Time 1	94,740 ± 663	0.7
Time 2	115,231 ± 922	0.8
Growing-stock growth (thousand cubic feet)		
AL–1990	10.69 ± 1.38	12.87
AL–2000	19.73 ± 2.11	10.69
AL–2005	21.20 ± 2.84	13.40
GA–1989	45.06 ± 1.63	3.62
GA–1997	45.56 ± 2.91	6.38
GA–2004	51.69 ± 9.15	17.70
KY–1988	232.38 ± 9.06	3.90
KY–2004	266.23 ± 9.05	3.40
MD–1986	45.45 ± 4.55	10.01
MD–1999	34.56 ± 6.36	18.41
NY–1993	120.24 ± 3.84	3.19
NC–1984	198.86 ± 3.80	1.91
NC–1990	163.94 ± 3.15	1.92
NC–2002	194.87 ± 8.65	4.44
NC–2005	395.34 ± 30.40	7.69
OH–1991	157.77 ± 4.48	2.84
PA–1989	471.38 ± 39.27	8.33
SC–1986	25.76 ± 1.12	4.36
SC–1993	28.62 ± 2.20	7.67
SC–2001	40.10 ± 3.31	8.25
SC–2005	32.28 ± 5.71	17.70
TN–1989	267.82 ± 7.87	2.94
TN–1999	309.45 ± 8.26	2.67
TN–2004	443.13 ± 35.01	7.90
VA–1984	309.54 ± 4.95	1.60
VA–1992	265.16 ± 4.30	1.62
VA–2001	335.35 ± 12.34	3.68
VA–2005	286.51 ± 16.93	5.91
WV–1989	488.82 ± 9.58	1.96
WV–2000	423.06 ± 67.27	15.90

Item	Sample estimate and confidence interval[a]	Sampling error
		percent
Growing-stock removals (thousand cubic feet)		
AL–1990	4.44 ± 2.14	48.21
AL–2000	5.15 ± 1.44	27.90
AL–2005	13.19 ± 7.59	57.57
GA–1989	29.84 ± 6.14	20.58
GA–1997	26.49 ± 3.99	15.06
GA–2004	6.81 ± 2.62	38.40
KY–1988	84.87 ± 8.50	10.01
KY–2004	156.04 ± 12.87	8.25
MD–1986	20.66 ± 5.76	27.87
MD–1999	35.18 ± 9.35	26.57
NY–1993	35.21 ± 3.28	9.32
NC–1984	65.13 ± 7.15	10.98
NC–1990	87.57 ± 10.20	11.65
NC–2002	74.69 ± 7.25	9.71
NC–2005	104.92 ± 26.96	25.70
OH–1991	76.09 ± 5.02	6.60
PA–1989	235.13 ± 34.75	14.78
SC–1986	15.45 ± 2.46	15.95
SC–1993	23.97 ± 3.77	15.74
SC–2001	16.08 ± 2.86	17.76
SC–2005	15.14 ± 5.47	36.16
TN–1989	83.03 ± 6.63	7.98
TN–1999	113.33 ± 8.67	7.65
TN–2004	190.48 ± 24.72	12.98
VA–1984	84.66 ± 7.01	8.28
VA–1992	136.15 ± 12.01	8.82
VA–2001	158.83 ± 13.83	8.71
VA–2005	168.37 ± 26.64	15.82
WV–1989	131.96 ± 10.21	7.74
WV–2000	239.28 ± 39.96	16.70

[a] One standard deviation.

Oswalt, Christopher M.; Turner, Jeffery A. 2009. Status of hardwood forest resources in the Appalachian Region including estimates of growth and removals. Resour. Bull. SRS–142. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 16 p.

The Appalachian Hardwood Region (AHR) is an important wood producing area of the Eastern United States. Here we present results from an investigation into the forest resources of the AHR with particular emphasis on the growth and removals of hardwood timber volume in the region. Total timberland acreage in the AHR remained relatively unchanged from the late 1980s and early 1990s (time 1 estimate) to the most recent estimate (time 2). However, the hardwood forests of the AHR continue to mature and a concomitant decline in early successional hardwood forests is being realized. Moreover, shifts in species composition may be occurring in the region. According to estimates of growth-to-removals ratios, while removals are increasing, growth continues to outpace removals at almost 2 to 1. This study provides an important assessment of the current status and recent utilization of hardwood species in the Appalachians and it provides a framework in which to continue to monitor the resources of the AHR.

Keywords: Appalachian Region, FIA, forest resources, growth-to-removals ratio, hardwood, timber removal.

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