LONG AND SHORT TERM CHANGES IN THE FORESTS OF THE CUMBERLAND PLATEAU AND MOUNTAINS USING LARGE SCALE FOREST INVENTORY DATA

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ABSTRACT

The Cumberland Plateau and Mountains (CPM) are a significant component of the eastern deciduous forest with biological and cultural resources strongly connected to and dependent upon the forest resources of the region. As a result, continuous inventory and monitoring is critical. The USDA Forest Service Forest Inventory and Analysis (FIA) program has been collecting data within the region since the 1950's, and provides a valuable resource for tracking the status of the CPM forests. Using two different datasets derived from large scale inventories within the region, both historical trends and short-term changes are analyzed. Across the CPM region, timberland has experienced less than a 1 percent decline from the early 1950's to present. Concomitantly, the CPM region has experienced a significant increase in standing growing stock volume. Volume estimates have increased between 100 and 200 percent across the region since the late 1960's and early 1970's. The CPM region currently contains an estimated 9.8 million acres of forest land and 18.2 billion cubic feet of volume. Both long-term and short-term changes indicate a stable forestland base within the region. While forests have shifted within the region from one forest type to another, the CPM continues to be dominated by natural hardwood forests.

INTRODUCTION

The Cumberland Plateau and Mountains (CPM) together, are a significant component of the Eastern Deciduous Forest. The CPM is rich with biological and cultural resources strongly connected to and dependent upon the forest resources of this region. As a result, continuous inventory and monitoring is critical to a forest land base being managed by and whose future condition is being influenced by multiple competing interests. The availability of systematically collected and unbiased forest information for forest land owners, managers and local, regional and state policymakers is essential to make sound scientifically based decisions regarding the forest resources of the region. The USDA Forest Service Forest Inventory and Analysis (FIA) program has been collecting data on CPM forests since the 1950s, and provides a valuable resource for tracking the status of these forests. The FIA program provides for the assessment of both long- and short-term changes to the CPM forests.

Of particular interest are recent inferences drawn from analyses conducted using fine-scale remotely-sensed data. McGrath and others (2004) concluded that the Cumberland Plateau forests "have been undergoing increasingly rapid rates of hardwood-to-pine conversions." Evans and others (2002) stated that the area has experienced "massive alteration of habitat at the landscape level." In addition to monitoring the forest resources of the CPM region, using broad-scale inventory data from the FIA program we are uniquely positioned to address these suppositions through the use of high-quality, robust data collected systematically across the entire area.

Specifically this paper addresses the following questions: 1) what are the general long-term trends in the forest resource across the Cumberland Plateau and Mountains area? 2) What are the general short-trends in the forest resource across the Cumberland Plateau and Mountains? 3) What, if any, changes have occurred in forest types on the Cumberland Plateau and Cumberland Mountains? 4) Has the overall footprint of planted forests (plantations) changed between 1990 and 2005?

METHODS

BROAD-SCALE INVENTORY

The FIA program is the primary source for information about the extent, condition, status and trends of forest resources across all ownerships in the United States (Smith and others 2002). FIA applies a nationally consistent sampling protocol using a quasi-systematic design covering all ownerships in the entire nation (Bechtold and Patterson 2005). FIA operates a multi-phase inventory based on an array of hexagons assigned to separate interpenetrating, non-overlapping annual sampling panels (Bechtold and Patterson 2005). In Phase 1, land area is stratified using aerial photography or classified satellite imagery to increase the precision of estimates using stratified estimation. In Phase 2, one permanent fixed-area plot is installed in each hexagon that contains accessible forest land and meets FIA specifications. Data are collected for more than 300 variables across multiple scales (e.g. plot, subplot, condition, and tree). Plot intensity for Phase 2 measurements is approximately one plot for every 6,000 acres of land (roughly 125,000 plots nationally).

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The plot design for FIA inventory plots consists of four 24.0 ft fixed-radius subplots spaced 120 ft apart in a triangular arrangement with one subplot in the center. All trees, with a diameter at breast height of at least 5 inches, are inventoried on forested subplots. Within each sub-plot, a 6.8 ft radius microplot offset 12 ft from sub-plot center is established. Within each microplot, all live tree seedlings are tallied according to species. Additionally, all trees with a d.b.h. between 1 and 5 inches are inventoried. Conifer seedlings must be at least 6 inches in height with a root collar diameter less than 1 inch. Hardwood seedlings must be at least 12 inches in height with a root collar diameter less than 1 inch.

DATA

All inventory data are made publicly accessible through the FIA database (FIADB). Data for this study were taken from the FIADB, version 3.0 (see Woudenberg and others 2010 for description of FIADB). The CPM was defined using Smalley's (1982) delineations. Two separate datasets were accumulated from data collected by the FIA program. The first dataset, hereafter referred to as historical data, was assembled based on all counties that contained the CPM region (Figure 1a) and was used for analyzing long-term trends of timberland area and growing stock volume. Historical data were available beginning in approximately the 1950s (Table 1). The second dataset, hereafter referred to as contemporary data, was assembled based on plots located within the CPM region (Figure 1b). Short-term, region-specific changes and the current status of the CPM forest resources were analyzed using data representing two points in time: 1990 and 2005 (Table 1). County-level data were necessary to examine long-term historical trends because most historical FIA data do not contain spatial information beyond the county of collection. Area of timberland and growing stock volume were used for long-term trend analysis because of the relative stability the variables offered.

ANALYSIS

Long-term trends were graphically assessed through comparison of both periodic and annual estimates across time. Statistical tests were not performed due to the variability in data collection and estimation procedures over such a long period of time. For short-term trends, we relied on comparisons of population estimates derived from the temporally indifferent estimators outlined by Bechtold and Patterson (2005). We compared two point-in-time estimates. We chose an end-point of 2005 because that represented the most current data when this analysis began. However, FIA has made great strides in making data available much faster recently and more recent data are now available for most states in the South. In addition to general trends in the forest resource, we were interested in shifts in forests types. To investigate temporal shifts in forest types across the CPM region, we calculated importance values (IVs) using frequency and dominance for each forest type and noted changes in rank from time 1 to time 2. We also identified significant changes in per acre basal area among forest types using simple analysis of variance (ANOVA) with Tukey mean seperation.

RESULTS

HISTORICAL DATA

Seventy counties (Alabama (19), Georgia (3), Kentucky (21), Tennessee (23) and Virginia (4)) contained significant portions of the CPM region based on visual observations. Across the 70-county region timberland (all forest land not withdrawn from timber production) declined an estimated 4 percent from the early 1960s to present (Figure 2).

The groups of counties within each of the 5 states that contain the CPM region have all experienced significant increases in standing growing stock volume. Volume estimates have increased approximately 93 percent across the region since the late 1960s and early 1970s (Figure 3). There have been greater increases in standing hardwood growing stock volume (125 percent increase) than softwood volume (15 percent increase). Significant declines in softwood growing stock volume occurred in the 1980s in Alabama, and in the late 1990s and early 2000s in Tennessee.

CONTEMPORARY DATA

In 1990 the CPM region was approximately 75 percent forested with an estimated 9.6 million acres of forest land (Table 2). According to the 2005 estimates, the region was 76 percent forested with an increase of approximately 260 thousand acres. In 2005 the Cumberland Mountains and Mid-, Northern, and Southern Cumberland Plateau regions, contained 1.5 million, 2.1 million, 3.1 million, and 3.2 million acres of forest land, respectively. The Cumberland Mountains and Mid-Cumberland Plateau experienced the largest gains in forest land area of over 100 thousand acres (9 and 6 percent, respectively). The Southern Cumberland Plateau gained approximately 80 thousand acres (3 percent) while the Northern Cumberland Plateau lost about 52 thousand acres (-2 percent).

While ownership patterns within the CPM region haven not significantly changed in the short-term between 1990 and 2005 (Table 2), changes in developmental stage (as approximated by FIA stand size class) have occurred. Across the CPM region the area of forest land represented by the large diameter stand size class has increased significantly (Figure 4). Area of large diameter stands increased approximately 22 percent while medium diameter declined 13 percent and small diameter stands declined 23 percent. The forests within the CPM region clearly are shifting to larger diameter stands.

Forest types across the CPM region, while having shifted slightly, largely remain dominated by hardwood species. Between 1990 and 2005, changes in forest type were

primarily declines in area of softwood and mixed types with concomitant gains in many hardwood dominated types (Figure 5). Significant declines in per acre basal area were identified for the mixed upland hardwood, loblolly pine/hardwood, and mixed upland hardwood type in the Cumberland Mountains, Mid-Cumberland Plateau, and Northern Cumberland Plateau subregions, respectively (Table 3). Significant gains from 1990 to 2005 were identified for the white oak type in the Cumberland Mountains, the white oak/red oak/hickory and yellow-poplar/white oak/northern red oak types in the Mid-Cumberland Plateau subregion, the chestnut oak type in the Northern Cumberland Plateau subregion, and the loblolly pine and shortleaf pine/oak types in the Southern Cumberland Plateau subregion.

There were an estimated 610 thousand acres of planted forests in the CPM region in 1990. Approximately 69 percent of all planted forests in the region were found in the Southern Cumberland Plateau subregion. By 2005 there were an estimated 606 thousand acres of planted forests in the CPM region, an insignificant decline of 4 thousand acres. While an increase of 1 percent was observed in the Southern Cumberland Plateau subregion, over the entire CPM region, only 6 percent of forests were classified as having a planted stand origin in both 1990 and 2005 (Table 2).

DISCUSSION

The CPM is a region of the United States with considerable forest resource wealth and considered regionally and nationally important as an area with significant biodiversity (Clatterbuck and others 2006, Druckenbrod and others 2006, Dale and others 2009). Sustaining the forests of the CPM region with a high degree of ecological integrity is important to a wide array of stakeholders. Moreover, the forests of the CPM region are noted to provide support to unique species combinations and habitat (Buehler and others 2006). While changes are occurring, long- and short-term, within the forested systems of the CPM region, those changes have not resulted in any significant forest acreage loss to the region. While long-term trends, using historical FIA data, indicate that some losses in forest cover may have occurred between the 1950s and the mid- to late-2000s (4 percent decline in timberland), short-term trends indicate that the region may now be gaining forests. It is important to note that the historical data are based on place-in-time county-level estimates that included some areas not currently defined as the CPM region. In addition, historical FIA data did not include estimates of reserved forest area, only commercial forests or timberland. Direct comparison of current estimates of forest land area within the CPM with historical estimates is not possible.

The majority of forests in the region have been and are currently within private land holdings. Very little has changed with time with respect to broad scale ownership patterns. While the recent divestments of forest land by forest products companies has altered local ownership patterns in many cases, forests in the CPM region remain primarily in private hands. In fact, only ca. 13 percent of forest land within the CPM is owned by public institutions, similar to ownership patterns common in the eastern United States (Turner and others 2008, Hartsell and Johnson 2009, Oswalt and others 2009).

Some recent changes in the forests of the CPM region may present future challenges, particularly that many of the forests of the region are becoming older. Using stand size class as a proxy for developmental stage (Trani and others 2001, Franzreb and others 2011) the forests of the CPM region can be viewed as an aging resource. Over a 15-year period the region experienced significant declines in early successional habitat (small diameter stands) and habitat that could be classified as mid-successional (medium diameter stands). Concomitantly, the region has experienced significant gains in stands in the later stages of development that contain mostly large diameter trees. This shift with time illustrates an aging forest resource wherein younger stands are not being developed. This trend is not uncommon to forest of the eastern U.S. (Turner and others 2008, Hartsell and Johnson 2009, Oswalt and others 2009, Rose 2009) and can be viewed in temporal shifts of diameter class and age class distributions to older and larger age and size classes. An unbalanced distribution of developmental/successional stages across the CPM may point toward future challenges to sustaining the nature of the current forests matrix within the region.

Forests of the CPM region have been and continue to be dominated by hardwood forest types. Over the 15-year period between 1990 and 2005, forest types appeared to be relatively stable. Slight changes have occurred and largely reflect the impact of recent insect disturbances in the region. The outbreak of the southern pine beetle (*Dendroctonus frontalis* Zimmermann) between 1999 and 2002 has been well documented (see Oswalt and others 2009). That event resulted in a large degree of softwood mortality and subsequent shifts of the species composition of many forests in the region from softwood dominated or hardwood-softwood mixed stands to hardwood dominated stands. This trend is evident throughout the CPM with the exception of gains in importance and per acres basal area of the loblolly pine forest type in the Southern Cumberland Plateau.

While the loblolly pine forest type, native to the Southern Cumberland Plateau, has experienced some gains in the Southern Cumberland Plateau, such gains do not support the position that southern yellow pine plantations are replacing native hardwood forests of the CPM region at alarming

rates. The FIA data collected across the region indicate a stable plantation population at nearly 6 percent of the forest land base. This information provides little support for the view that hardwood-to-pine conversion is a serious threat to the region at this time.

CONCLUSIONS

The forests of the CPM region have considerable ecologic and economic value. This forested resource, particularly with multiple competing interests, should continue to be monitored for changes that may warrant altered social behavior and/or management strategies. Currently, the forests of the region are highly productive and increasing in coverage. However, early successional forests are becoming more scarce. Presently, forests of the CPM region are thriving and hardwood dominated.

ACKNOWLEDGEMENTS

This work was supported by the U.S. Forest Service Southern Research Station Forest Inventory and Analysis (RWU 4801) program. The authors gratefully acknowledge the support of past and present filed personnel responsible for collecting the inventory data that supported this research. In addition, the authors would like to thank the support provided by Helen Beresford and Jeffery Turner of the SRS-FIA program along with each reviewer that helped improve this manuscript.

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Table 1—Inventory years with available data for each state in the Cumberland Plateau and Mountains (CPM) region

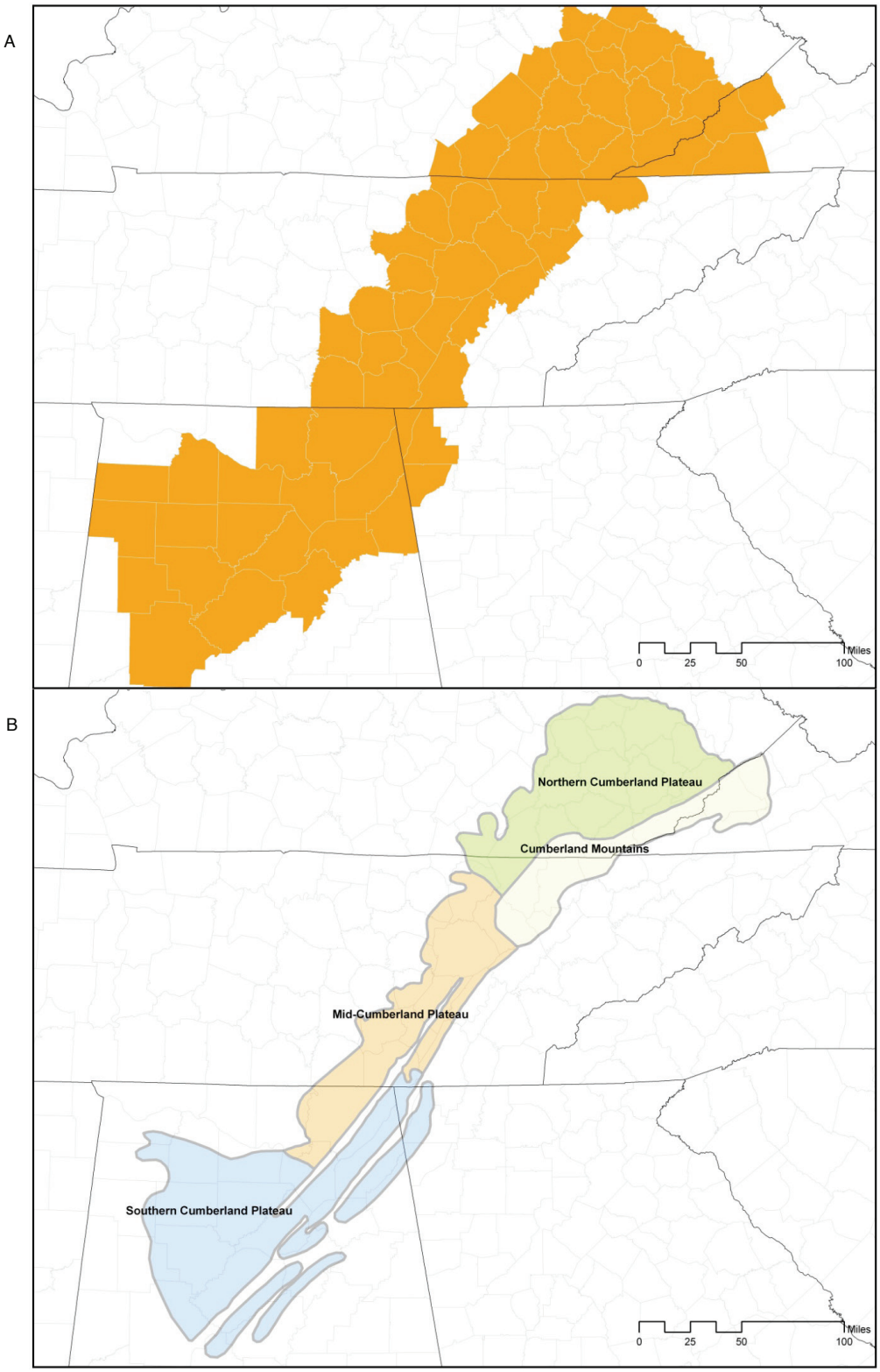
State	Historical Data	Contemporary Data	
		1990	2005
	Inventory year		
Alabama	1953, 1963, 1972, 1982, 1990, 2000, 2005	1990	2005
Georgia	1963, 1972, 1982, 1989, 1997, 2004	1989	2004
Kentucky	1949, 1963, 1975, 1988, 2004, 2005	1988	2005
Tennessee	1950, 1961, 1971, 1980, 1989, 1999, 2004, 2005	1989	2005
Virginia	1957, 1966, 1977, 1984, 1992, 2001, 2005	1992	2005

Table 2—Area of forest land by percent public or private ownership and percent planted origin for each subregion of the CPM region for 1990 and 2005

Year	Region	Forest land	Public	Private	Planted
		acres	*percent*		*percent*
1990	Cumberland Mountains	1,357,201	12	88	2
	Mid-Cumberland Plateau	2,011,473	10	90	5
	Northern Cumberland Plateau	3,121,808	21	79	2
	Southern Cumberland Plateau	3,108,798	5	95	14
	Total	9,599,281	13	87	6
2005	Cumberland Mountains	1,472,956	16	84	2
	Mid-Cumberland Plateau	2,128,964	11	89	4
	Northern Cumberland Plateau	3,069,523	22	78	1
	Southern Cumberland Plateau	3,188,282	10	90	15
	Total	9,859,725	15	85	6

Table 3—Mean basal area and associated standard error, calculated importance value and importance value rank for 1990 and 2005 along with change in basal area and associated p-value for statistical test of basal area change for each subregion of the CPM region

Region	Forest type	1990				2005				BA Change	P-value
		Basal area		IV	Rank	Basal area		IV	Rank		
		Mean	Stnd. Error			Mean	Stnd. Error				
Cumberland mountains	Eastern hemlock	131	-	0.06	7	181	28	0.07	6	50	
	Virginia pine	68	14	0.05	10	77	20	0.04	10	9	
	Eastern white pine/northern red oak/white ash	128	-	0.06	8	112	27	0.04	9	-16	
	Eastern red cedar/hardwood	34	9	0.02	13	3	-	0.00	14	-31	
	Shortleaf pine/oak	102	10	0.06	6	90	6	0.04	12	-12	
	Virginia pine/southern red oak	73	9	0.06	5	106	-	0.04	11	33	
	Chestnut oak	96	12	0.07	4	120	11	0.09	4	24	
	White oak/red oak/hickory	91	4	0.16	2	112	5	0.18	1	21	
	White oak	88	5	0.05	11	114	14	0.05	7	26	0.0028
	Northern red oak	96	38	0.04	12	95	18	0.05	8	-1	
	Yellow poplar/white oak/northern red oak	106	6	0.14	3	101	7	0.14	2	-5	
	Mixed Upland Hardwoods	94	5	0.19	1	75	7	0.13	3	-19	0.0254
	River birch/sycamore	-	-	0.00	14	76	-	0.03	13		
	Sugar maple/beech/yellow birch	85	7	0.05	9	117	11	0.09	5	32	
Mid-Cumberland Plateau	Eastern white pine/eastern hemlock	190	-	0.06	4	163	-	0.05	10	-27	
	Eastern hemlock	112	8	0.04	11	157	35	0.05	9	44	
	Loblolly pine	89	12	0.06	5	76	11	0.06	6	-13	
	Shortleaf pine	49	9	0.02	18	12	-	0.00	18	-37	
	Virginia pine	104	7	0.06	3	80	15	0.05	8	-24	
	Eastern white pine/northern red oak/white ash	87	6	0.03	15	145	59	0.05	11	57	
	Eastern red cedar/hardwood	87	20	0.03	14	96	2	0.04	13	9	
	Shortleaf pine/oak	104	6	0.05	7	94	20	0.03	14	-10	
	Virginia pine/southern red oak	91	9	0.06	2	94	10	0.06	7	3	
	Loblolly pine/hardwood	94	13	0.04	12	33	22	0.02	16	-62	0.0500
	Post oak/blackjack oak	57	33	0.02	16	70	5	0.03	15	13	
	Chestnut oak	113	5	0.04	9	109	13	0.06	5	-3	
	White oak/red oak/hickory	84	2	0.30	1	102	3	0.21	1	19	<0.0001
	White oak	83	6	0.04	10	134	44	0.08	3	52	
	Yellow poplar/white oak/northern red oak	75	7	0.05	8	108	10	0.07	4	32	0.0343
	Sweetgum/yellow poplar	45	21	0.02	17	78	18	0.04	12	33	
	Mixed Upland Hardwoods	91	7	0.05	6	78	8	0.08	2	-13	
	Sugarberry/hackberry/elm/green ash	103	53	0.03	13	38	5	0.01	17	-65	
Northern Cumberland Plateau	Eastern white pine	73	17	0.03	15	164	22	0.05	7	91	
	Eastern hemlock	60	2	0.02	16	145	40	0.05	9	85	
	Shortleaf pine	100	13	0.05	7	89	11	0.03	14	-11	
	Virginia pine	96	7	0.05	5	99	13	0.05	8	3	
	Pitch pine	84	26	0.03	13	18	-	0.01	19	-66	
	Eastern red cedar/hardwood	12	-	0.01	18	69	8	0.02	18	56	
	Shortleaf pine/oak	105	10	0.05	6	76	21	0.02	15	-29	
	Virginia pine/southern red oak	95	9	0.05	8	72	9	0.04	11	-23	
	Other pine/hardwood	74	13	0.03	14	66	19	0.02	16	-8	
	Post oak/blackjack oak	104	19	0.04	11	66	31	0.02	17	-38	
	Chestnut oak	90	6	0.06	4	115	9	0.06	6	25	0.0322
	White oak/red oak/hickory	91	4	0.09	2	101	3	0.18	1	10	
	White oak	85	6	0.05	9	100	4	0.08	4	15	
	Northern red oak	23	-	0.01	17	156	40	0.05	10	133	
	Yellow poplar/white oak/northern red oak	87	4	0.08	3	95	5	0.09	3	7	
	Sweetgum/yellow poplar	11	-	0.00	19	100	17	0.04	12	89	
	Mixed Upland Hardwoods	90	2	0.28	1	78	5	0.09	2	-12	0.0144
	River birch/sycamore	97	16	0.04	12	125	34	0.04	13	28	
	Sugar maple/beech/yellow birch	91	9	0.04	10	99	7	0.07	5	9	
Southern Cumberland Plateau	Longleaf pine	94	-	0.03	14	43	24	0.02	18	-51	
	Loblolly pine	82	4	0.14	2	100	5	0.14	1	18	0.0089
	Shortleaf pine	94	23	0.04	11	118	26	0.04	11	24	
	Virginia pine	80	6	0.06	4	98	7	0.07	4	18	
	Eastern redcedar/hardwood	97	-	0.03	13	107	10	0.04	16	10	
	Longleaf pine/oak	56	13	0.02	18	85	24	0.03	17	29	
	Shortleaf pine/oak	74	7	0.04	6	112	12	0.04	10	38	0.0079
	Virginia pine/southern red oak	82	7	0.05	5	70	7	0.05	9	-12	
	Loblolly pine/hardwood	72	5	0.08	3	80	8	0.08	3	8	
	Post oak/blackjack oak	114	-	0.04	7	78	8	0.04	15	-36	
	Chestnut oak	93	10	0.04	8	101	7	0.06	6	8	
	White oak/red oak/hickory	71	3	0.23	1	94	10	0.12	2	23	0.0045
	White oak	75	-	0.03	17	116	12	0.05	8	41	
	Yellow poplar/white oak/northern red oak	58	11	0.03	15	81	7	0.04	12	23	
	Sweetgum/yellow poplar	71	12	0.03	12	74	7	0.05	7	3	
	Mixed Upland Hardwoods	61	7	0.03	16	52	5	0.07	5	-9	
	Sweetgum/nutall oak/willow oak	86	15	0.04	10	92	12	0.04	13	6	
	Sugarberry/hackberry/elm/green ash	99	20	0.04	9	105	18	0.04	14	6	



Projection: GCS North American
Datum: D North American 1983
Source: USDA Forest Service
Geographic base data are provided by ESRI
By: Christopher M. Oswalt
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was derived from multiple sources

Figure 1—Location of the Cumberland Plateau and Mountains (CPM) region for a) historical data and b) contemporary data.

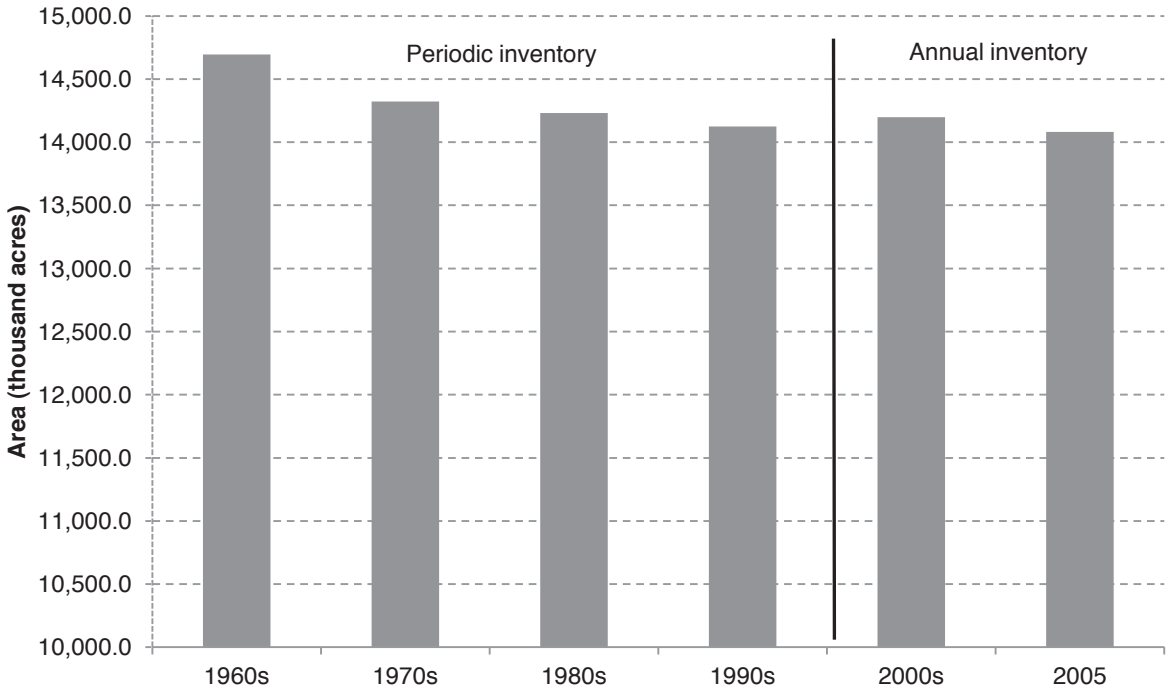

Figure 2—Area of timberland in the counties containing the CPM region from the 1960s to 2005.

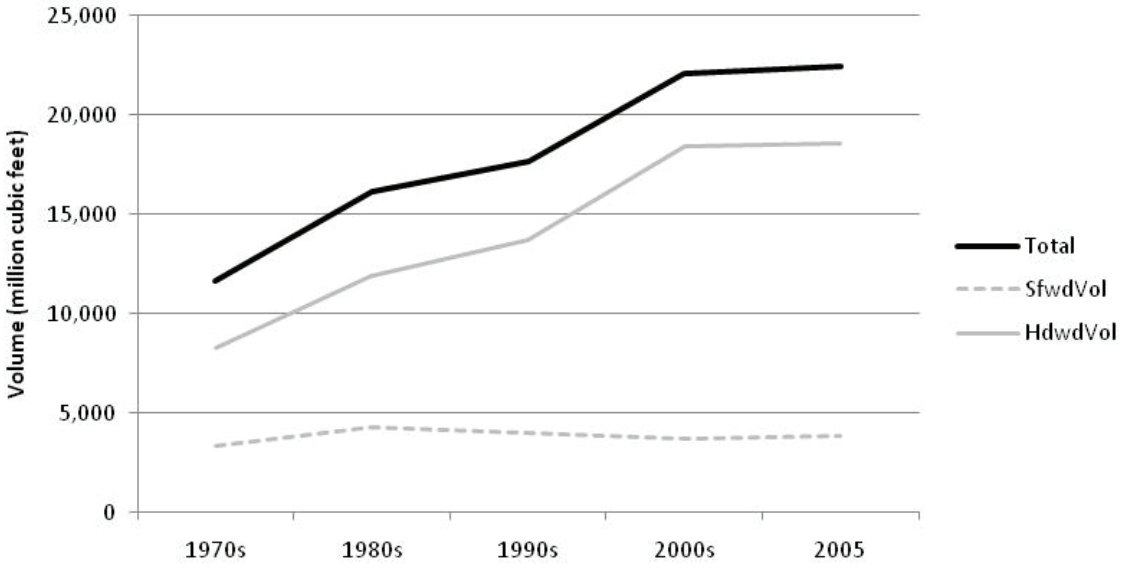

Figure 3—Volume of growing stock trees growing in the counties containing the CPM region from the 1970s to 2005.

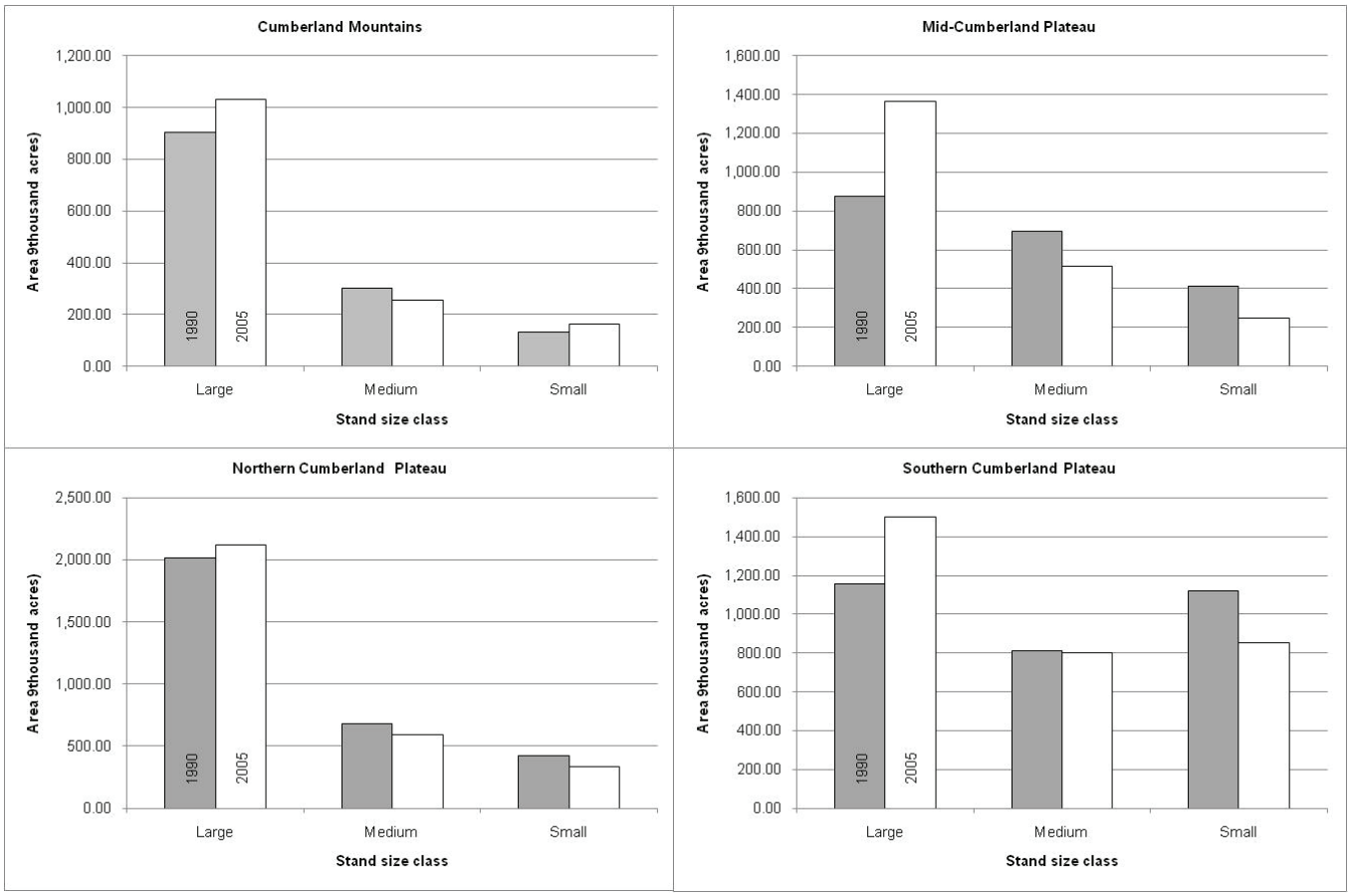

Figure 4—Area of forest land for each subregion of the CPM by stand size class (small = seedlings/saplings, medium = poles, and large = sawtimber) for 1990 and 2005.

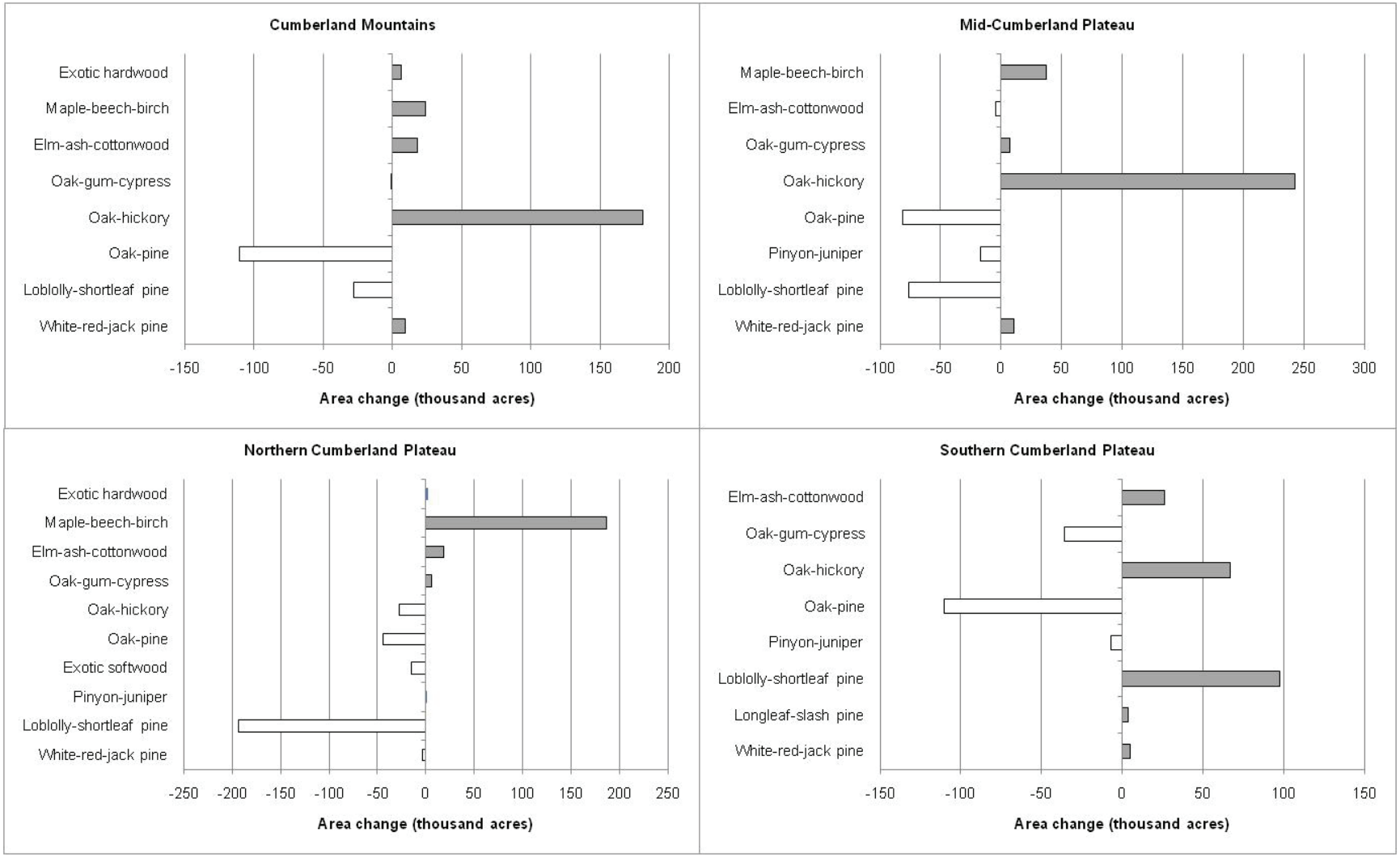

Figure 5—Change in area of forest land for each subregion of the CPM by forest type group for 1990 and 2005.