SHORTLEAF PINE COMPOSITION AND STRUCTURE IN THE UNITED STATES

W. Keith Moser, Mark Hansen, William H. McWilliams, and Raymond M. Sheffield[1]

ABSTRACT.—Although shortleaf pine currently occupies a prominent position in many eastern forests, particularly on upland sites, many scientists and managers have expressed concern about the future of this species in the absence of the disturbance patterns that facilitated its establishment up to now. Reductions in timber harvesting and fire, in particular, may give the advantage to competitors such as oaks, sweetgum, and maples. Commercial owners have favored the faster-growing loblolly pine over shortleaf pine. Using data from the Forest Inventory and Analysis program of the U.S. Forest Service, we looked at current data and temporal trends to gauge the trajectory of shortleaf pine forests in the eastern United States. The shortleaf pine volume per acre of timberland has decreased over the last two to three decades. The shortleaf pine basal area component on forestland has decreased in absolute terms and also represents a decreasing proportion of the total basal area, suggesting that associated species are increasing in their share of the overstory. The total number of shortleaf pine seedlings/saplings in the understory of stands has been decreasing and the proportion of all seedlings/saplings that are shortleaf pines has been declining over the last 20 or so years. The declining proportion of regeneration represented by shortleaf pine suggests a future eastern U.S. forest with substantially reduced proportions of the species in the overstory. Reintroducing disturbances, such as fire, is essential to maintain shortleaf pine's overstory presence and associated biological and economic benefits.

INTRODUCTION AND METHODS

Southern pines, including shortleaf pine, have had a prominent role in eastern U.S. forests for thousands of years. While current pine forests evolved through a combination of ecological and human-influenced factors, changes in disturbance patterns are altering both the species mix and the structure of the nation's pineries. Other authors at this conference present their interpretation of shortleaf pine stand dynamics and influences; in this paper, we examine trends, status, and implications of the structure and composition of shortleaf pine forests in the eastern United States.

We examined data from the national Forest Inventory and Analysis Program (FIA) of the U.S. Forest Service (Frayer and Furnival 1999). The FIA program conducts comprehensive forest inventories to estimate the area, volume, growth, and removal of forest resources in the United States, in addition to taking measurements on the health and condition of these resources. The program's sampling design has a base of one plot per approximately 6,000 acres, which provides a consistent, unbiased sample across the entire landscape. The national FIA program consists of four regional programs that provide estimates of forest area, volume, change, and forest health throughout the United States (McRoberts 1999). We used data from two of these regional FIA programs—the Northern and Southern FIA programs—to depict forest conditions for the eastern United States. For historical data, we use data generated from past FIA reports for states in the eastern U.S. and data generated by the FIA Mapmaker program (Miles 2006). For current structure and regeneration, we used data generated by the FIA database. The states and inventory dates we used in our analysis are listed in Table 1.

Shortleaf pine is found throughout the southeastern quadrant of the United States and is the second most important southern pine (McWilliams et al. 1986). The species is most prevalent in two groups: loblolly-shortleaf pine and oak-pine. The loblolly-shortleaf pine forest-type group is the predominant forest type group of the southern pine region (Walker 2001). As defined by the FIA, the two forest-type groups included eight detailed types within the oak-pine group and eight pine types within the loblolly-shortleaf pine group. These groups are defined by the proportion of total stocking represented by various pine species and their associates. The shortleaf pine type is defined as forests in which pines accounts for at least 50 percent of the stocking of all live trees, with shortleaf pine the most common

[1]Research Forester (WKM and MHH), Northern Research Station, Forest Inventory and Analysis Program, U.S. Forest Service, 1992 Folwell Ave., St. Paul, MN 55108; Supervisory Research Forester (WMW), Northern Research Station, Forest Inventory and Analysis Program, U.S. Forest Service, 200 Campus Blvd, Suite 200, Newtown Square, PA, 19073; Supervisory Research Forester (RMS), Southern Research Station, Forest Inventory and Analysis Program, 200 W.T. Weaver Blvd., Asheville, NC, 28804. WKM is corresponding author: to contact, call (651) 649-5155 or email at wkmoser@fs.fed.us

Table 1.—FIA statewide inventories used in this study.

State	Annual Inventories		Periodic Inventories			
	Year	Number of Timberland Plots	Year	Number of Timberland Plots	Year	Number of Timberland Plots
Alabama	2004	3298	2000	4399	1990	3917
Arkansas	2005	3353	1995	3135		
Florida	2005	1756	1995	5506	1987	5583
Georgia	2004	5209	1997	7045	1989	7522
Illinois	2004	767	1998	1671	1985	1095
Indiana	2005	958	1998	1546	1986	1998
Kansas	2004	374	1994	1676	1981	937
Kentucky	2004	3286	1988	1927		
Louisiana	2005	2443	1991	2413		
Maryland	2004	68	1999	525	1986	653
Mississippi			1994	3185		
Missouri	2004	3706	1989	4673		
New Jersey	2004	56	1999	383	1987	250
North Carolina	2002	3913	1990	5921	1984	5580
Ohio	2004	963	1991	1652		
Oklahoma			1993	1090		
Pennsylvania	2004	3061	1989	2971		
South Carolina	2005	1989	1993	4446	1986	4382
Tennessee	2003	2134	1999	2732	1989	2275
Texas	2005	3066	1992	2056		
Virginia	2003	3151	1992	4399	1984	4432
West Virginia	2004	309	2000	2153		

pine. Mixed pine-hardwood stands are those in which pine accounts for 25 to 50 percent of total stocking. Of the major forest types in the eastern United States, shortleaf pines are common associates of loblolly pine, oaks, hickories, and gums.

RESULTS

Shortleaf pine is found in 22 states and 85 forest-type groups. It is most often found in the loblolly-shortleaf pine forest-type group, but is also found in such types as longleaf-slash pine, pine-oak and several other upland hardwood forest types. The latest estimates from each of the states in the historic shortleaf pine range add up to 12.9 billion cubic feet of the species on timberland. Shortleaf pine volume has generally decreased across the region over time, sometimes at a rapid rate.

Although the species is present from Pennsylvania to Texas and Florida (Fig. 1), it is the most prevalent in the forests of the south-central states of Arkansas, Oklahoma, Mississippi, and Missouri.

The FIA stand-size variable can provide some indication of the stages of stand development (Oliver and Larson 1996), but the correlation with stand or tree age is less robust, because the classification is based solely on tree diameter (McWilliams et al. 2002). Each FIA plot has two to three "age" trees that are used to develop productivity equations. Because only the most dominant overstory trees are sampled, the ages may not represent all plot trees, and age data will not be considered here. Using the most recent data, shortleaf pine timberland area had a stand size distribution of 8 percent seedling-sapling, 23 percent poletimber, and 69 percent sawtimber. The shortleaf pine-oak forest-type group had a slightly more balanced stand structure, with 13 percent of the area in seedling-saplings, 31 percent in poletimber, and 56 percent in sawtimber. The predominance of larger trees has implications for calculations of growth and mortality, as we will see later.

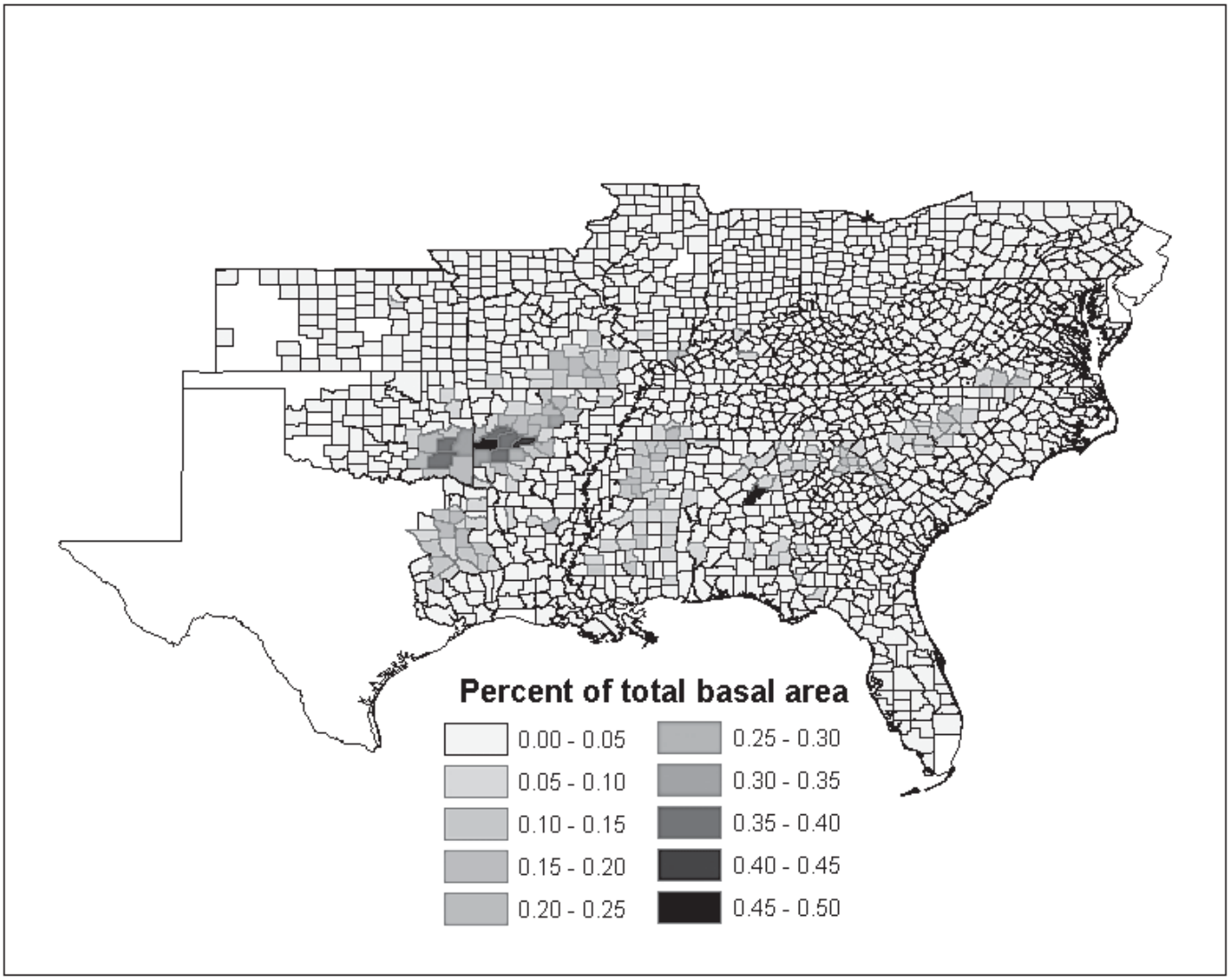

Figure 1.—Shortleaf pine as a percentage of total timberland basal area, based on the most recent FIA inventories from each state.

Shortleaf Pine Overstory: Status and Trends

Area

Out of approximately 241 million acres of timberland in the 22 states of the shortleaf pine range, shortleaf pine and shortleaf pine-oak forest types occupy over 7.4 million acres (Table 2). Over 4.7 million acres (64 percent) are in large-diameter stands and about 738,000 acres (10 percent) are in small-diameter stands, with the remaining 2 million acres in medium-diameter stands.

Number of trees

Of the 1.9 billion shortleaf pine trees, 791 million, or 42 percent, are found in the shortleaf pine forest type (Table 3). Another 335 million, or 18 percent of all shortleaf pine trees, are in the shortleaf pine-oak forest type. Beyond these two forest types, shortleaf pine trees do not have a prominent presence in any forest type in the United States.

The five top states, based on number of trees are Arkansas, Oklahoma, Mississippi, Alabama, and Georgia (Table 4). There are 1.9 billion shortleaf pine trees in the states in the species' range: 785 million are in large-diameter stands, 685 million in medium-diameter stands and 414 million in small-diameter stands. All things being equal, we would expect more trees per acre in small-diameter stands than in other size classes, so the fact that there are proportionally more trees in the large-diameter class reinforces the observation that the bulk of shortleaf pine forests are in large-diameter stands.

Table 2.—Timberland area of shortleaf pine, shortleaf pine-oak, and all forest types in those regions in the eastern United States with shortleaf pine forest type, in millions of acres and from the most recent inventory.[2] The most recent inventories for Maryland and New Jersey are not complete; completed panels do not list any shortleaf pine volume, so those states were not included in calculations. For West Virginia, the 2000 periodic inventory data was used.

Forest type and region	Total	Large diameter	Medium diameter	Small diameter
Shortleaf pine				
Central states[a]	218,293	162,375	50,654	5,264
Mid-Atlantic states[b]	7,884	-	-	7,884
Atlantic states[c]	573,995	341,224	174,667	58,104
Gulf states[d]	3,138,664	2,230,161	686,749	221,754
Total	3,938,836	2,733,760	912,070	293,006
Shortleaf pine-oak				
Central states[a]	382,805	252,923	120,704	9,178
Mid-Atlantic states[b]	106,312	69,046	29,484	7,782
Atlantic states[c]	693,560	428,763	171,387	93,410
Gulf states[d]	2,315,348	1,239,695	740,687	334,966
Total	3,498,025	1,990,427	1,062,262	445,336
All forest types				
Central states[a]	21,974,818	12,978,559	6,872,589	2,031,029
Mid-Atlantic states[b]	16,046,291	9,467,123	4,743,453	1,745,410
Atlantic states[c]	97,347,847	44,207,968	27,071,852	24,975,568
Gulf states[d]	105,688,465	48,557,114	30,751,469	25,842,126
Total	241,057,421	115,210,764	69,439,363	54,594,133

[2]a – Illinois, Indiana, Missouri (Kansas has shortleaf pine volume but no shortleaf pine forest type); b – Pennsylvania (Maryland and New Jersey not included due to incomplete inventories); c – Florida, Georgia, Kentucky, North Carolina, South Carolina, Virginia, and West Virginia; d – Alabama, Arkansas, Louisiana, Mississippi, Oklahoma, Tennessee, and Texas.

Table 3.—Number of shortleaf pine trees by forest type, using the most recent inventories from each state.

Forest type	Number of Growing Stock Trees (millions)	Percent of all Trees in the Type	Percent of all Shortleaf Pine Trees in the Region	Million Acres
Shortleaf pine	791.1	49.4%	42.1%	3.9
Shortleaf pine/oak	335.4	26.7%	17.8%	3.5
Loblolly pine	325.3	1.4%	17.3%	45.6
White oak/red oak/hickory	137.8	1.0%	7.3%	43.0
Loblolly pine/hardwood	63.1	1.1%	3.4%	13.7
Post oak/blackjack oak	41.3	2.1%	2.2%	6.1
Mixed upland hardwoods	39.5	0.6%	2.1%	24.9
Virginia pine	25.3	2.1%	1.3%	2.3
Sweetgum/yellow poplar	17.8	0.7%	0.9%	7.7
White oak	14.6	0.8%	0.8%	5.2
Other types	89.7	0.0%	4.8%	111.7

Table 4.—Number of shortleaf pine growing stock trees on timberland, by State and stand size class. The most recent inventories for Maryland and New Jersey are not complete; completed panels do not list any shortleaf pine volume. For West Virginia, the 2000 periodic inventory data was used.

State	Total	Large diameter	Medium diameter	Small diameter	Nonstocked
Alabama	167,247,530	50,916,318	70,360,118	45,971,094	–
Arkansas	509,819,996	228,566,160	197,829,315	83,424,521	–
Florida	5,941,473	4,193,999	193,772	1,553,702	–
Georgia	141,542,129	63,466,096	51,397,764	26,678,269	–
Illinois	8,582,649	8,300,201	282,448	–	–
Indiana	1,297,227	1,258,092	39,135	–	–
Kansas	311,943	311,943	–	–	–
Kentucky	13,220,721	6,846,929	4,057,996	2,315,795	–
Louisiana	33,386,094	24,248,403	3,554,730	5,582,960	–
Mississippi	195,436,442	76,413,093	42,631,002	76,392,347	–
Missouri	134,082,175	69,945,736	49,252,301	14,884,139	–
North Carolina	86,577,023	37,559,019	25,508,996	23,509,008	–
Ohio	135,537	135,537	–	–	–
Oklahoma	313,421,254	75,708,912	153,153,603	84,558,740	–
Pennsylvania	4,173,670	–	36,719	4,136,952	–
South Carolina	59,302,378	24,593,186	27,251,995	7,457,197	–
Tennessee	32,287,953	18,093,002	11,196,273	2,998,678	–
Texas	127,593,640	71,912,480	26,795,401	28,845,757	40,002
Virginia	43,827,211	19,144,117	20,917,245	3,765,850	–
West Virginia	5,676,645	2,892,416	425,163	2,359,066	–
Total	1,883,863,691	784,505,639	684,883,974	414,434,076	40,002

Volume

Growing stock volume of shortleaf pine in the latest inventories was almost 13 billion cubic feet (Table 5). Arkansas led the way with 3.4 billion cubic feet, followed by Mississippi, Texas, Alabama, and Oklahoma. The state with the smallest estimated shortleaf pine volume was Pennsylvania with 801 thousand cubic feet. Nationally, shortleaf pine volume is much lower compared to historical times. Figure 2 displays the nearly universal decline in the species' volume over the last three decades.

Net Growth and Removals

For those states where recent data exist, shortleaf pine averaged 428 million cubic feet per year in net growth, which is defined as gross growth less mortality. This number represents less than 4 percent of current volume for those states (Table 5). The values ranged from -3.4 percent in West Virginia to more than 6 percent in Oklahoma. For the states where we have removals data, removals represent less than 6 percent of current volume, and ranged from 0 percent of volume in several states to more than 15 percent in Louisiana.

The presence of a particular species is influenced not only by environmental considerations, but also by how human activity impacts the species. Along these lines, a useful indicator of shortleaf pine resource dynamics is the net growth to removals ratio. Ratios less than 1.0 indicate removals exceed growth, while values above 1.0 indicate inventory expansion. We examined the latest estimates of net volume growth and removal volume for the species. The gross growth to removals ratio was 0.58, indicating that our estimated removals exceeded the net growth. Among states with both positive growth and removals, the ratio ranged from 0.23 in Georgia to 4.96 in Missouri.

Table 5.—Growing stock volume, mortality, growth and removals, in cubic feet, of shortleaf pine in the eastern United States. Data is based on the latest inventory for each state, as of Sept. 1, 2006. Maryland and New Jersey are not listed because these inventories are only partially completed and completed panels do not list any shortleaf pine volume. For West Virginia, the 2000 periodic inventory data was used for all estimates. For Virginia, North Carolina, Alabama, South Carolina, Tennessee, Georgia, Ohio, and Pennsylvania mortality, growth, and removals estimates were taken from most recent periodic inventories.

State	Total Growing Stock Volume	Mortality	Mortality Percentage	Net Growth	Growth to Removals	Ratio
Alabama	1,098,283,367	26,291,884	2.4	46,197,186	106,398,925	0.43
Arkansas	3,410,072,606	39,214,174	1.1	101,416,898	112,978,627	0.90
Florida	59,225,060	0	0.0	2,982,499	4,818,029	0.62
Georgia	940,083,263	31,900,953	3.4	19,178,706	82,881,734	0.23
Illinois	74,826,427	339,968	0.5	1,787,358	0	--
Indiana	29,960,121	400,852	1.3	748,674	0	--
Kansas	1,889,991	0	0.0	0	0	--
Kentucky	164,265,225	3,685,351	2.2	2,572,188	1,290,085	1.99
Louisiana	371,289,865	4,081,610	1.1	18,133,050	57,278,885	0.32
Mississippi	1,529,628,337	20,996,813	1.4	72,883,929	165,796,601	0.44
Missouri	798,489,530	3,477,856	0.4	25,093,884	5,058,655	4.96
North Carolina	716,936,742	0	0.0	198,984	0	--
Ohio	2,796,283	241,087	8.6	-10,598	17,257	-0.61
Oklahoma	1,019,164,707	2,854,448	0.3	62,573,293	48,419,185	1.29
Pennsylvania	801,685	0	0.0	3,577	0	--
South Carolina	356,902,941	11,228,537	3.1	7,873,755	27,191,035	0.29
Tennessee	437,310,556	8,440,432	1.9	17,588,975	18,070,517	0.97
Texas	1,511,567,329	23,648,948	1.6	45,364,165	88,023,443	0.52
Virginia	351,939,107	7,955,820	2.3	3,971,042	15,794,677	0.25
West Virginia	12,841,996	540,975	4.2	-436,636	0	--
Total	12,888,275,138	185,299,708	1.4	428,120,928	734,017,654	0.58

Status of Proportion of Shortleaf Pine in Eastern U.S. Forest Overstory

As the underlying theme of this paper is "Where is shortleaf pine going?", we examined trends in the percentage of total basal area that is in shortleaf pines (Table 6). We looked at changes between inventories in the 1980s, 1990s, and 2000s. All states showed an overall decline during this period.

Regeneration is heavily influenced by the size and composition of the forest overstory (Smith et al. 1996). We have seen a declining trend in the proportion of total timberland in shortleaf pine overstory, with a few exceptions, throughout the eastern United States. Given the relative longevity of shortleaf pine, much of the current shortleaf pine overstory is likely a reflection of disturbance conditions far in the past. Shortleaf pine regeneration, however, should reflect more recent disturbances. Accordingly, we looked at shortleaf pine seedling/sapling data from the last one to three inventories in each state to gain some insight into the future of shortleaf pine forests (Table 6 and Fig. 3).

The eastern U.S. forests are not lacking for tree regeneration (Fig. 3). In most states, we have observed the presence of shortleaf pine regeneration, although not in large quantities, except for Arkansas and Oklahoma. Like overstory basal area, shortleaf pine regeneration was also flat or declining over this period. While these numbers do not indicate particular areas in the state where regeneration is successfully replacing shortleaf pine overstory, the overall trends – particularly the smaller proportion of regeneration versus overstory basal area – point to a decline in the species' presence in future forests.

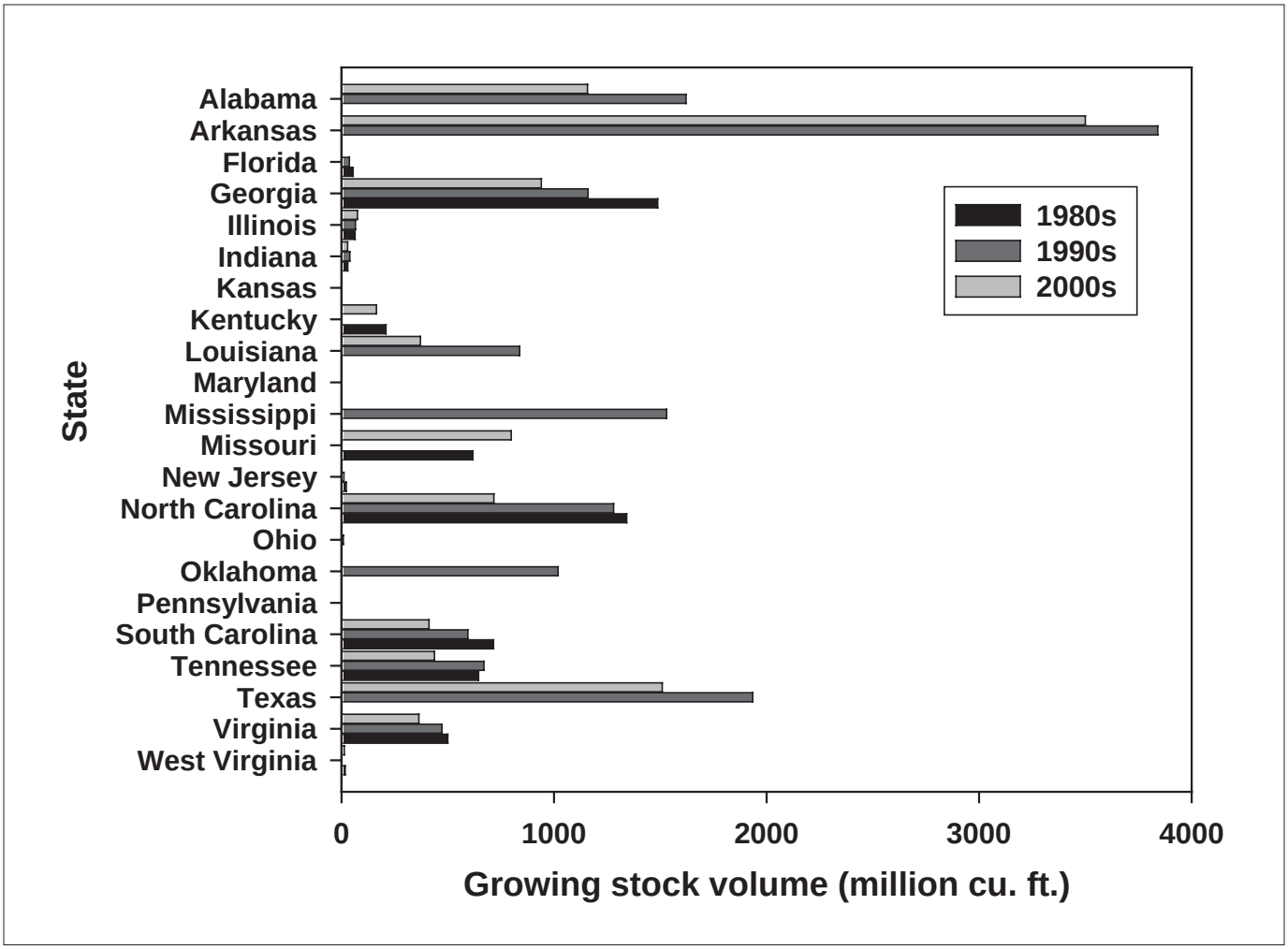

Figure 2.—Shortleaf pine growing stock volume by inventory decade and state. For each state, the bars progress (where data exist) from the 1980s on the bottom to 2000s on the top.

Table 6.—Percentage of total basal area in shortleaf pine basal area ("x/") and shortleaf pine seedlings/saplings as a percentage of all seedlings/saplings ("/x"), by state and inventory period. All percentages rounded to nearest whole percent. Percentages less than 0.5 percent are shown as "0".

State	1980s	1990s	2000s	State	1980s	1990s	2000s
Alabama		5/2	4/1	Missouri	4/1		5/1
Arkansas		13/4	11/3	New Jersey	1/1	0/0	
Florida	0/0	0/0	0/0	North Carolina	4/1	3/1	2/0
Georgia	4/1	1/0	2/1	Ohio		0/0	0/0
Illinois	1/0	1/0	1/0	Oklahoma		15/9	
Indiana	1/0	1/0	1/0	Pennsylvania	0/0		0/0
Kansas	0/0	0/0	0/0	South Carolina		3/2	2/1
Kentucky	1/1		0/1	Tennessee	3/1	2/0	1/0
Louisiana		3/1	1/0	Texas		10/2	6/1
Maryland	0/0	0/0		Virginia	2/0	2/0	2/0
Mississippi		5/1		West Virginia	0/0		0/0

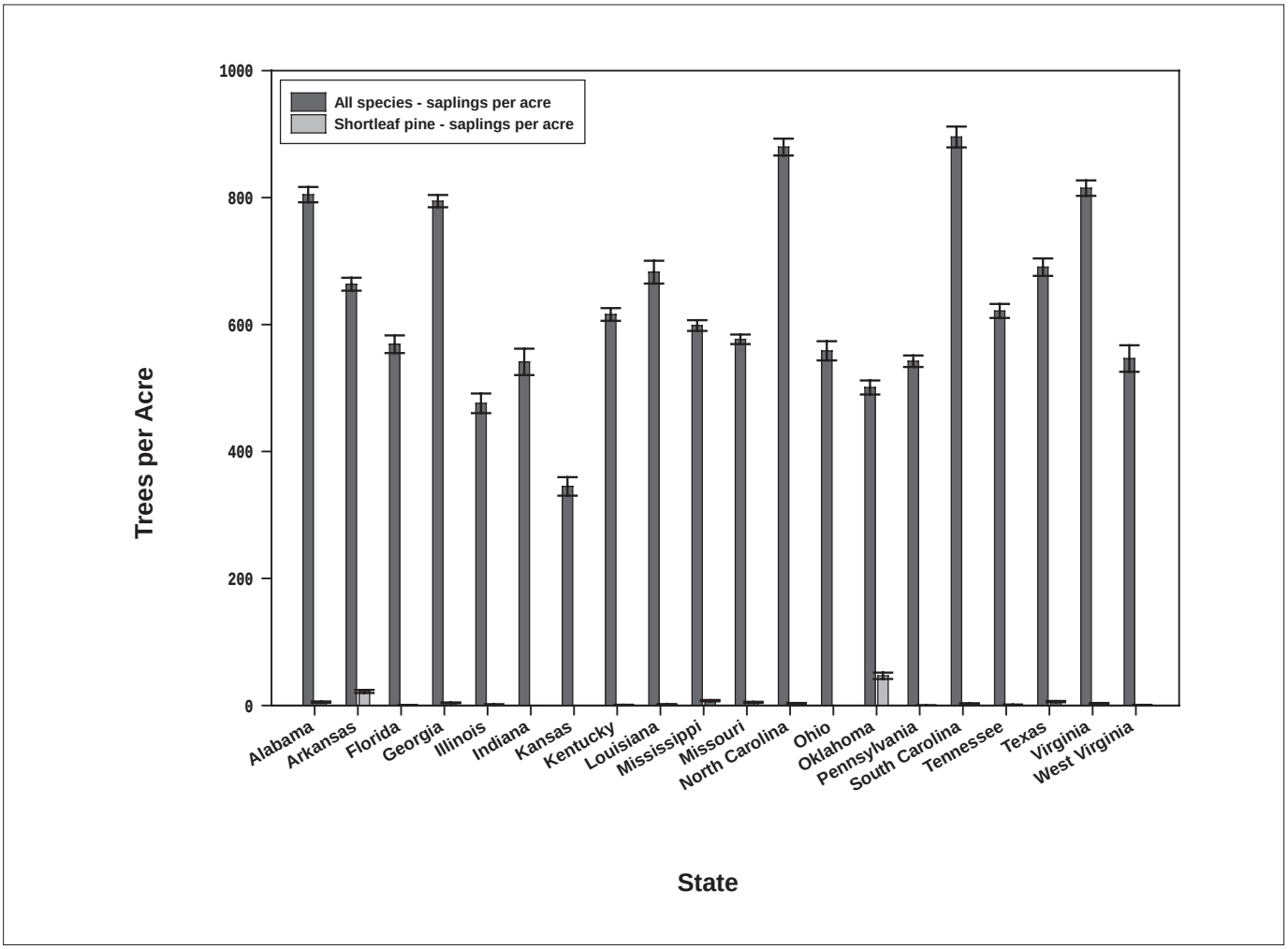

Figure 3.—Seedlings and saplings of all species and shortleaf pine, per acre, by state. The most recent inventories for Maryland and New Jersey are not complete; completed panels do not list any shortleaf pine volume.

CONCLUSIONS

After reaching a low point in the 1960s and 1970s, timberland in the eastern U.S. has recently started to increase. Shortleaf pine, however, has been decreasing in the number of trees and volume over the last several decades. Although we did find shortleaf pine regeneration in several states, the proportion was less than shortleaf pine's proportion of overstory basal area. The species is largely concentrated in large-diameter stands throughout its range. Such stands are likely older; older trees are frequently slower growing, which is, in turn, reflected in turn a smaller growth-to-removals ratio.

Johnson et al. (2002) emphasize the importance of accumulating oak regeneration in the understory and outlines the disturbances, anthropogenic and natural, that encourage this accumulation. The same principles apply to species such as the southern pines, particular shortleaf pine and longleaf pine (Moser 2003). Such disturbances promote two processes: the concentration of early growth on the pine seedling/sapling root system resulting from dieback of the above-ground component, and the elimination of less fire-resistant species that would otherwise compete successfully for resources. Two of the most prominent disturbances are harvesting and fire. Increasing urbanization and regulation have put pressure on both of these disturbance types. Furthermore, where shortleaf pine has been harvested, it has frequently been replaced by planted loblolly pine.

The declining proportion of regeneration represented by shortleaf pine is particularly disquieting, as it provides a foretelling of forest overstory composition. It is hard to imagine a future eastern U.S. forest landscape with the current proportion of shortleaf pine in the overstory, given these regeneration trends. While re-instituting large-scale disturbances will pose problems in a settled landscape such as the South, they should be considered part of the toolbox that resource managers use as they seek to maintain this important species.

LITERATURE CITED

Frayer, W.E.; Furnival, G.M. 1999. Forest survey sampling designs: A history. Journal of Forestry. 97(12): 4-10.

Johnson, P.S.; Shifley, S.R.; Rogers, R. 2002. The ecology and silviculture of oaks. New York: CABI Publishing. 501 p.

McRoberts, R.E. 1999. Joint annual forest inventory and monitoring symposium: the North Central perspective. Journal of Forestry. 97(12): 27-31.

McWilliams, W.H.; Sheffield, R.M.; Hansen, M.H.; Birch, T.W. 1986. The shortleaf resource. In: Proceedings of the symposium on the shortleaf pine ecosystem; 1986 March 31 – April 2; Little Rock, AR. Monticello, AR: Arkansas Cooperative Extension Service: 9-24.

McWilliams, W.H.; O'Brien, R.A.; Reese, G.C.; Waddell, K.L. 2002. Distribution and abundance of oaks in North America. In: McShea, W.J.; Healy, W.H., eds. Oak forest ecosystems: ecology and management for wildlife. Baltimore: Johns Hopkins Press: 13-32.

Miles, P. D. 2006. Forest inventory mapmaker web-application version 2.1. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station. [Online only] Available at: www.ncrs2.fs.fed.us/4801/fiadb/index.htm

Moser, W.K. 2003. Oaks explained. A book review of Ecology and Silviculture of Oaks. Forest Science. 49(2): 377-378(2).

Oliver, C.D.; Larson, B.C. 1996. Forest stand dynamics. 2d ed. New York: John Wiley.

Walker, L.C. 1995. The southern pine region. In: Barrett, J.W., ed. Regional silviculture of the United States. New York: John Wiley: 271-334.