OAK COMPOSITION AND STRUCTURE IN THE EASTERN UNITED STATES

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Abstract.—Although oak species currently occupy a dominant position in most eastern deciduous forests, particularly on upland sites, many scientists and managers have expressed concern about the future of this genus 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 maples. 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 oak forests in the Eastern United States. The area of the two upland oak groups—oak-hickory and oak-pine—covered 160.3 million acres or 43 percent of eastern timberland. The oak volume per acre of timberland has increased over the last four to five decades. Yet, we are seeing a decline in the proportion of total timberland with at least 20 ft^2ac^{-1} of select red or white oaks (the "select oak" stands). While the select oak basal-area component within these stands increased slightly, it represents a decreasing proportion of the total basal area in the stand, suggesting that associated species are increasing in their share of the overstory. While the total number of seedlings/saplings in the understory of stands with select red or white oak[5] basal area greater than 20 ft^2 ac^{-1} has been increasing, the proportion of all seedlings/saplings that are select white oak seedlings/saplings has been declining over the last 20 or so years. The declining proportion of regeneration represented by oak species suggests a future eastern U. S. forest with substantially reduced proportions of oaks in the overstory. Reintroducing disturbances such as fire is essential to maintain oaks' overstory presence and associated biological and economic benefits.

INTRODUCTION AND METHODOLOGY

Oaks have been in eastern U. S. forests for at least 6,000 years Lorimer (1993). While current oak forests evolved through a combination of ecological and human-influenced factors (McWilliams et al. 2002), changes in disturbance patterns are altering stand development trajectories to the detriment of oak (Larson and Johnson 1998; Smith 2005). Other authors at this conference will present their interpretation of oak regeneration patterns that lead to eventual canopy occupancy (see Abrams, this volume); in this paper we examine trends, status, and implications of the structure and composition of oak forests in the Eastern United States.

We used data from the national forest inventory and analysis program (FIA) of the USDA 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, and measures the health and condition of these resources. The program's sampling design has a base intensity of one plot per approximately 6,000 acres and is assumed to produce a random, equal probability sample. The national FIA program consists of five regional programs[6] that provide estimates of forest area, volume, change, and forest health throughout the United States (McRoberts 1999). We used data from three of these regional FIA programs—North Central, Northeastern and Southern—to depict forest conditions for the Eastern United States. For historical data we used data generated from past Forest Inventory reports for

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[5]The categories "select red oaks" and "select white oaks" have historically referred to those species preferred by mill owners for their uniform characteristics, quality and yield of higher grades of lumber. In examining trends over the last 25 or so years, we categorized stands as select red or white oak acreage as in those stands with at least 20 ft^2ac^{-1} of the total basal area in select red white oak species and limited our analyses to those categories. These trends reflect management and utilization of those species that are most identified with the name "oak" and that comprise a significant proportion of the genus' volume.

[6]Soon to be four. The North Central and Northeastern FIA programs will merge into the Northern FIA program by 1 October, 2006.

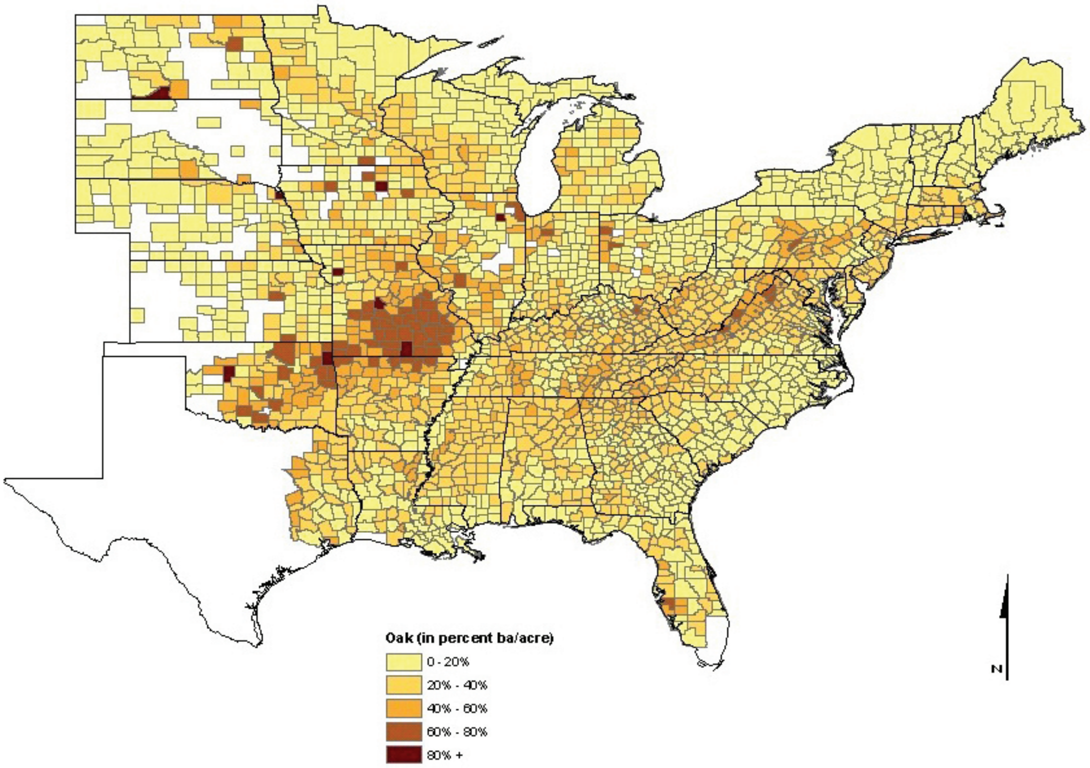

Figure 1.—Oak species' percentage of total timberland basal area, based on the most recent FIA inventories from each state.

states in the Eastern United States and data generated by the FIA Mapmaker program (Miles 2005). For current structure and regeneration, we used data generated by the FIA database.

Of the major deciduous forest-type groups in the Eastern United States, oaks are common associates of all but the northernmost groups of spruce-fir and aspen birch. Oak is most prevalent in the two upland oak groups: oak-hickory and oak-pine. Oaks also are members of other upland deciduous forest types. As defined by the FIA, upland oak forest type groups included eight detailed types within the oak-pine group and 11 oak types among the 17 types within the oak-hickory group. These groups are defined by the proportion of total stocking represented by oaks. Oak-hickory group includes stands where half or more of the stocking is contributed by oak or oak-dominated stands. For the oak-pine group, stocking of oaks and other deciduous species is from 25 to 50 percent (McWilliams et al. 2002).

RESULTS

Current Distribution of Mixed-oak Stands in Eastern United States

We used inventory data from the FIA database to identify the presence of oaks in the Eastern United States. Figure 1 is a map that displays the proportion of the total basal area occupied by all oak species. The occurrence of oak throughout forest stands in the east is readily apparent. This map shows that while eastern oaks are present from Maine to Louisiana and Minnesota to Florida, they comprise the most dominant portion of the canopy in the Ozarks and in portions of the Appalachian Mountains. Other areas with a high proportion of oaks include the Central Lowlands of Minnesota and Wisconsin, and the Tennessee River valley.

The area of the two upland oak groups covered 160.3 million acres or 43 percent of eastern timberland in the most recent inventories (Table 1). Upland oak forests compose at least 48 percent of the timberland in the

Table 1.—Area of timberland in the Eastern United States, in millions of acres and from the most recent inventory, by region and broad forest type, with percent of region total[1]

	Total	Upland oak[a]		Other upland deciduous		Lowland oak[b]		Other lowland deciduous		Conifer		Other	
		Area	Percent	Area	Percent	Area	Percent	Area	Percent	Area	Percent	Area	Percent
Lake States[c]	49.08	8.30	17	24.90	51	-	0	3.97	8%	11.39	23	0.52	1
Central States[d]	25.21	19.06	76	2.02	8	0.09	0	2.96	12	0.85	3	0.23	1
New England States[e]	31.31	4.52	14	16.58	53	-	0	0.81	3	9.30	30	0.10	0
Mid-Atlantic States[f]	56.03	26.93	48	22.50	40	0.11	0	2.21	4	3.82	7	0.46	1
Atlantic states[g]	96.01	47.84	50	1.04	1	3.91	4	9.60	10	32.99	34	0.62	1
Gulf states[h]	105.85	52.05	49	0.10	0	8.03	8	10.13	10	35.00	33	0.53	1
Plains states[i]	5.33	1.56	29	0.55	10	0.01	0	1.32	25	1.67	31	0.23	4
Total	368.82	160.27	43	67.7	18	12.15	3	30.98	8	95.03	26	2.69	1

[1]Source: Forest Inventory Database (Miles 2005).
[a]Includes oak-hickory and oak-pine forest-type groups.
[b]Includes swamp chestnut oak - cherrybark oak, sweetgum-Nuttall oak-willow oak, and overcup oak-water hickory forest types.
[c]Michigan, Minnesota, and Wisconsin.
[d]Illinois, Indiana, Iowa, Missouri.
[e]Connecticut, Massachusetts, Maine, New Hampshire, Rhode Island, and Vermont.
[f]Delaware, Maryland, New Jersey, New York, Ohio, Pennsylvania, and West Virginia.
[g]Florida, Georgia, Kentucky, North Carolina, South Carolina, and Virginia.
[h]Alabama, Arkansas, Louisiana, Mississippi, Oklahoma, Tennessee, and Texas.
[i]Kansas, Nebraska, North Dakota, and South Dakota.

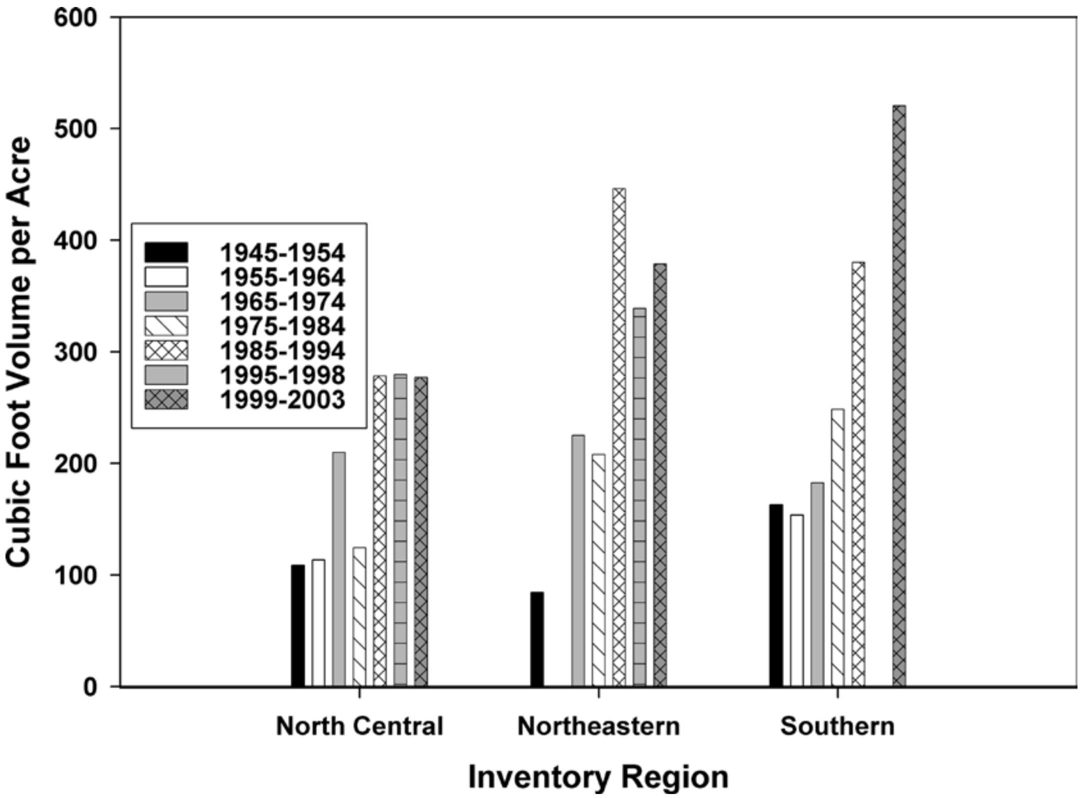

Figure 2.—Average volume of oak species per acre of timberland ($ft^3\ ac^{-1}$) by FIA program. North Central states: Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, South Dakota, and Wisconsin; Northeastern states: Connecticut, Delaware, Maryland, Maine, Massachusetts, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, Rhode Island, Vermont, and West Virginia; Southern states: Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, and Virginia.

Atlantic, Central, Gulf and Mid-Atlantic states. Other upland deciduous groups cover 67.7 million acres or 18 percent of eastern timberland. The Gulf states had the most oak, with 32 percent of the total eastern U.S. upland oak timberland area and 66 percent of the lowland oak timberland.

Oak volume has generally increased across the region (Fig. 2), in some cases at a declining rate. In upland oak stands with at least 20 $ft^2\ ac^{-1}$ of oak basal area, most acreage was in the sawtimber-size stands (Table 2). There are several explanations for this distribution. First, oaks are long-lived species and thus spend a lower proportion of their total life in the seedling-sapling or poletimber size classes. Second, according to FIA protocol, mixed-age stands often are assigned to the size class of the largest component. For example, a stand that has one-third of the stocking in each size class is called sawtimber.

Some authors have suggested that the age-class distribution of oak stands is unbalanced and skewed toward older stands (Abrams and Nowacki 1992; Abrams 2005; Healy et al. 1997; Lorimer 1993). 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 several "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; those data are not considered here.

FIA has timberland area delineated by forest types which, in turn, are combined into forest type groups. We examined the components of upland oak type forest-type groups: oak-pine and oak hickory by forest type and stand size class (Table 2). The white oak/red oak/hickory

Table 2.—Timberland area of upland oak forest type groups by forest type and stand size class, for the states east of the Great Plains

Forest type	Total	Seedling-sapling		Poletimber		Sawtimber		Nonstocked	
		Area	Percent of Total	Area	Percent of Total	Area	Percent of Total	Area	Percent of Total
Oak/pine group	6.9	0.7	10	4.3	62	1.9	28	-	-
White pine/red oak/white ash	3,836.90	420.6	11	1,175.70	31	2,240.60	58	-	-
Eastern redcedar/hardwood	2,895.70	769.2	27	1,481.50	51	644.9	22	-	-
Longleaf pine/oak	1,248.90	639.6	51	330.7	26	275.9	22	2.7	0
Shortleaf pine/oak	4,398.20	579.9	13	1,438.80	33	2,379.50	54	-	-
Virginia pine/southern red oak	2,178.90	439.1	20	820.5	38	919.3	42	-	-
Loblolly pine/hardwood	15,792.10	6,104.70	39	3,722.50	24	5,959.80	38	5.1	0
Slash pine/hardwood	1,797.30	697	39	441.7	25	653.5	36	5	0
Other pine/hardwood	2,846.60	707.2	25	978.7	34	1,157.80	41	2.9	0
Total oak/pine group	35,001.50	10,358.00	30	10,394.40	30	14,233.20	40	15.70	0
Oak/hickory group	1,444.10	922.5	64	243.7	17	277.9	19	-	-
Post oak/blackjack oak	5,680.30	808.5	14	2,460.90	43	2,410.90	42	-	-
Chestnut oak	5,728.70	165.4	3	1,750.10	31	3,813.20	67	-	-
White oak/red oak/hickory	49,419.70	5,586.10	11	13,927.10	28	29,906.40	61	-	-
White oak	4,779.10	72.6	2	1,183.10	25	3,523.50	74	-	-
Northern red oak	3,782.20	110.5	3	805.5	21	2,866.20	76	-	-
Yellow-poplar/white oak/red oak	7,450.90	739.7	10	1,674.50	22	5,036.60	68	-	-
Sassafras/persimmon	965	299.3	31	390	40	275.7	29	-	-
Sweetgum/yellow-poplar	6,649.20	2,614.80	39	1,798.60	27	2,235.80	34	-	-
Bur oak	582.1	26.7	5	118.2	20	437.2	75	-	-
Scarlet oak	527.6	30.9	6	207.9	39	288.8	55	-	-
Yellow-poplar	1,250.20	176.5	14	378	30	695.6	56	-	-
Black walnut	653.8	81.5	12	186.5	29	385.9	59	-	-
Black locust	474.9	168.2	35	206.9	44	99.8	21	-	-
Southern scrub oak	1,281.10	904.8	71	326.6	25	39.5	3	10.2	1
Chestnut oak/black oak/scarlet oak	3,051.70	177	6	944.4	31	1,930.40	63	-	-
Red maple/oak	2,381.60	368	15	965.1	41	1,048.50	44	-	-
Mixed upland hardwoods	29,166.60	7,640.70	26	8,851.60	30	12,652.10	43	22.2	0
Total oak / hickory group	125,268.80	20,893.70	17	36,418.70	29	67,924.00	54	32.40	0
Total (Thousand acres)	160,270.30	31,251.70	19	46,813.10	29	82,157.20	51	48.1	0
Total(Thousand hectares)	64,861.40	12,647.60		18,945.30		33,249.00		19.5	

forest type was by far the largest with approximately 50 million acres. The next largest forest type was in mixed upland hardwoods, with slightly less than 30 million acres. The loblolly pine/hardwood forest type was the third largest at around 15 million acres.

Using the most recent data, oak timberland area had a stand-size distribution of 19 percent seedling-sapling, 29 percent poletimber and 51 percent sawtimber. The oak/hickory forest type group summary was similar at 17, 29, and 54 percent, respectively. The largest component of this group was the white oak/red oak/hickory, a forest type common in parts of the Southern Appalachians and the Ozark Plateau (McWilliams 2002). Sawtimber accounted for the majority of the acreage in this forest type, with 61 percent of the area classified as sawtimber-sized stands and only 11 percent classified as seedling-sapling. Other individual oak-hickory forest types with percentages of the total area in seedling/saplings that were less than the oak/hickory group as a whole included chestnut oak (3 percent), post oak/blackjack oak (14 percent), white oak (2 percent), northern red oak (3 percent), bur oak (5 percent) and scarlet oak (6 percent).

The oak-pine forest type group had a more balanced stand structure, with 30 percent of the area in seedling-saplings, 30 percent in poletimber, and 40 percent in sawtimber. This group's largest component, loblolly pine/hardwood, distributed 39 percent seedling-sapling, 24 percent poletimber, and 38 percent sawtimber. The forest types with percentages of the total area in seedling/saplings that were less than the oak/pine group as a whole included white pine/red oak/white ash with 11 percent seedling-sapling, shortleaf pine/oak 1(3 percent) and Virginia pine/southern red oak (20 percent).

It is interesting to note both the higher average percentage of seedling-sapling timberland area in oak-pine forests vs. oak-hickory forests and the greater percentage of regeneration among those oak-pine types that are considered below the forest-type group average compared to oak-hickory below-average forest types. McWilliams et al. (2002) stated that these young oak-pine stands commonly convert to pine stands as the pine species outgrow their competitors, so how much of these oak-pine seedling-sapling areas will result in mature forests with a significant component of oak remains to be seen.

Oak Overstory: Status And Trends

To examine overall trends in oak forest species in the overstory, we divided the estimated eastern U.S. timberland into three categories based on FIA plot-level data: stands with oak basal area greater than or equal to 20 ft^2ac^{-1} (OAK 20 PLUS), stands with oak basal area less than that amount but greater than zero (OAK LT 20), and stands with no oak basal area (OAK ZERO) (Fig. 3). The results vary across the region, but there is a slight decline in the percentage of plots in the "oak basal area greater than or equal to 20 ft^2ac^{-1}" category and the proportion of plots with zero oak basal area is increasing. We can conclude that there is a downward trend in oak basal area but as yet no precipitous decline across the region.

We also examined upland oak overstory growing-stock volume according to individual species. Table 3 shows the volumes in descending order for species in the red and white oak groups. Northern red oak had the largest red oak volume followed by black oak. White oak had the largest white oak group volume followed by chestnut oak.

Mortality estimates are the principal indicator of health from FIA inventories and are calculated on an equivalent annual basis (McWilliams et al. 2002). Overall oak mortality was 0.79 percent (Table 3). The mortality of white oak species averaged 0.55 percent while red oak species' mortality averaged 0.98 percent of growing-stock volume. Those red oak species with the highest mortality included pin oak (1.78 percent), Nuttall oak (1.74 percent) and scarlet oak (1.34 percent). The white oak group species with the highest mortality rate was overcup oak at 0.81 percent.

McWilliams et al. (2002) noted that species with the highest mortality are subjected to the most stress agents and gave examples of American elm and Dutch elm disease and balsam fir and spruce budworm. While there could be a host of localized factors affecting mortality,

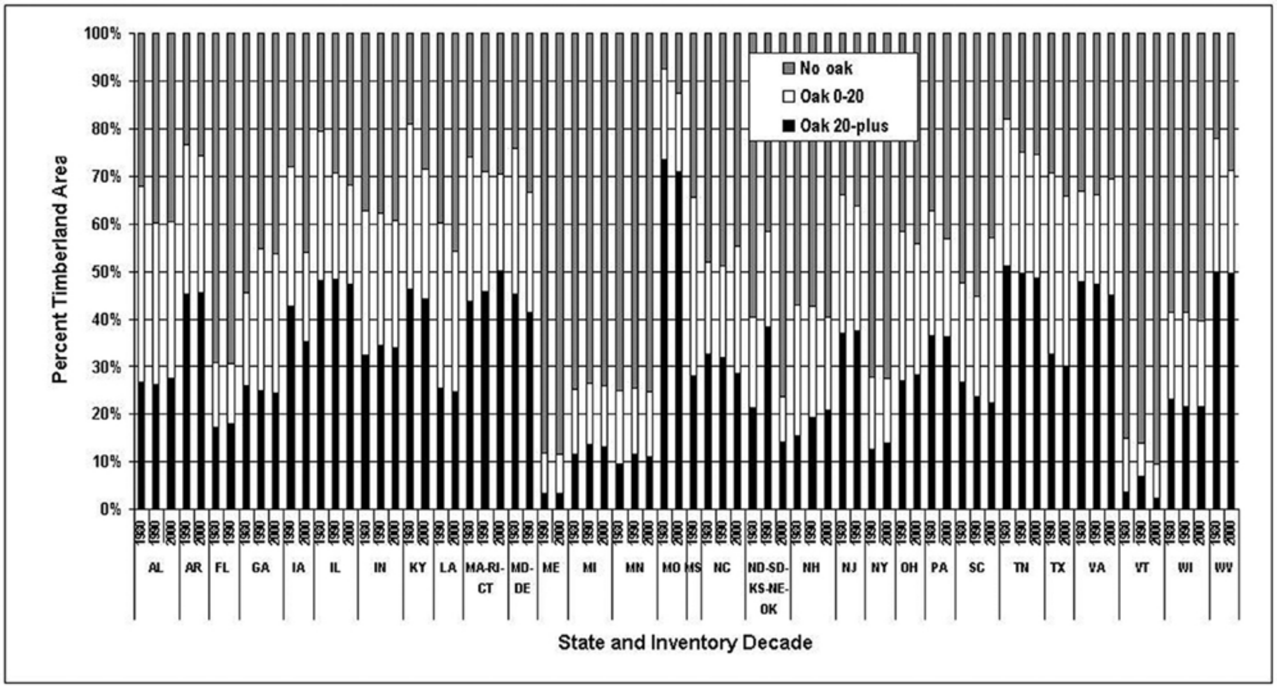

Figure 3.—Percentage of timberland area by oak category class, state and decade of inventory. Multiple inventories in one decade are averaged. “No oak” = 0 ft^2 ac^{-1} oak species basal area; “Oak 0-20” = 0-19.9 ft^2 ac^{-1} oak basal area; “Oak 20-plus” = 20+ ft^2 ac^{-1} oak species basal area.

disease situations that are density- and age-mediated, such as oak decline in Missouri (Lawrence et al. 2002), could help explain the apparent high mortality of scarlet oak and pin oak.

Net Growth and Removals

The presence of a particular species is influenced not only by environmental considerations but also by how human activity impacts the species. A useful indicator of oak resource dynamics (McWilliams et al. 2002) is the ratio of growth to removals. Ratios less than 1.0 indicate overcutting of the resource while values above 1.0 indicate inventory expansion. We examined the latest estimates of net volume growth and removal volume by species (Table 4). The ratio for all oak species was positive; species that were most closely matched in terms of growth and removals included southern red oak (1.05), Nuttall oak (0.88), willow oak (1.17), and scarlet oak (1.18), suggesting that utilization of the oak resource is regionally sustainable. The high proportion of sawtimber stands implies that net growth will be primarily from increases in current tree diameter rather than ingrowth (McWilliams et al. 2002).

Status of Proportion of Oaks in Eastern U.S. Forest Overstory

In most of those states with select red oak (Table 4) stands that met the previously-mentioned criteria, mean overstory basal area of select red oaks increased from the 1980’s through 2003. Because oak regeneration potential is at least partially related to the proportion of oaks in the overstory (Johnson et al. 2002), it would be helpful to examine trends in the proportion of oaks in the total stand basal area. As the underlying theme of this paper is “where oak is going,” we examined trends in the percentage of total basal area that is in select red oaks (Fig. 4). We looked at changes between inventories in the 1980’s vs. 1990’s, 1980’s vs. 2000’s, and 1990’s vs. 2000’s. While some states showed an increase in the proportion of overstory basal area represented by SRO, most states showed an overall decline during this period.

The situation was similar for white oaks. Regionwide, there was an increase in white oak basal area in stands with at least 20 ft^2ac^{-1} of white oak, but this basal area represents a decreasing proportion of total stand basal area (Fig. 5).

Table 3.—Growing-stock volume, mortality, growth and removals, in cubic feet, of oak species groups in the Eastern United States (excluding the Plains states); data based on the latest inventory for each state

Species	Growing-stock volume	Mortality	% Mortality	Net growth	Removals	Growth removals ratio
Red Oak						
northern red oak	20,655,454,559	153,296,330	0.74	538,477,979	329,792,788	1.63
black oak	12,630,532,249	153,531,016	1.22	332,118,409	231,452,931	1.43
water oak	8,018,169,993	83,017,464	1.04	344,814,570	257,593,597	1.34
southern red oak	6,535,917,882	56,645,858	0.87	235,162,961	224,973,434	1.05
scarlet oak	6,460,923,509	86,851,528	1.34	157,857,759	134,157,620	1.18
laurel oak	3,374,331,616	35,516,992	1.05	137,585,927	99,398,151	1.38
willow oak	3,018,642,800	35,342,884	1.17	112,112,411	95,500,704	1.17
cherrybark oak	2,695,838,154	18,276,233	0.68	114,284,906	91,056,971	1.26
pin oak	804,771,728	14,337,991	1.78	21,554,964	15,717,424	1.37
northern pin oak	709,967,448	4,309,812	0.61	21,454,369	6,079,116	3.53
Nuttall oak	634,755,257	11,015,356	1.74	12,282,211	13,956,389	0.88
Shumard oak	557,716,992	3,466,047	0.62	23,187,254	16,453,650	1.41
live oak	513,642,097	1,082,584	0.21	11,480,662	3,167,426	3.62
shingle oak	402,528,673	2,815,132	0.70	17,596,495	2,769,956	6.35
blackjack oak	280,545,827	2,851,693	1.02	10,777,416	722,612	14.91
Total red oak	67,293,738,784	662,356,920	0.98	2,090,748,293	1,522,792,769	1.37
White Oak						
white oak	28,401,475,433	139,793,091	0.49	843,535,496	568,816,692	1.48
chestnut oak	12,831,623,025	96,296,070	0.75	259,564,479	160,100,511	1.62
post oak	6,273,795,886	33,244,411	0.53	212,414,329	136,672,484	1.55
bur oak	1,936,207,204	4,064,910	0.21	93,947,682	15,584,760	6.03
overcup oak	1,522,137,119	12,326,322	0.81	40,340,051	29,043,911	1.39
chinkapin oak	904,100,004	2,287,263	0.25	28,954,892	6,237,172	4.64
swamp chestnut oak	883,000,453	5,083,805	0.58	24,765,460	20,524,158	1.21
swamp white oak	417,660,508	1,159,890	0.28	14,165,984	4,016,859	3.53
Durand oak	24,008,130		0.00	470,805		--
Delta post oak	20,239,202		0.00	833,243	514,152	1.62
dwarf post oak	7,357,431		0.00	674,570		--
Total white oak	53,221,604,395	294,255,762	0.55	1,519,666,991	941,510,699	1.61
Total oak	120,515,343,177	956,612,682	0.79	3,610,415,284	2,464,303,469	1.47

Table 4.—Select red and white oak species

Select red oaks	Select white oaks	
Northern red oak	White oak	Chinkapin
Cherrybark oak	Swamp white oak	Durand oak
Shumard oak	Swamp chestnut oak	Bur oak

Oak Past

Historical disturbance patterns such as clearcuts, fire, or land clearing contributed to oak's current dominance in upland forests (Liptzin and Ashton 1999; Rogers and Johnson 1998; Johnson et al. 2002; Van Lear and Waldrop 1989; Van Lear 1991). However, human land-use changes altered disturbance type and intensity (Abrams 2005; Smith 2005), creating environmental conditions more favorable to other species (Parker and Merritt 1995; Larsen and Johnson 1998; Smith 2005.

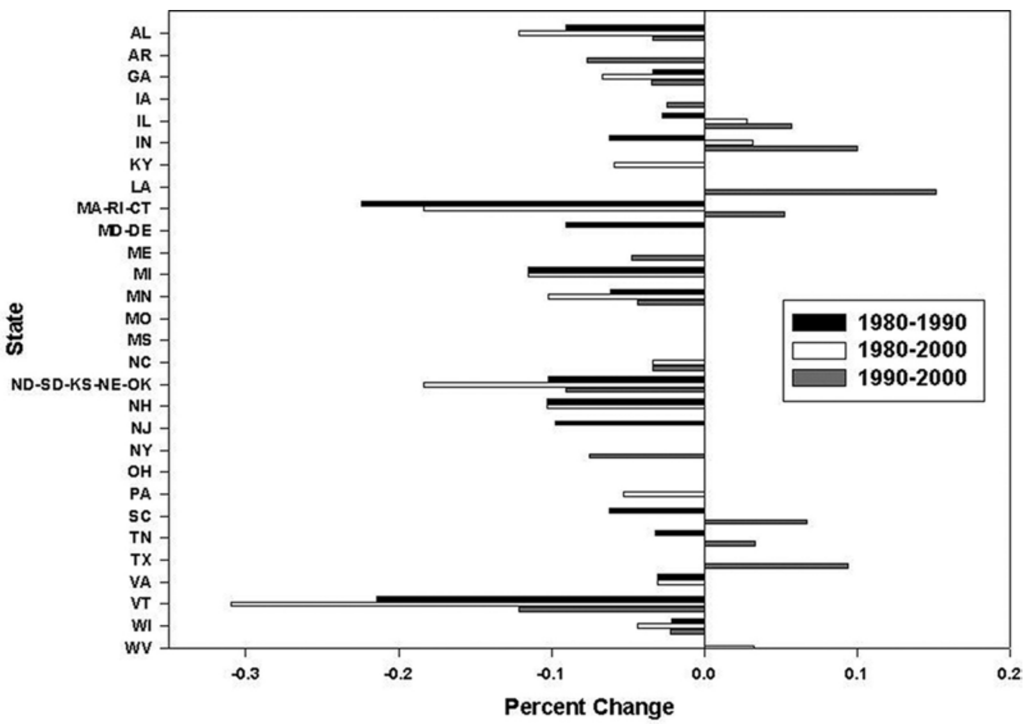

Figure 4.—Percent change in proportion of total basal area of select red oak species in stands with at least 20 ft^2 ac^{-1} of select red oaks, by state and inventory decade.

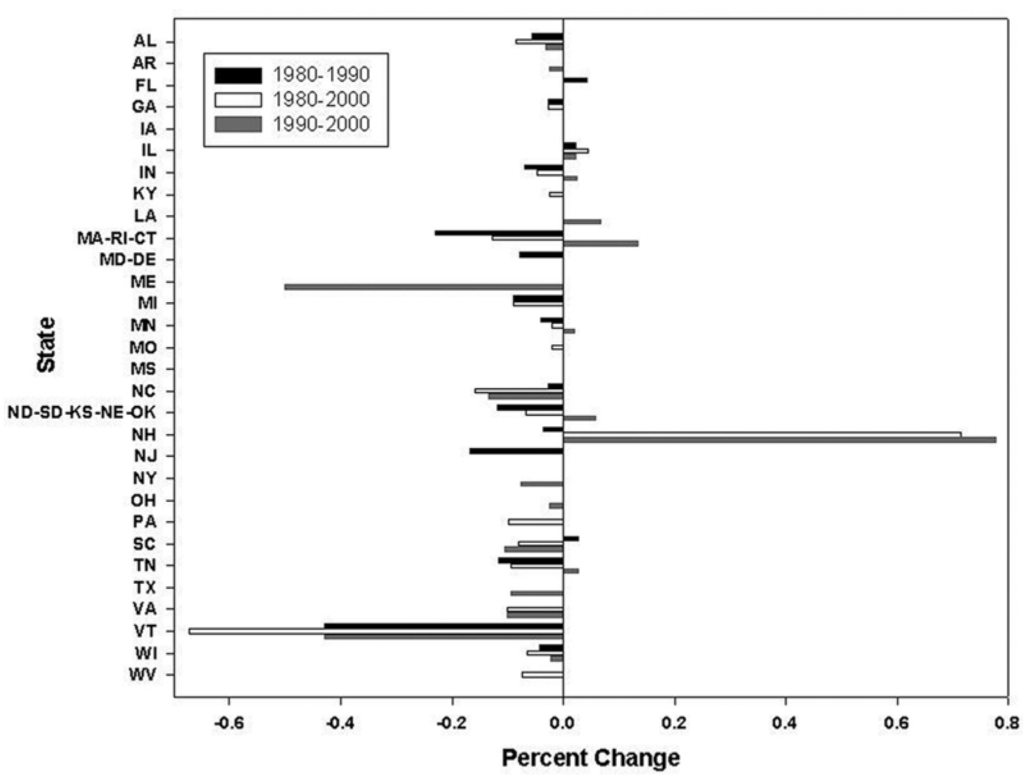

Figure 5.—Percent change in the proportion of total basal area of select white oak species in stands with at least 20 ft^2 ac^{-1} of select white oaks, by state and inventory decade.

We examined temporal trends in the oak resource as a component of total timberland acreage. The dynamic nature of property ownership in this region affects the amount of land area in the timberland base and these changes impact all species. Timberland acreage was highest in the early decades followed by a gradual decline to a low in the 1970's that was sparked by the intensification of land use, particularly the conversion to agriculture in the 50's and 60's, the decline of open space, particularly forestland, to urban development (See Smith, this volume). From 1970 to present, timberland area increased due to the gradual abandonment and reforestation of farmland, particularly during periods of economic downturn in the farm sector.

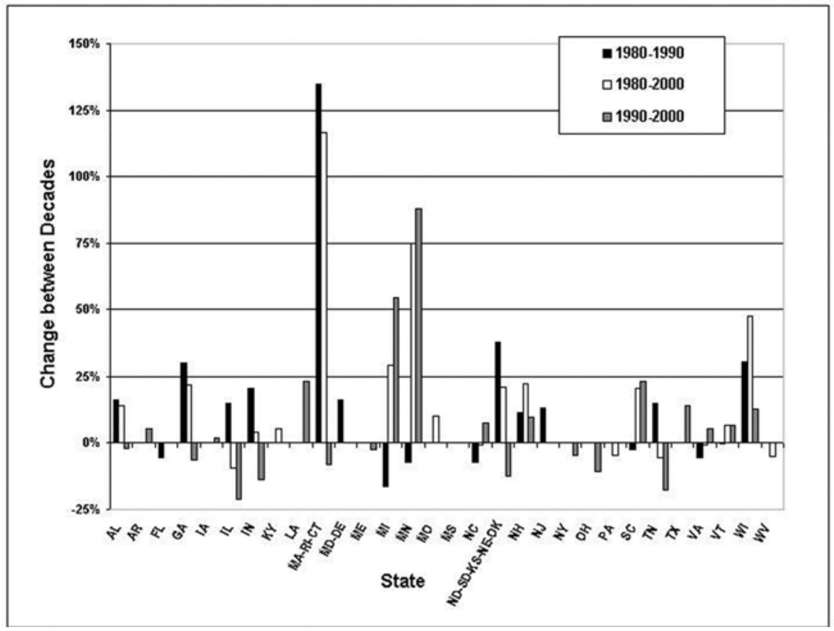

Figure 6.—Percentage change in trees per acre of all species of seedlings/saplings on all timberland, between inventory decades.

Oak Future

A common technique for regenerating oaks is the two-cut shelterwood method (Johnson et al. 2002). To take advantage of oak's life history strategy, the first cut removes enough overstory to create growing space (light on the forest floor) for regeneration. While seedlings/saplings may not grow rapidly in this partial tree shade in the understory (Johnson 1993; Larsen and Johnson 1998), the seedlings/saplings will maintain and expand a root system even while being topkilled repeatedly. With the established root systems, many of the seedlings/saplings are able to grow faster after removal of the residual overstory during the final cut of the shelterwood.

This silvicultural treatment mimics the perceived natural disturbance regime, exemplified by fire, that facilitated natural oak establishment in eastern hardwood stands (Johnson et al. 2002). Oak seedlings/saplings become established in the understory, sometimes in gaps (Ashton and Larson 1996; Rentch et al. 2003) and then undergo a series of topgrowth and dieback until some disturbance releases them to grow to the canopy.

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 oak overstory, with several exceptions, throughout the Eastern United States. Given the relatively long lives of certain oak species, the current oak presence likely reflects disturbance conditions far in the past. However, oak regeneration, should reflect more recent disturbances (or the lack of them). Accordingly, we looked at oak seedling/sapling data from the last one to three inventories in each state to gain insight into the future of oak forests.

The Eastern U.S. forests are not lacking for regeneration. In most states, we have observed increasing seedling/sapling densities of all species between the 1980's and 2000's (Fig. 6). Observed declines in seedling/sapling numbers occurred in certain states between inventories in the 1990s and in the 2000s, and may merely reflect the severe drought conditions in the Midwest (Lawrence et al. 2002) rather than a long-term trend.

Red Oak Regeneration

We first looked at seedlings/saplings of select red oak species in what we defined as select red oak stands. Of these species, northern red oak is the most important component of this category and apparently benefited from the large-scale anthropogenic influences of the 19th and 20th centuries (Abrams 2005) and other factors. Across the Eastern United States we observed increases or slight decreases in the number of select red oak seedlings/saplings per acre over time (Fig. 7). While several states showed dramatic gains in the number of seedlings, most of the changes were more modest.

As with the analysis of red oak in the overstory, we were interested in temporal trends in the proportion of red oak seedlings/saplings to the total number of seedlings/saplings. Across most of the states, we have observed a decline in the percentage of all seedlings/saplings represented by select red oak species over time (Fig. 8).

White Oak Regeneration

As with the red oak seedlings/saplings, we have white oak regeneration information from the last 20 or so years, with some states better represented than others. White oaks were an extremely important component of the pre-settlement landscape (Abrams 2005) and still have the greatest growing-stock volume of any oak species (Table 4). White oaks are more shade tolerant than red oaks, so given the increasing density of deciduous forests in the eastern U.S., we thought there might be evidence of seedling/sapling accumulation in the understory.

While the total number of seedlings/saplings in the understory of stands with select white oak basal area greater than 20 ft^2 ac^{-1} has been increasing, the proportion of all seedlings/saplings that are select white oak seedlings/saplings has been declining over the last several inventories (Fig. 9). The decline in white oak proportion, extending across the entire eastern United States and over several decades, suggests that this trend is neither temporary nor an anomaly of the data, but

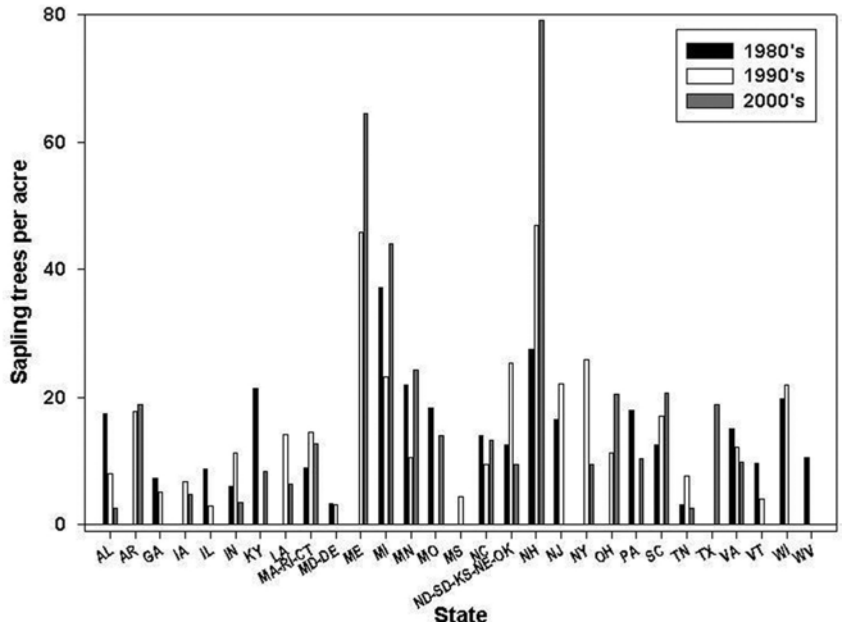

Figure 7.—Select red oak seedlings/saplings per acre, by state and inventory year.

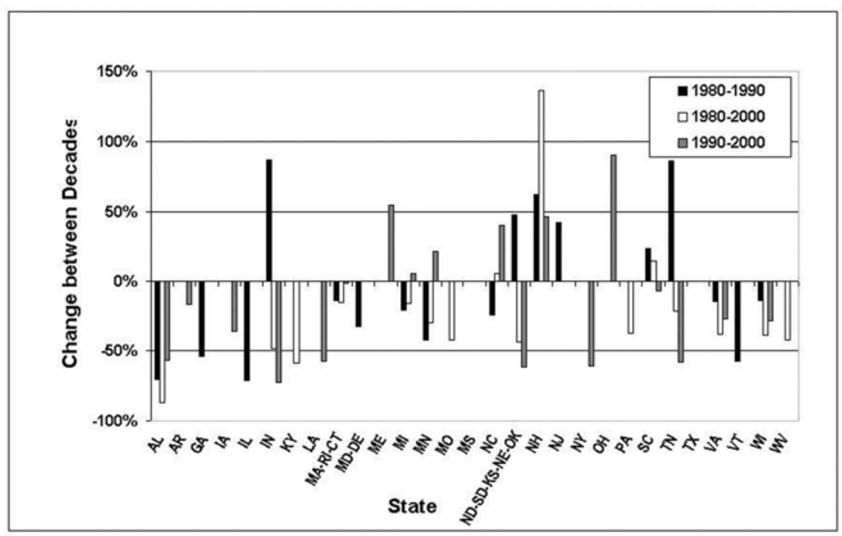

Figure 8.—Percent change in the proportion of all seedlings/saplings that are select red oak species between decades, in stands with at least 20 ft^2 ac^{-1} of select red oak overstory. For example, "1980 – 1990" compares an inventory conducted in the 1990's with the same state's inventory conducted in the 1980's.

a representation of an established trajectory in oak regeneration.

SUMMARY

After reaching its low point in the 1960's and 1970's, timberland in the eastern U.S. has recently started to increase. The oak volume per acre of timberland has increased over the last four to five decades as overstory trees increased in size. While total oak volume has been increasing, there is a decline in the proportion of total timberland with at least 20 ft^2ac^{-1} of select red or white oaks (the "select oak" stands). Within these stands, the select red or white oak basal-area component increased slightly. While the oak basal area has been increasing, it represents a decreasing proportion of the total basal area in the stand.

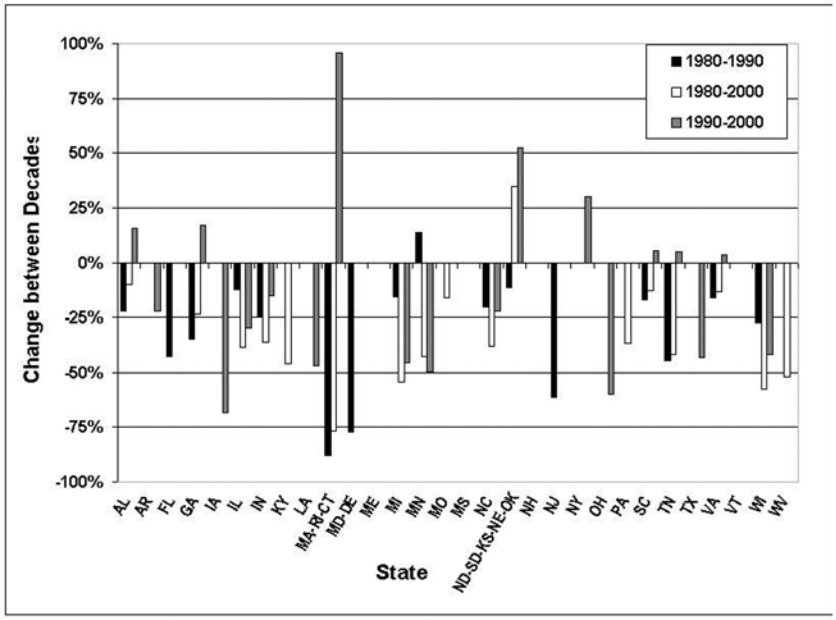

Figure 9.—Percent change in the proportion of all seedlings/saplings that are select white oak species between decades, in stands with at least 20 ft^2 ac^{-1} of select white oak overstory.

Johnson et al. (2002) detailed the importance of accumulating oak regeneration in the understory and outlines the disturbances, anthropogenic and natural, that encourage this accumulation. Such disturbances promote two processes: the concentration of early growth on the oak seedling/sapling root system resulting from repeated dieback of the above-ground component, and the elimination of less fire-resistant species that otherwise would compete successfully for resources. Two of the most prominent disturbances are harvesting and fire. Both disturbances have been declining in eastern oak forests in recent times. Contributing to decreasing proportions of oak seedlings/saplings and seedlings/saplings as reflected in our data across the eastern United States.

The declining proportion of regeneration represented by oak species is particularly disquieting as it provides a foretelling of future forest overstory composition. Given these regeneration trends, it is hard to imagine a future eastern U.S. forest landscape with the current proportion of oaks in the overstory. While reinstituting disturbances such as fire will be problematic in the highly populated landscape of this region, it should be considered part of the toolbox that resource managers use as they seek to maintain the many benefits that oak forest provides.

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