NORTH CAROLINA'S OAK DECLINE:

A STUDY USING FIA DATA

by

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ABSTRACT

Theoretically, forest succession in much of North Carolina will eventually lead to oak-hickory forests. However, the 2002 Forest Inventory and Analysis (FIA) survey shows a decline in many different hardwood species in addition to pines. Although oak-type forestland area increased, total oak growing stock volume decreased from 1990 to 2002 for the first time since 1964. This is the result of increased mortality and removals, and decreased growth. Middle-aged stands saw the most drastic negative changes. Removals by stand initiating activities were 79 percent greater in 2002 than in 1984, while weather-related oak mortality has increased by 1,178 percent since 1984. This corresponds to increased hurricane presence, which averages 0.25 direct landfalls per year. However, the periods corresponding to the 1990 and 2002 FIA surveys averaged 0.5 and 0.42 direct landfalls per year, respectively. The undamaged or non-diseased oak volume also decreased from 79 percent (1984) to 56 percent (2002) of total oak volume.

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INTRODUCTION

Long-term ecosystem changes have always been difficult to quantify. Forests present an especially difficult subject of study due to their marked heterogeneity and long time period over which they change. However, this is exactly the study that must be embarked upon in the state of North Carolina, as over 62 percent (17,684,400 acres) of the state (31,174,900 acres) is classified by the United States Forest Service Forest Inventory and Analysis (FIA) as timberland (Brown 2004), and timberland is being converted to other uses at a rapid rate.

Historically, much of North Carolina was dominated by oak-hickory forests prior to the arrival of Europeans. In the more than four centuries that have passed since European contact, North Carolina has witnessed great ecological change, with the large-scale clearing of forests for farm and range land, followed eventually by pine reforestation due to South-wide farmland abandonment, now changing to the domination of the hardwood as old-field pines transition to succession.

The North Carolina forest covertype patchwork was widely expected to start moving from pine to hardwood dominance over the course of the last half century. Later-successional tree species such as oak and hickory were expected to increase in abundance, while pine acreage and volumes were expected to decrease. However, while pines have decreased in abundance, hardwoods have as well.

Concurrently, North Carolina's forests are under unparalleled threats. Although some farmland is still succeeding to forestland, North Carolina's timberland acreage is declining as the economic success of urban areas has driven the expansion of suburbia.

This study seeks to quantify the direction and magnitude of the dynamic process of forest change, especially in regard to oaks, and to evaluate the causes of forest change, integrating older, historic data with the most current forest census information available. This study has focused almost exclusively on the population dynamics of oaks for several reasons. A more detailed study is possible with a subset of the hardwoods. Oaks are also important ecologically as masting species, economically as timber-producing species, and aesthetically.

DATA

In 1928, the US Forest Service received a Congressional mandate to provide "… a comprehensive survey of the present and prospective requirements for timber and other forest products of the United States…" (McSweeney-McNary Forest Research Act of 1928, P.L.70-466), thus launching the Forest Inventory and Analysis (FIA) program. The goal of this program is to provide a periodic snapshot of the state of our forests approximately every ten years. While the program has evolved greatly over the past 79 years, it has always represented the most comprehensive view of this country's forests.

North Carolina's forests have been surveyed seven times since the program's inception, the first in 1938 and the most recent in 2002. The surveys have become increasingly complex, now examining the state on three different spatial scales, or phases. Phase 1 plots are sampled using remote sensing technology to infer general information such as land use. Phase 2 plots are sampled by FIA inventory foresters who collect a wide range of data on individual trees, including multiple indicators of plot condition, tree size and health, and more detailed land use. Phase 3 plots are subplots of a subset of phase 2 plots and are more intensely sampled for environmental information such as soil depth, soil quality, and air quality. The middle spatial scale ("Phase 2") has been used in this study.

Each phase 2 plot is comprised of one or more conditions. If the condition is forested, the inventory forester estimated the stand age for that condition. This study makes use of this estimation cautiously as many of the stands containing oak trees are uneven-aged and thus stand age is only a rough proxy for tree age.

The national FIA program has recently moved to a new format, Forest Inventory and Analysis Database (FIADB). Currently, three North Carolina surveys are available in FIADB format (1984, 1990, and 2002); however, their use in long-term studies is challenging. No North Carolina surveys preceding 1984 are yet available in electronic format. Additionally, in an amendment to the Food Securities Act, Congress mandated that FIA sufficiently obscure plot locations to protect landowner privacy. Plot numbers were also scrambled to ensure that past information could not be used to identify plot locations in recent surveys. The result is that plots cannot be tracked through time in all of the publicly available FIA surveys.

FIA inventories are constructed to meet specified sampling error rates at the State level to a sixty-seven percent confidence limit. FIA mandates that error pertaining to area estimates cannot exceed three percent per one million acres of timberland (USDA-FS 2006). For areas smaller or larger than one million acres, the error rate increases or decreases, respectively. For example, an area with one hundred thousand acres would have an error rate of 9.5% (i.e., 3% x $1{,}000{,}000)^{(1/2)}/(100{,}000)^{(1/2)}= 9.49\%$) at the sixty-seven percent confidence level. FIA does not mandate a maximum allowable error rate for volume estimates; rather, the volume error rate (five percent per one billion cubic feet of growing stock on timberland) is a target (USDA-FS 2006). However, for each survey, FIA has statistically analyzed the data to estimate error rates (most lower than mandated or suggested error rates) for the different types of data, which this study will use.

While it may be interesting and informative to do analyses on an individual species basis, I have purposefully avoided this due to the higher error rates associated with lower volumes (see above). Instead, I have worked mostly on the basis of genera or other species assemblages to leverage the higher statistical power and lower error rate associated with larger volumes. Thus, instead of examining changes in northern red oak or post oak, I have defaulted to the red and white oak groups, or more commonly, simply oaks (*Quercus spp*.). The one exception is the Appendix, which shows individual species volumes from 1974 to 2002.

All volumes, numbers, and areas are for timberland, which is defined generally as all land having the potential to be productively managed for timber. Specifically, timberland sites must meet each of three criteria. First, timberland sites must be safely accessible to field personnel, and is at least 10-percent stocked by trees of any size or has been so stocked in the past. The site must not be subject to nonforest uses that prevent tree regeneration and succession. Second, timberland sites must be able to produce at least 20 cubic feet of wood per acre per year. This mean annual increment estimate is either from direct tree measurements, or an estimate in the field or office. Third, timberland sites must not include reserved land, on which the management of land for wood production is prohibited (FIADB).

While it would be ideal to conduct these analyses on all forestland, the appropriate data are not currently present in North Carolina surveys. FIA is moving from a periodic to a continuous inventory system; when this change happens, these data will be included. For this study, one must note that the results and conclusions are only representative of timberland. While the percent of total forestland represented by timberland has dropped consistently from 1964 to 2002 mostly due to increased reserved land acreage, it still represents approximately 97 percent of total forestland (see Table 1).

METHODS

FIADB data for 1984, 1990, and 2002 were procured from the FIA website. Unfortunately, no electronic data are available for prior surveys. Additional information from prior surveys was available (via technical bulletins); when available, these gave this study a longer historical context. MS Access 2003 was used in the analysis of electronic FIA data, and data from 1974 and earlier were digitized and manipulated in MS Excel 2003.

All numbers and volumes are for growing stock trees only. Severely damaged and/or diseased trees are not included in these totals, with the exception of Figure 13. Stand age is used throughout this analysis; to make the data manageable, 10-year age classes were made. Volumes of all stands whose age fell inside a given age class were added together, and ascribed to the midpoint of the relevant stand age class.

Stand age is a mediocre proxy for tree age. Oaks are often members of uneven-aged stands; thus, characterizing all trees in a stand as a single age is a simplification of reality. Of most concern are categories with very little volume or very few trees, such as older stands. Error estimates were calculated using the method described above. When two volume figures were added, as with calculating average annual mortality plus removals, the error rate was estimated by adding the two rates. The above calculation yields a sixty-seven percent confidence interval.

RESULTS

Many hardwood genera and species groups are seeing drastic declines (Figures 1 through 3 and Tables 1 through 3). Oaks have sustained 36% of the total hardwood average annual mortality volume despite the fact that they represent 31% of the total hardwood population (Brown 2004). Oaks are declining for the first time since FIA began surveying North Carolina. In 2002, North

Carolina oaks had 87 percent of the 1990 volume and 61 percent of the 1990 number of trees (Table 4). While several other species groups showed comparable volume declines, the only species group showing a greater decline in number of trees is maples (53.2 percent of 1990 numbers), which many view as increasing in forest ecological stature. Only two species groups showed an increase in abundance from 1990 to 2002: tulip poplar (122 percent of the 1990 volume in 2002) and "other" species (109 percent of the 1990 volume in 2002). Of the other hardwoods (see Appendix for species groups), most notable increases come from black cherry (125%), sycamore (131%), ash (105%), and silverbell (127%). The most notable decrease in this category is black locust (60%).

No single species or group of species can account for oak volume decline. Excluding minor oak species such as Shummard and shingle oaks, all oak species declined in volume from 1990 to 2002 (Appendix). Major species that did not decline substantially include southern red oak and chestnut oak. 2002 northern red oak volume was approximately 92% of the 1990 volume; all other species' 2002 volumes were less than 90% of the 1990 volumes. Major oak species showing 2002 volumes with 85% or less of their 1990 volumes include scarlet oak (85%), cherrybark oak (82%), willow oak (81%), laurel oak (73%), black oak (72%), swamp chestnut oak (65%), and post oak (54%). The oak species with the largest volume statewide, white oak, had a 2002 volume which is 87% of its 1990 volume. These species are from both the red and white oak groups, and inhabit both mesic and xeric locations.

While sampling error is somewhat of a concern for individual species analysis, it is less of a concern for oak inventory analysis. Table 3 shows that error estimates are small in comparison with oak inventory changes among survey years.

These declines are statewide. Each of the four North Carolina survey units (Mountains, Piedmont, Northern & Southern Coastal Plain) have declining numbers and volume of oak trees (Figure 4). The Mountains survey unit shows the least amount of decline; the Piedmont oak numbers showed a decline while the Piedmont oak volume did not. The two coastal plain units showed comparable declines in both oak volume and numbers. Because of the corresponding increase in error rate with a decrease in volume, county-level data were not analyzed.

Decreasing timberland area is not among the most important causes of North Carolina oak decline. While total timberland area has been decreasing over the last few surveys, oak-dominated forest types have increased in area since 1984 (Figure 5).

Oak population decline appears to be especially prominent in smaller trees (less than 20 inches in diameter). Figure 6 shows a profound decline of oak trees since 1974 among the small diameter classes. The greatest decline in oak tree numbers has come between 1990 and 2002. Larger oak trees, however, are becoming slightly more abundant. This explains why oak growing stock volume has not declined as rapidly as oak growing stock numbers.

Stands in which oak trees are present, are aging. The percentage of oak growing stock volume in stands belonging to stand age class midpoints less than 60 years is declining. The most profound declines have occurred in stands with stand age class midpoints of 35 to 55 years (see figures 8 and 9). Older stands have increased in numbers and volume, and younger stands have maintained their volumes. However, the majority of the oak wood volume is found in these middle-aged stands.

Over the last three surveys, growth, mortality, and removals each present an increasingly negative picture of oak population dynamics. Figure 9 shows the broad causes of the declining oak population: declining average annual growth, increasing average annual mortality, and increasing average annual removals (hereafter growth, mortality, and removals), over the last three surveys. From a simple accounting perspective, Figure 10 shows that the increased rate of removal plus mortality with the decreased growth rate leads to a loss in inventory. Mortality doubled between 1984 and 1990, then remained roughly unchanged in 2002. In 1990 and 2002, removals increased 35 and 42 percent, respectively, from 1984 levels. Lastly, 1990 and 2002 growth rates were 93 and 78 percent, respectively, of 1984 levels.

In comparison with 1984, 1990 and 2002 showed greatly elevated rates of mortality. 1984 shows somewhat of a higher mortality volume in middle-aged stands (40-100); however, 1990 and 2002 show far higher mortality volumes, especially in this age range (Figure 11). Figure 12 shows mortality broken down by agent of death. Most of the categories show little significant difference between the years; however, average annual weather-related mortality increased dramatically from 1984 to 1990 and 2002.

Direct landfalls of hurricanes or tropical storms are particularly damaging to North Carolina's forests. Figure 15 shows the number of storms that have made direct landfall on the North Carolina coast by decade. This chart shows that the average number of hurricanes per year that made direct landfall on the North Carolina coast during the years of the last two FIA surveys (1984-1990 and 1990-2001) were much higher than in the period corresponding to the 1984 FIA survey (1974 to 1983). 1996 was a particularly active year, with Hurricanes Fran and Bertha and Tropical Storm Arthur all making landfall on North Carolina. Additionally, the average number of hurricanes per year that have made direct landfall on North Carolina since the 2002 FIA survey is at the highest level While it is too early to know if this trend will continue through an entire decade, one could expect that more hurricanes would lead to additional weather-related mortality volume, detected in the next FIA survey.

Another possible weather-related phenomenon is the increase in the number of damaged and diseased trees (those that do not fit the category of "growing stock" but are still living). Figure 6 shows the great drop in the proportion of oak trees that are living, that are considered growing stock (from 83 percent in 1990 to 56 percent in 2002).

Increased removals have also shaped the resulting 2002 oak inventory. Figure 16 shows removals by the age of the stand when the inventory forester conducted the survey. The great volume of wood apparently removed from these young stands (age 5, age class midpoint) is explained by the following example. If a 75-year old mixed hardwood stand had been harvested in 1995, the inventory forester would return to the site in 2002 and record the new stand age (5 or 6 years), estimate the amount of wood removed, and ascribe it to this young stand. Clearly, this wood was not removed from a 5 or 6 year old stand; however, this is the age of the stand when the inventory forester returned to the site. This is the chief shortcoming of a dataset which does not allow the tracking of plots through time; nonetheless, one may conclude that these stands underwent a stand-initiating treatment, such as clearcutting. The 1990 and 2002 average annual removal volumes for this "young" age class midpoint are 65 and 79 percent greater, respectively, than the 1984 average annual removal volume. This indicates a significant increase in the average annual oak volume removed by stand-initiating treatments.

Figure 17 shows the same data with the exclusion of the 5 year age class midpoint datapoints. These data show the volume removed from stands whose age at the time of survey are greater than 10 years old, indicating that these removals were the result of a selective cutting treatment such as a high-grade, seed-tree cut, shelterwood cut, or timber stand improvement. Average annual removals as a result of partial cuts have remained relatively unchanged in the last three surveys. One might surmise that the residual stand age has increased slightly over time, possibly indicating the aging of the oak population; however, the errors associated with volume estimation and stand age estimation (see Discussion) and the sampling error (see Data) prohibit any significant conclusions.

Middle-aged oak stands also show a marked decline in average annual growth (Figure 18). While the youngest stand age class shows an increase in average annual growth, all other stand age classes show a decrease, especially those stands whose age class midpoint is 35 to 55 years. For these middle-aged stands, the 2002 and 1990 average annual growth were estimated at 62 and 84 percent, respectively, of 1984 growth.

DISCUSSION AND CONCLUSION

The results of this oak study are dramatic and significant. For the first time since at least 1964, oak inventory is declining, because of decreased growth, and increased mortality and removals. Especially affected are oaks in middle-aged stands, where decreased growth and increased mortality and removals are most prominent. Elevated average annual oak mortality volumes have been largely the result of weather-related injuries, which have likely affected the dramatic rise in the proportion of oak volume that is damaged or diseased. Increases in North Carolina hurricane landfall since the most recent FIA inventory may result in further increases in weather-related mortality.

A declining and damaged oak population would be expected to yield a lower total volume of mast. Many different species, from acorn weevils to turkeys and even black bears, depend on acorns, which are high protein and starch. Smaller mast production would negatively affect North Carolina forests' carrying capacities for these species.

These trends will also have an economic impact in North Carolina. While oak sawtimber markets are much stronger in the west than in the east, a rough estimation of the impact of increased mortality on North Carolina's timber industry can be made with a composite of oak and hardwood prices across the state ($26.24 per ton in the fourth quarter of 2006, Forest2Market). Also assuming an approximate conversion of 7 tons per one thousand board feet (MBF), mortality of 261,607 MBF of sawtimber per year from 1990 to 2001 translates to an average annual loss of $48,000,000 in stumpage revenues. Mortality losses from 1984 to 1989 and from 1974 to 1983 are likewise estimated at $38,700,000 and $17,300,000 per year, assuming current prices. These numbers are an underestimate in several regards: stumpage value, shown above, is only a portion of a tree's economic worth; contributions to North Carolina's economy that are not captured in the above measure include transportation, milling, exportation, and finishing.

In the larger context of forest health, this trend is quite disturbing. Damaged and diseased trees are more susceptible to extreme weather and drought, and are better hosts for insects and pathogens, both native and nonnative. Several non-native oak pests have either recently arrived or will soon arrive in North Carolina. Since 1869, the gypsy moth has steadily moved to the south and west of its first introduction site near Boston and currently infests most of Virginia. Its most favored hosts are oaks. Within 3 to 5 years of initial arrival to an area, gypsy moth often kills between 20 and 35 percent of its favored hosts (oaks being the primary); it could be expected that a stressed oak population would sustain higher levels of mortality. There are similar concerns for other pests, including oak wilt and sudden oak death, which are expected to cause extensive mortality among North Carolina's oak population, particularly red oaks.

North Carolina's hardwoods, especially the oaks, are in decline across the state of North Carolina. This trend is the result of increases in both removals and mortality, and decreases in net growth. The results of this study suggest the need for further research to more fully understand North Carolina's rapidly changing hardwood forest.

FIGURES

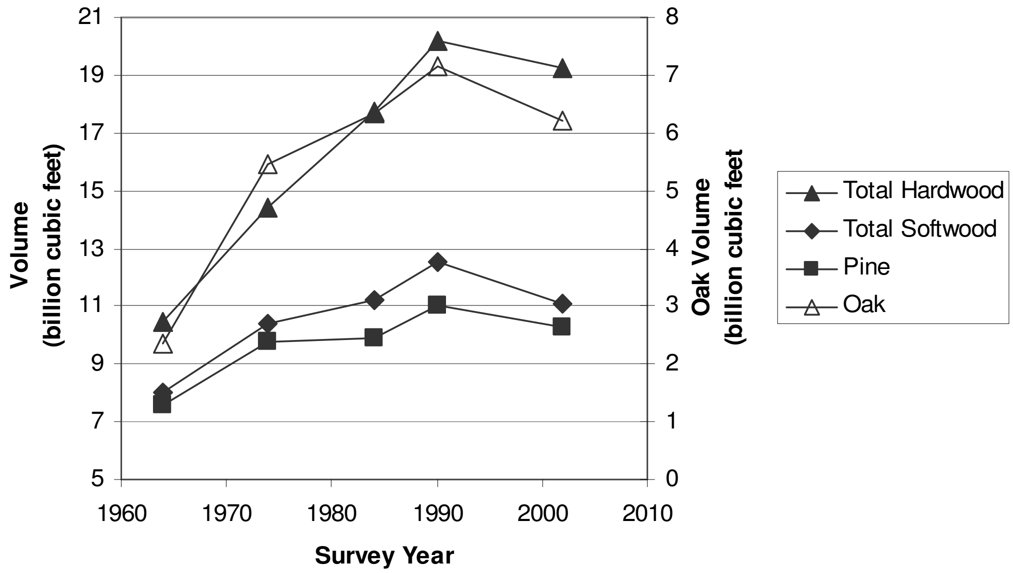

FIGURE 1. Both softwood and hardwood growing stock volumes decreased for the first time since at least 1964. Oak volume has decreased more severely than total hardwood volume.

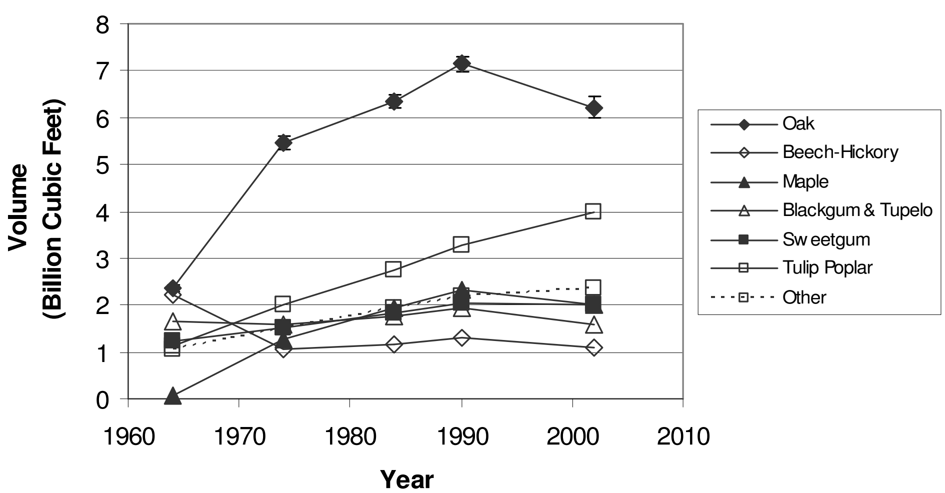

FIGURE 2. North Carolina hardwood growing stock volume by species group and survey year. Until 2002, all species groups showed an increase in volume, with the exception of beech/hickory. However, the 2002 survey showed volume declines for all but two hardwood species groups: tulip poplar and other (includes magnolias, ash, sycamore, black walnut and cherry, among others—see Appendix 2). While oaks displayed the fourth-largest percent drop in volume (maples, beech/hickory, and blackgum were lower), oaks showed the second largest drop in absolute volume. Because of the larger volume, the oak volume decrease has the lowest associated error rate of all categories (see DATA).

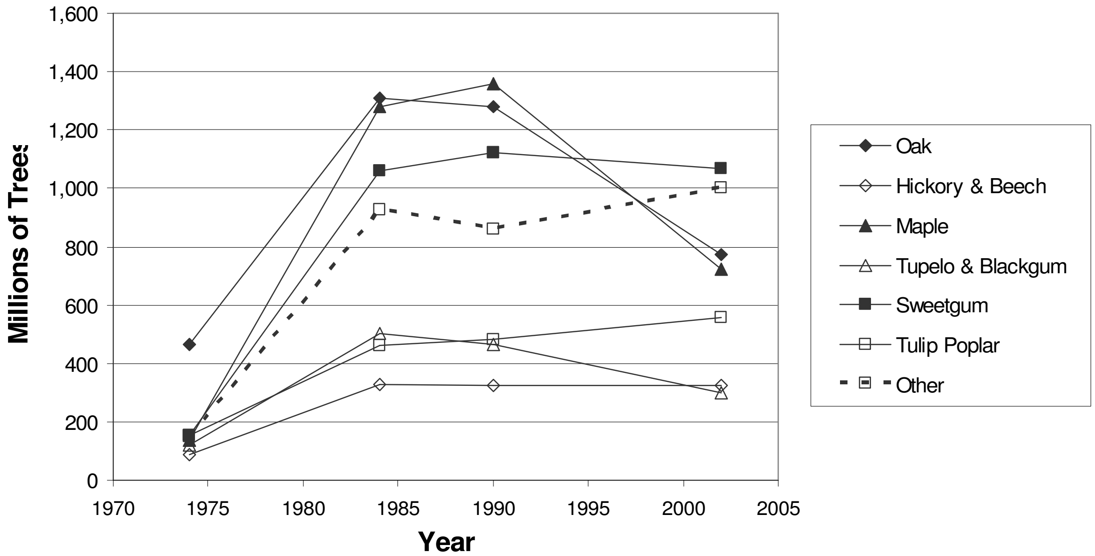

FIGURE 3. North Carolina hardwood growing stock by number of trees and survey year. As in figure 2, oaks have the second largest percent decline from 1990 to 2002, while maples have the largest.

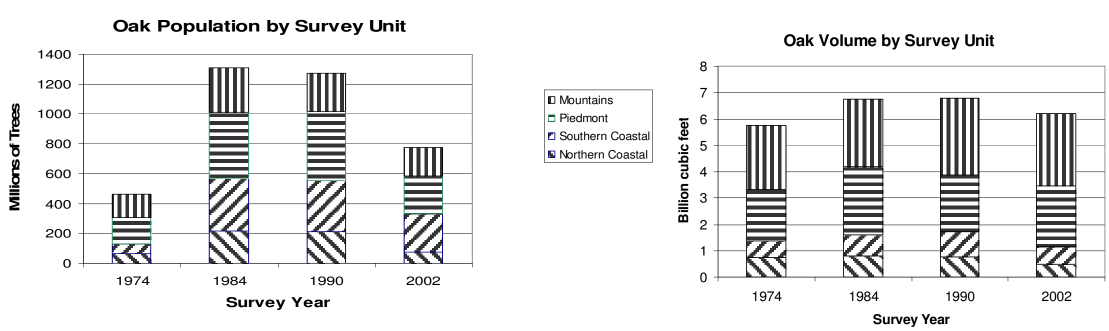

FIGURE 4. North Carolina growing stock oak population by survey unit and year. The drop in number of trees (left) from 1990 to 2002 occurred in every North Carolina survey unit. All units except the Piedmont showed declines in volume from 1990 to 2002.

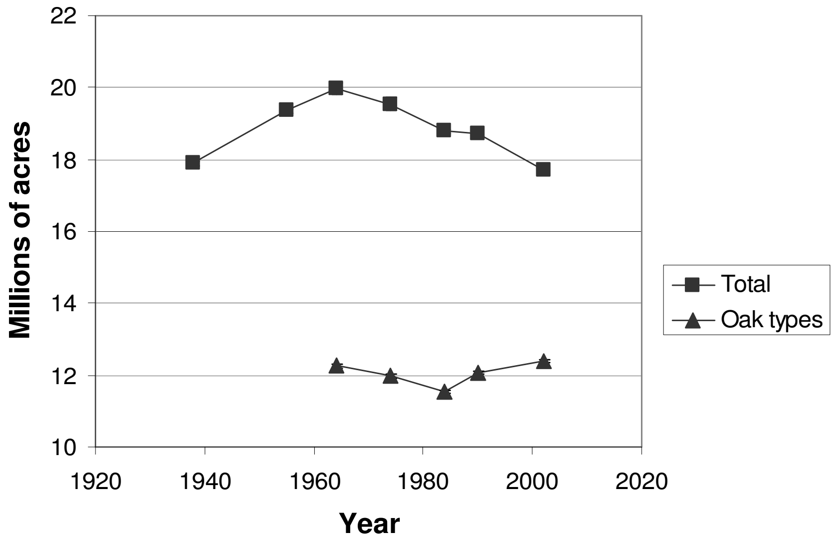

FIGURE 5. Total North Carolina commercial forestland has decreased over 6 percent since 1984; however, oak-dominated commercial forestland (oak-pine, oak-hickory, and oak-gum-cypress) has increased by 7 percent during the same time period. Error bars are too small to be displayed.

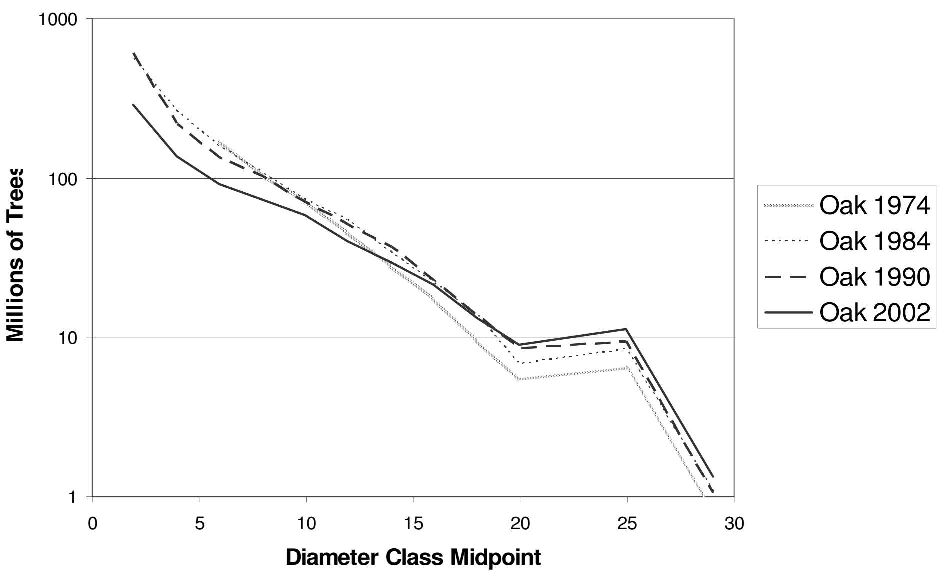

FIGURE 6. The number of growing stock oak trees in North Carolina by diameter class midpoint and survey year. The number of small trees has steadily declined since 1974, with the greatest drop from 1990 to 2002. Larger trees (20 inches and greater in diameter) have become more abundant.

FIGURE 7. North Carolina oak volume by ten year stand age classes. Stand age class midpoints from 35 to 55 years show the most marked declines from 1984 to 2002.

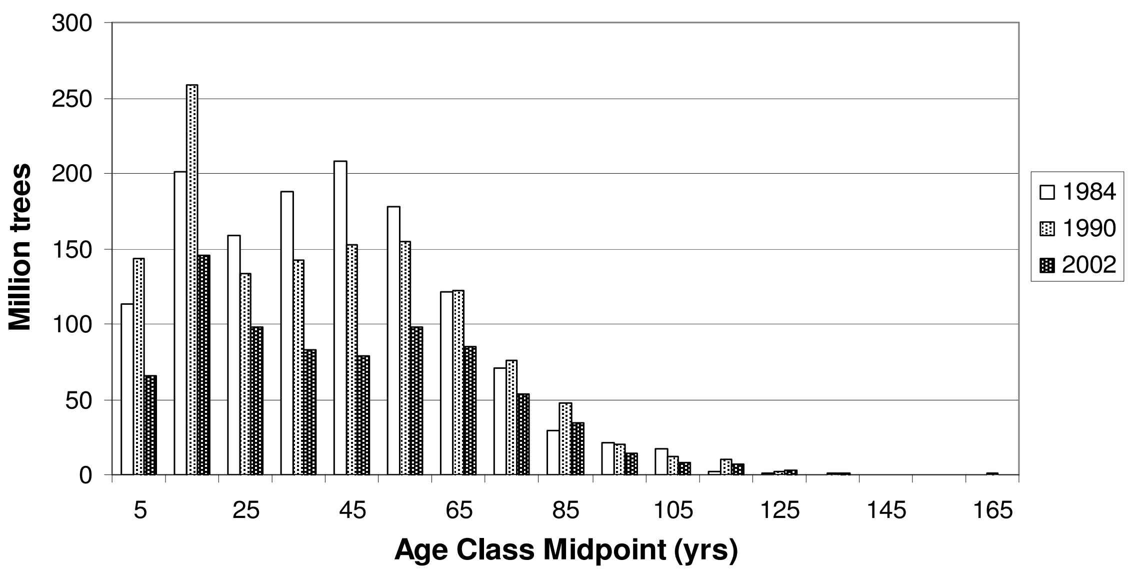

Figure 8. North Carolina oak population structure by ten year age classes. As in Figure 8, stand age class midpoints from 35 to 55 years show an especially large decline from 1984 to 2002.

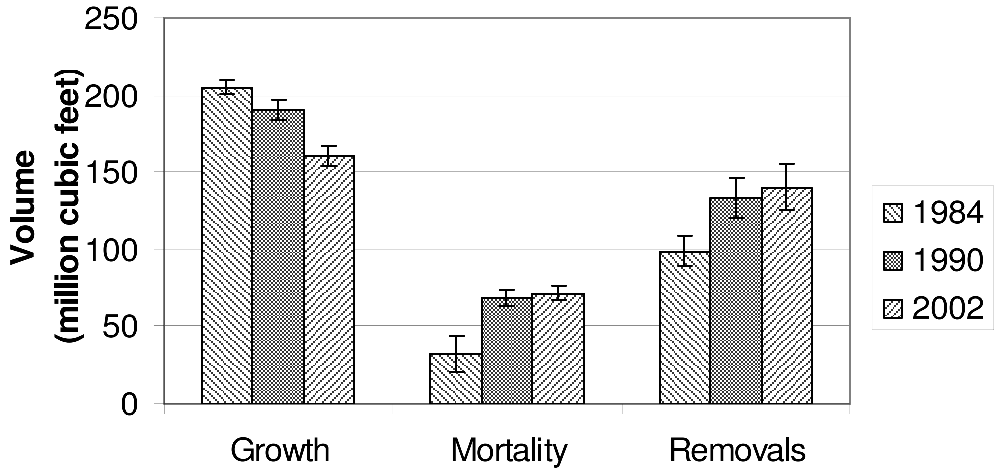

FIGURE 9. Average annual growth, mortality, and removals of North Carolina oak population by survey year. Error bars represent the sixty-seven percent confidence level (see DATA).

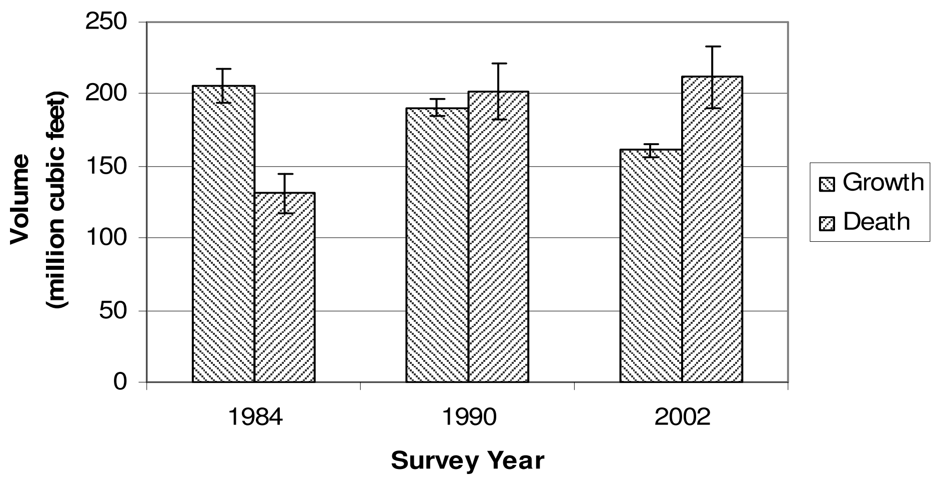

FIGURE 10. Total average annual growth, and removals plus mortality, of North Carolina oaks by survey year. Error bars represent the sixty-seven percent confidence level.

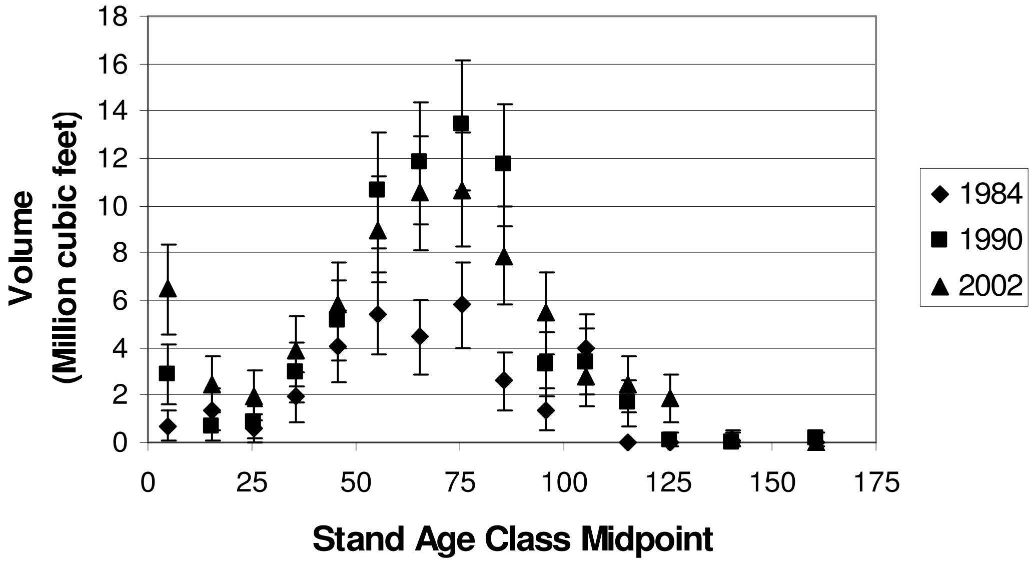

FIGURE 11. Average annual mortality of North Carolina oaks by stand age class midpoint. Note especially high mortality in mid-aged stands, and impressive increase in mortality of young stands. Note that error estimates have used 2002 error rates, as error was not estimated for mortality prior to 2002.

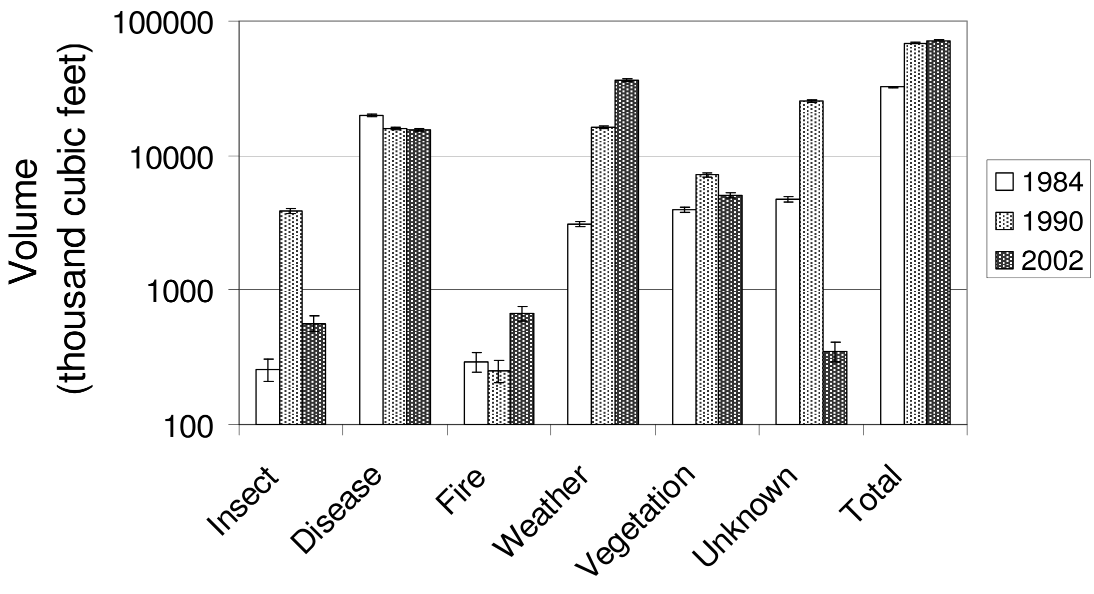

Figure 12. Mortality by the agent of death, and survey year, with error estimates. Error bars indicate the sixty-seven percent confidence level.

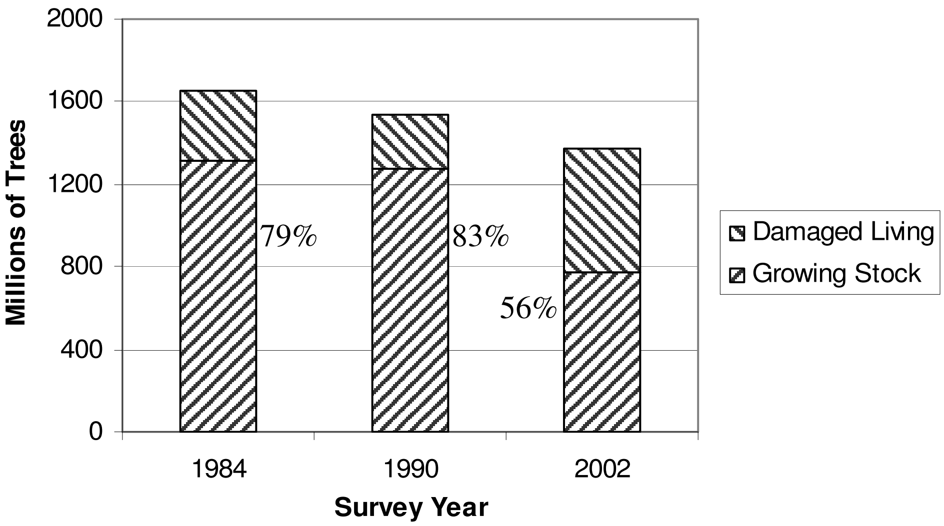

FIGURE 13. The proportion of total living oak trees that are growing stock decreased greatly from 1984 and 1990 to 2002, to 56 percent. The loss of growing stock to cull stock partly accounts for the precipitous drop in oak growing stock numbers.

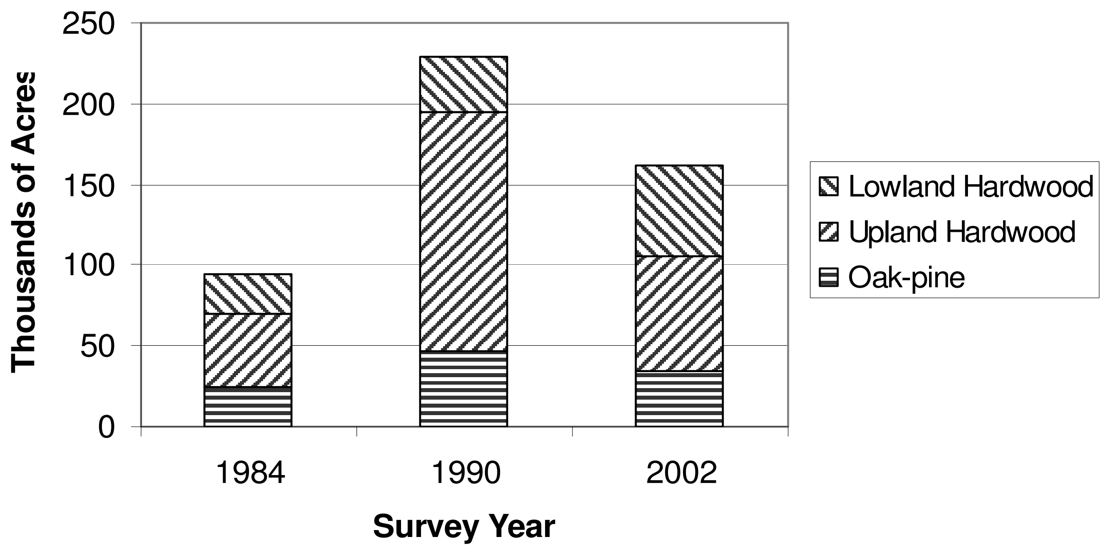

Figure 14. The oak-type acreage affected by natural disturbance has risen since 1984, especially in upland hardwood forests.

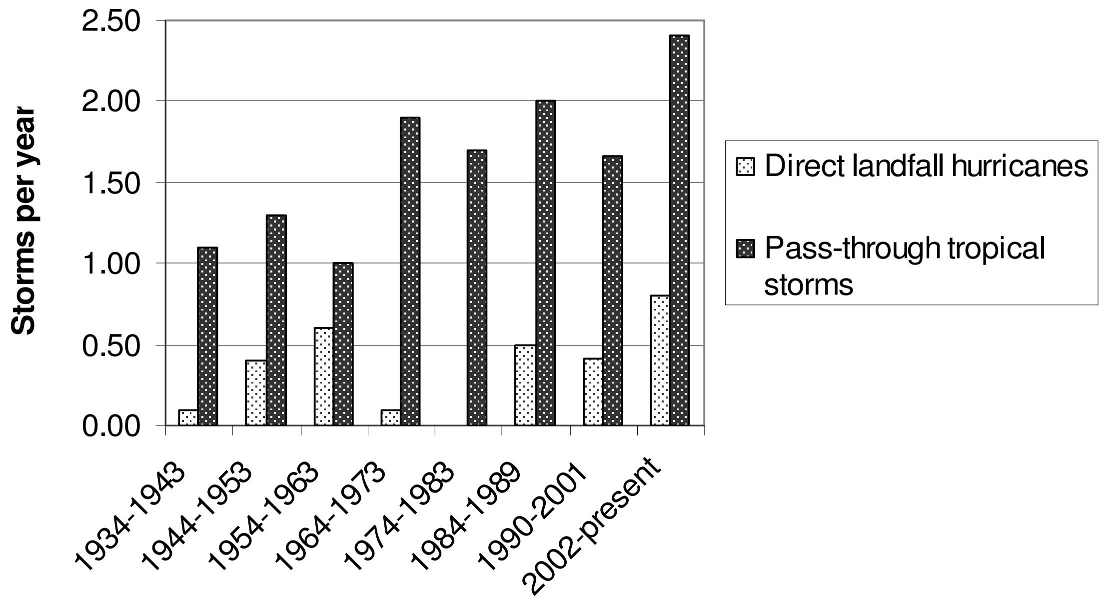

Figure 15. While average annual tropical storms that pass through the state have remained roughly unchanged since 1964, the average number of hurricanes that make direct landfall on the coast of North Carolina have increased dramatically from 1974-1983 (corresponds to FIA 1984 survey) to 1984-1989 (corresponds to FIA 1990 survey) and 1990-2001 (corresponds to FIA 2002 survey). Data courtesy of the State Climate Office of North Carolina.

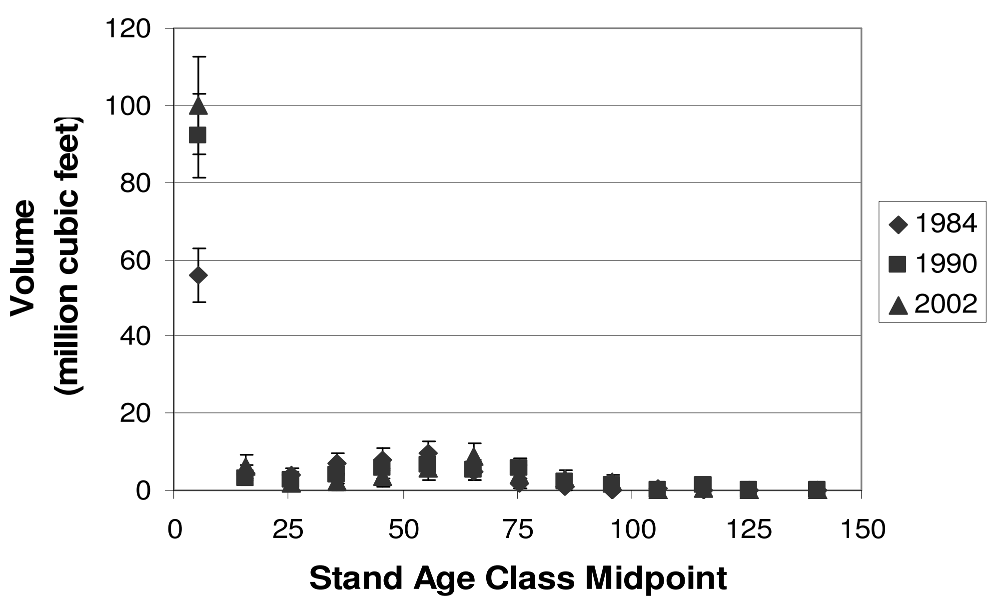

FIGURE 16. Average annual removals of North Carolina oaks by stand age. Note what seems to be the high incidence of removals at young stand ages. This indicates that, at the time of the survey, these stands had already been clearcut (or at least the majority of stems removed) so that the age of the stand is between 0 and 10 years old. The fact that this point has increased from 1984 to 2002 indicates an increase in stand-initiating activities of stands with oaks present.

FIGURE 17. This version of figure 16 excludes the five-year-old age class midpoint stands, showing the removal of oaks by the residual stand age class midpoint. Unfortunately, the residual stand age is not a reliable indicator of the stand age prior to disturbance, as evidenced in figure 16.

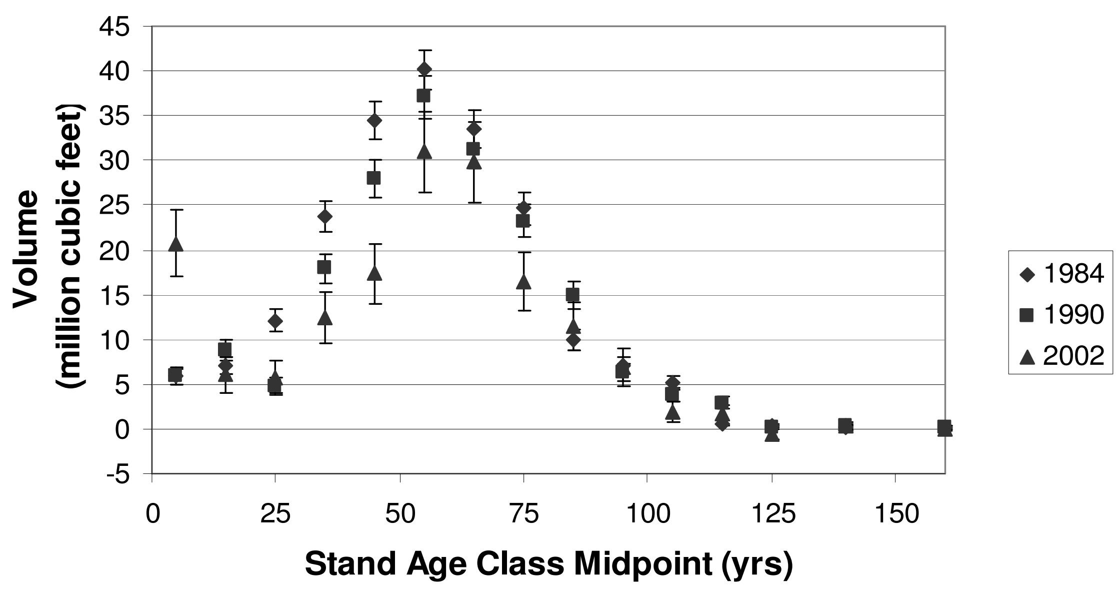

FIGURE 18. Average annual oak volume growth has declined dramatically. In middle-aged stands (age class midpoint from 35 to 55), 1990 and 2002 growth were estimated at 84 and 62 percent of 1984 growth estimates.

TABLE 1. North Carolina land use from 1964 to 2002 (thousands of acres).

Year	All Uses	Forestland				Nonforest
		Total	Timberland	Productive Reserved	Other	
1964	31,367.30	20,448.10	20,027.30	372.00	48.80	10,919.20
1974	31,287.54	20,024.86	19,544.84	433.79	46.23	11,262.68
1984	31,228.22	18,952.86	18,450.27	459.78	42.81	12,275.36
1990	31,060.30	19,277.55	18,710.38	524.36	42.81	11,782.75
2002	31,174.90	18,268.70	17,684.40	552.10	32.10	12,906.20

TABLE 2. Growing stock volume (billion cubic feet) of North Carolina hardwood species groups, and associated error.

Volume					
	1964	**1974**	**1984**	**1990**	**2002**
Oak	2.352	5.465	6.332	7.137	6.207
Hickory-Beech	2.209	1.063	1.158	1.316	1.077
Maple	0.084	1.265	1.932	2.332	1.993
Sweetgum	1.246	1.526	1.827	2.051	2.011
Nyssa spp.	1.649	1.592	1.767	1.937	1.571
Other	1.063	1.498	1.931	2.168	2.371
Tulip Poplar	1.123	2.011	2.763	3.271	3.991
Error					
	1964	**1974**	**1984**	**1990**	**2002**
Oak	0.072	0.137	0.145	0.164	0.233
Hickory-Beech	0.070	0.060	0.062	0.070	0.097
Maple	0.014	0.066	0.080	0.094	0.132
Sweetgum	0.053	0.072	0.078	0.088	0.133
Nyssa spp.	0.061	0.074	0.077	0.085	0.117
Other	0.049	0.071	0.080	0.090	0.144
Tulip Poplar	0.050	0.083	0.096	0.111	0.187

TABLE 3. Number of North Carolina hardwood trees (millions of trees) by species groups.

	1974	**1984**	**1990**	**2002**
Oak	463.93	1,310.90	1,280.12	774.25
Hickory-Beech	86.17	327.50	323.15	323.15
Maple	135.66	1,280.47	1,357.76	721.84
Sweetgum	153.97	1,059.23	1,121.65	1,068.78
Nyssa spp.	120.48	504.27	465.76	299.82
Other	150.32	926.77	861.69	999.96
Tulip Poplar	151.88	460.96	481.65	555.67

TABLE 4. Percent of 1990 tree numbers and volumes in 2002.

	Volume	Number
Oak	87.0	60.5
Hickory-Beech	81.8	100.0
Maple	85.5	53.2
Sweetgum	98.1	95.3
Nyssa spp.	81.1	64.4
Other	109.4	116.0
Tulip Poplar	122.0	115.4

TABLE 5. Total oak growing stock volume (billion cubic feet) for stands aged greater and less than sixty years.

	1984	1990	2002
< 60	3.309	3.056	2.727
> 60	3.022	4.078	4.039

TABLE 6. Growing stock volume (million cubic feet) of North Carolina hardwood groups. Note that in 2002, Chestnut Oak was included in Other White Oaks. Likewise, groups such as Bay & Magnolia were included in Other Eastern Hardwoods until 1974.

	1964	1974	1984	1990	2002
Select white oaks	1,069.00	1,556.55	1,762.54	2,065.31	1,772.30
Select red oaks	479.20	696.45	905.28	1,031.53	959.90
Chestnut oak	0.00	807.85	1,018.43	1,195.78	
Other white oaks	803.50	324.37	322.25	303.50	1,352.90
Other red oaks	1,398.40	2,079.83	2,323.23	2,541.24	2,121.90
Hickory	609.30	820.40	871.77	960.84	818.20
Yellow birch	30.00	42.90	44.73	67.88	45.80
Hard maple	54.40	87.16	123.35	173.11	127.30
Soft maple	810.50	1,178.16	1,808.74	2,158.62	1,866.10
Beech	134.10	243.09	286.58	355.37	258.30
Sweetgum	1,246.20	1,526.30	1,827.07	2,051.01	2,011.10
Tupelo & Blackgum	1,649.10	1,592.00	1,766.58	1,936.77	1,571.30
Ash	242.80	309.12	431.58	487.67	515.60
Cottonwood	6.70	21.80	26.46	28.22	22.90
Basswood	61.10	71.31	116.10	129.95	115.60
Yellow-poplar	1,123.00	2,011.05	2,762.95	3,271.17	3,990.70
Bay & Magnolia		71.37	111.15	178.46	157.00
Black Cherry	28.70	47.70	74.58	85.44	106.70
Black Walnut	25.70	27.42	42.97	48.83	51.70
Sycamore		67.00	83.87	102.99	135.20
Black Locust		176.64	213.73	230.87	138.80
Elm		180.05	200.36	199.50	180.70
Other Eastern Hardwoods	667.60	483.02	585.70	607.89	900.80
Total Hardwoods	10,439.30	14,421.53	17,709.98	20,211.96	19,220.80

Table 7. Disturbance type by acreage and survey year, for oak-type forests. Listed below is the corresponding 67 percent confidence interval.

	1984	1990	2002
Final harvest	134,856	164,205	120,700
Partial harvest	47,113	37,630	49,600
Commercial thinning	6,351	2,238	3,700
Other stand improvements	8,302	4,662	4,500
Site preparation	41,310	49,481	31,600
Other treatment	41,208	60,786	35,800
Natural disturbance	94,733	228,990	130,100
Final harvest	3,415	3,647	4,993
Partial harvest	2,019	1,746	3,200
Commercial thinning	741	426	874
Other stand improvements	847	615	964
Site preparation	1,890	2,002	2,555
Other treatment	1,888	2,219	2,719
Natural disturbance	2,862	4,307	5,183

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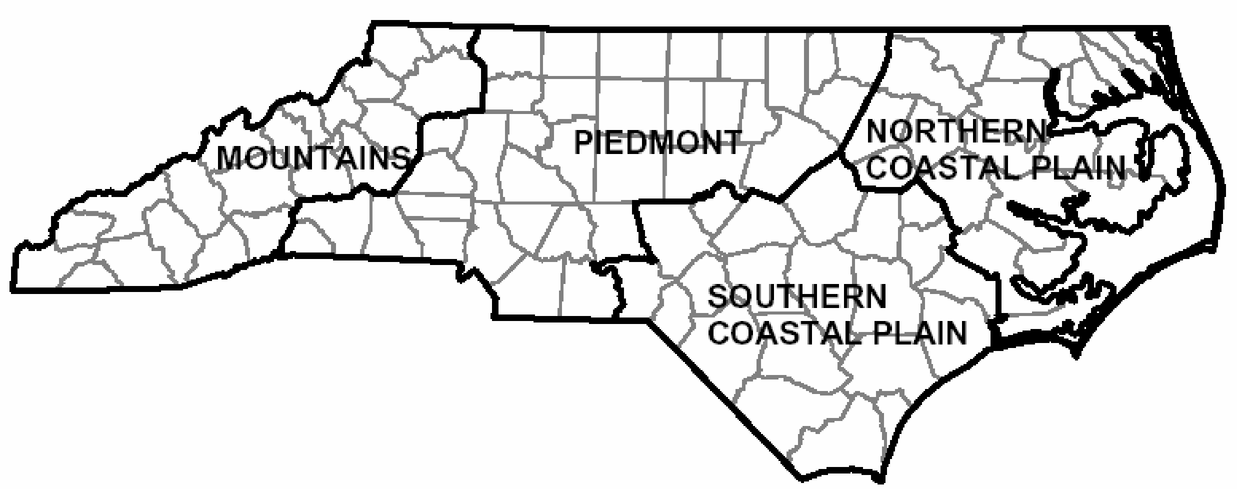
APPENDIX 1: North Carolina FIA Survey Units



APPENDIX 2: North Carolina Species and Volumes: 1984, 1990, and 2002

Name		Code or Group				Growing Stock Volume (million cubic feet)			
Common Name	***Scientific Name***	***Sp. Code***	***Sp. Grp. Code***	***Species Group Code Name***	***Group***	***1984***	***1990***	***2002***	***2002 / 1990***
slash pine	Pinus elliottii	111	1	Longleaf and Slash Pines	Softwood	129.46	182.62	73.16	40%
longleaf pine	Pinus palustris	121	1	Longleaf and Slash Pines	Softwood	442.61	418.26	406.78	97%
shortleaf pine	Pinus echinata	110	2	Loblolly and Shortleaf Pines	Softwood	1,336.69	1,289.13	718.46	56%
loblolly pine	Pinus taeda	131	2	Loblolly and Shortleaf Pines	Softwood	5,650.85	6,541.62	6,610.59	101%
Table Mountain pine	Pinus pungens	123	3	Other Yellow Pines	Softwood	21.89	27.05	19.29	71%
pitch pine	Pinus rigida	126	3	Other Yellow Pines	Softwood	186.73	201.88	117.18	58%
pond pine	Pinus serotina	128	3	Other Yellow Pines	Softwood	815.97	796.78	439.91	55%
Virginia pine	Pinus virginiana	132	3	Other Yellow Pines	Softwood	1,304.11	1,546.31	1,058.87	68%
eastern white pine	Pinus strobus	129	4	Eastern White and Red Pines	Softwood	591.84	716.91	854.35	119%
spruce spp.	Picea spp	90	6	Spruce and Balsam Fir	Softwood	18.37	20.40		176%
red spruce	Picea rubens	97	6	Spruce and Balsam Fir	Softwood			35.87	
hemlock spp.	Tsuga	260	7	Eastern Hemlock	Softwood	184.39	217.15		119%
eastern hemlock	Tsuga canadensis	261	7	Eastern Hemlock	Softwood			255.46	
Carolina hemlock	Tsuga caroliniana	262	7	Eastern Hemlock	Softwood			2.98	
baldcypress	Taxodium distichum	221	8	Cypress	Softwood	335.86	325.02	301.53	93%

pondcypress	Taxodium ascendens	222	8	Cypress	Softwood	86.41	110.86	107.02	97%
Fraser fir	Abies fraseri	16	9	Other Eastern Softwoods	Softwood			3.70	
Atlantic white-cedar	Chamaecyparis thyoides	43	9	Other Eastern Softwoods	Softwood	77.71	73.30	26.34	36%
redcedar / juniper	Juniperus	57	9	Other Eastern Softwoods	Softwood	57.59	63.10		115%
southern redcedar	Juniperus virginiana var. silicicola	67	9	Other Eastern Softwoods	Softwood			0.07	
eastern redcedar	Juniperus virginiana	68	9	Other Eastern Softwoods	Softwood			72.49	
white oak	Quercus alba	802	25	Select White Oaks	Oak	1,644.40	1,946.29	1,697.56	87%
swamp white oak	Quercus bicolor	804	25	Select White Oaks	Oak	10.65	9.94	2.43	24%
swamp chestnut oak	Quercus michauxii	825	25	Select White Oaks	Oak	107.48	109.09	71.34	65%
chinkapin oak	Quercus muehlenbergii	826	25	Select White Oaks	Oak	0.00		0.96	
cherrybark oak	Quercus pagoda	813	26	Select Red Oaks	Oak	76.89	69.53	56.99	82%
northern red oak	Quercus rubra	833	26	Select Red Oaks	Oak	821.67	949.90	881.05	93%
Shumard oak	Quercus shumardii	834	26	Select Red Oaks	Oak	6.72	12.09	21.82	180%
overcup oak	Quercus lyrata	822	27	Other White Oaks	Oak	43.13	38.16	17.39	46%
chestnut oak	Quercus prinus	832	27	Other White Oaks	Oak	1,018.43	1,195.78	1,191.67	100%
post oak	Quercus stellata	835	27	Other White Oaks	Oak	279.11	265.34	143.62	54%
live oak	Quercus virginiana	838	27	Other White Oaks	Oak	0.00	0.00	0.18	
scarlet oak	Quercus coccinea	806	28	Other Red Oaks	Oak	753.00	801.42	679.48	85%
southern red oak	Quercus falcata	812	28	Other Red Oaks	Oak	400.86	419.18	417.30	100%
shingle oak	Quercus imbricaria	817	28	Other Red Oaks	Oak	1.61	1.96	5.09	259%
laurel oak	Quercus laurifolia	820	28	Other Red Oaks	Oak	205.75	224.50	164.25	73%
blackjack oak	Quercus marilandica	824	28	Other Red Oaks	Oak			16.28	
water oak	Quercus nigra	827	28	Other Red Oaks	Oak	272.80	296.96	259.17	87%
pin oak	Quercus palustris	830	28	Other Red Oaks	Oak	5.65	5.23		
willow oak	Quercus phellos	831	28	Other Red Oaks	Oak	227.17	283.58	229.01	81%
black oak	Quercus velutina	837	28	Other Red Oaks	Oak	456.38	508.41	367.60	72%
hickory spp.	Carya	400	29	Hickory	Beech-hickory	871.77	960.84	0.17	85%
water hickory	Carya aquatica	401	29	Hickory	Beech-hickory			2.64	
bitternut hickory	Carya cordiformis	402	29	Hickory	Beech-hickory			25.36	
pignut hickory	Carya glabra	403	29	Hickory	Beech-hickory			404.92	
pecan	Carya illinoinensis	404	29	Hickory	Beech-hickory			0.39	
shellbark hickory	Carya laciniosa	405	29	Hickory	Beech-hickory			1.25	

shagbark hickory	Carya ovata	407	29	Hickory	Beech-hickory			65.64	
mockernut hickory	Carya alba	409	29	Hickory	Beech-hickory			317.85	
yellow birch	Betula alleghaniensis	371	30	Yellow Birch	Other	44.73	67.88	45.77	67%
Acer barbatum	Florida maple	311	31	Hard Maple	Maple	10.38	9.94	9.56	96%
sugar maple	Acer saccharum	318	31	Hard Maple	Maple	112.97	163.17	117.23	72%
chalk maple	Acer leucoderme	323	31	Hard Maple	Maple			0.49	
red maple	Acer rubrum	316	32	Soft Maple	Maple	1,793.89	2,134.22	1,855.04	87%
silver maple	Acer saccharinum	317	32	Soft Maple	Maple	3.33	8.37	0.22	3%
American beech	Fagus grandifolia	531	33	Beech	Beech-hickory	286.58	355.37	258.34	73%
sweetgum	Liquidambar styraciflua	611	34	Sweetgum	Sweetgu m	1,827.07	2,051.01	2,011.15	98%
water tupelo	Nyssa aquatica	691	35	Tupelo and Blackgum	Tupelo and Blackgu m	426.75	504.00	465.68	92%
blackgum	Nyssa sylvatica	693	35	Tupelo and Blackgum	Tupelo and Blackgu m	153.34	193.65	226.70	117%
swamp tupelo	Nyssa biflora	694	35	Tupelo and Blackgum	Tupelo and Blackgu m	1,186.50	1,239.13	878.94	71%
ash spp.	Fraxinus	540	36	Ash	Other	431.58	487.67		104%
white ash	Fraxinus americana	541	36	Ash	Other			223.64	
green ash	Fraxinus pennsylvanica	544	36	Ash	Other			226.89	
pumpkin ash	Fraxinus profunda	545	36	Ash	Other			58.43	
cottonwood and poplar spp.	Populus	740	37	Cottonwood and Aspen	Other	26.46	28.22		84%
balsam poplar	Populus balsamifera	741	37	Cottonwood and Aspen	Other			11.25	
eastern cottonwood	Populus deltoides	742	37	Cottonwood and Aspen	Other			11.60	
bigtooth aspen	Populus grandidentata 37 3 X X X	743	37	Cottonwood and Aspen	Other			0.78	
basswood spp.	Tilia	950	38	Basswood	Other	116.10	129.95		89%
American basswood	Tilia americana	951	38	Basswood	Other			62.14	
white basswood	Tilia americana var. heterophylla	952	38	Basswood	Other			52.15	
Carolina basswood	Tilia americana var. caroliniana	953	38	Basswood	Other			1.33	
yellow-poplar	Liriodendron tulipifera	621	39	Yellow Poplar	Yellow Poplar	2,762.95	3,271.18	3,990.67	122%
black walnut	Juglans nigra	602	40	Black Walnut	Other	42.97	48.83	51.69	106%

boxelder	Acer negundo	313	41	Other Eastern Soft Hardwoods	Other	11.52	16.02	10.88	68%
buckeye, horsechestnut	Aesculus	330	41	Other Eastern Soft Hardwoods	Other	33.24	37.80		85%
yellow buckeye	Aesculus flava	332	41	Other Eastern Soft Hardwoods	Other			32.05	
birch spp.	Betula	370	41	Other Eastern Soft Hardwoods	Other	352.97	399.67		96%
river birch	Betula nigra	373	41	Other Eastern Soft Hardwoods	Other			97.83	
hackberry spp.	Celtis	460	41	Other Eastern Soft Hardwoods	Other	33.57	38.66		143%
sugarberry	Celtis laevigata	461	41	Other Eastern Soft Hardwoods	Other			23.13	
hackberry	Celtis occidentalis	462	41	Other Eastern Soft Hardwoods	Other			32.11	
loblolly-bay	Gordonia lasianthus	555	41	Other Eastern Soft Hardwoods	Other	33.77	79.88	63.82	80%
silverbell	Halesia	580	41	Other Eastern Soft Hardwoods	Other	20.54	25.92	33.01	127%
butternut	Juglans cinerea	601	41	Other Eastern Soft Hardwoods	Other	3.02	3.27	0.84	26%
cucumbertree	Magnolia acuminata	651	41	Other Eastern Soft Hardwoods	Other	42.81	50.85	48.65	105%
southern magnolia	Magnolia grandiflora	652	41	Other Eastern Soft Hardwoods	Other	33.17	44.48	0.24	
sweetbay	Magnolia virginiana	653	41	Other Eastern Soft Hardwoods	Other	44.22	54.10	27.63	
mountain magnolia	Magnolia fraseri	655	41	Other Eastern Soft Hardwoods	Other			65.29	
paulownia, empress-tree	Paulownia tomentosa	712	41	Other Eastern Soft Hardwoods	Other			1.95	
redbay	Persea borbonia	721	41	Other Eastern Soft Hardwoods	Other			19.05	
sycamore	Platanus occidentalis	731	41	Other Eastern Soft Hardwoods	Other	83.87	102.99	135.22	131%
black cherry	Prunus serotina	762	41	Other Eastern Soft Hardwoods	Other	74.58	85.44	106.72	125%
sassafras	Sassafras albidum	931	41	Other Eastern Soft Hardwoods	Other			6.27	
elm spp.	Ulmus	970	41	Other Eastern Soft Hardwoods	Other	201.09	199.50		91%
winged elm	Ulmus alata	971	41	Other Eastern Soft Hardwoods	Other			45.77	
American elm	Ulmus americana	972	41	Other Eastern Soft Hardwoods	Other			102.61	
slippery elm	Ulmus rubra	975	41	Other Eastern Soft Hardwoods	Other			32.35	
sweet birch	Betula lenta	372	42	Other Eastern Hard Hardwoods	Other			287.58	
flowering dogwood	Cornus florida	491	42	Other Eastern Hard Hardwoods	Other			4.06	
common persimmon	Diospyros virginiana	521	42	Other Eastern Hard Hardwoods	Other	15.59	17.78	16.85	95%

honeylocust	Gleditsia triacanthos	552	42	Other Eastern Hard Hardwoods	Other	5.37	4.56		
American holly	Ilex opaca	591	42	Other Eastern Hard Hardwoods	Other	46.64		39.78	
mulberry spp.	Morus	680	42	Other Eastern Hard Hardwoods	Other	6.15	5.89		51%
white mulberry	Morus alba	681	42	Other Eastern Hard Hardwoods	Other			1.12	
red mulberry	Morus rubra	682	42	Other Eastern Hard Hardwoods	Other			0.54	
oak, deciduous	Quercus	800	42	Other Eastern Hard Hardwoods	Other			1.35	
black locust	Robinia pseudoacacia	901	42	Other Eastern Hard Hardwoods	Other	213.73	230.87	138.82	60%
striped maple	Acer pensylvanicum	315	43	Eastern Noncommercial Hardwoods	Other			2.97	
mountain maple	Acer spicatum	319	43	Eastern Noncommercial Hardwoods	Other			0.63	
ailanthus	Ailanthus altissima	341	43	Eastern Noncommercial Hardwoods	Other			7.34	
serviceberry	Amelanchier	356	43	Eastern Noncommercial Hardwoods	Other			7.44	
American hornbeam, musclewood,	Carpinus caroliniana	391	43	Eastern Noncommercial Hardwoods	Other			11.04	
American chestnut	Castanea dentata	421	43	Eastern Noncommercial Hardwoods	Other			0.07	
eastern redbud	Cercis canadensis	471	43	Eastern Noncommercial Hardwoods	Other			2.03	
hawthorn	Crataegus	500	43	Eastern Noncommercial Hardwoods	Other			0.83	
Osage-orange	Maclura pomifera	641	43	Eastern Noncommercial Hardwoods	Other			0.06	
apple spp.	Malus	660	43	Eastern Noncommercial Hardwoods	Other			0.31	
eastern hophornbeam	Ostrya virginiana	701	43	Eastern Noncommercial Hardwoods	Other			4.53	
sourwood	Oxydendrum arboreum	711	43	Eastern Noncommercial Hardwoods	Other			153.65	
pin cherry	Prunus pensylvanica	761	43	Eastern Noncommercial Hardwoods	Other			8.29	
turkey oak	Quercus laevis	819	43	Eastern Noncommercial Hardwoods	Other			12.99	
bluejack oak	Quercus incana	842	43	Eastern Noncommercial Hardwoods	Other			0.27	
willow	Salix	920	43	Eastern Noncommercial Hardwoods	Other	25.79	23.48	14.83	63%
American mountain-ash	Sorbus americana	935	43	Eastern Noncommercial Hardwoods	Other			0.07	

chinaberry	Melia azedarach	993	43	Eastern Noncommercial Hardwoods	Other			0.05	
Unknown dead hardwood	Unknown	999	43	Eastern Noncommercial Hardwoods	Other			15.94	
Total						28,951.20	32,742.35	30,324.86	93%