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Incidence and Impact of Oak Decline in Western Virginia, 1986

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Abstract

Oak decline incidence, distribution, and losses in the Northern Piedmont and Mountain Survey Units of Virginia were estimated from data collected during a 1986 inventory of Virginia's forests. Oak decline occurred on 1.1 million acres, and it was estimated to cause an annual mortality between 7.4 and 13.8 million cubic feet since the previous survey in 1977. Incidence and mortality volume were greatest, in the Northern Mountain Unit. Oak decline affected about one-fourth of the oak stands on National Forests. Incidence was lower on other ownerships. Analyses of associations of species composition, site quality, age, and physiograply with oak decline indicate that hazard rating may be possible. Highest incidence was associated with average to poor site quality, advanced stand age, xeric landforms, and stands with a high percentage of oak. Volume losses were greatest on high-quality sites and mesic landforms. The site index/age ratio appears valuable as a measure of physiological age and may be a better oak decline predictor than either site index or age alone. Reduced cutting, lengthened rotations, and problems with regenerating oaks are causes for concern, especially on public land, over whether oaks will be a major component of new stands on affected areas.

Keywords: Quercus, mortality, volume loss, forest management, tree age, stand condition, decline.

Introduction

Oak decline is a complex disease involving interactions between environmental and biological stresses and subsequent attacks by secondary pests. It causes crown dieback, reduces radial growth, and kills trees. Species in the red oak group are damaged more than those in the white oak group, and black and scarlet oak are most prone to mortality (Starkey and others 1989).

Since the early 1980's, reports of oak decline from Arkansas to Virginia have been increasing (Starkey and others 1989). Wide distribution, high timber value, and contributions to wildlife habitat make the oaks the most important group of upland hardwood tree species in the Southern United States. More than 65 million acres of southern timberland (35 percent of the total) are occupied by upland hardwood forest types in which oak species predominate (USDA Forest Service 1988). Oak decline is currently the most widespread disease problem in southern oak forests, but its distribution and the timber losses it causes have not been well documented.

The fifth forest inventory of Virginia was conducted by the Southeastern Forest Experiment Station's Forest Inventory and Analysis Work Unit (FIA) in 1986. This inventory provided an opportunity to estimate oak decline incidence and losses over a wide geographic area. The objectives of the analyses were: (1) to determine the geographic distribution of oak decline in three Survey Units in western Virginia, (2) to estimate the acreage affected and the volume of timber killed, and (3) to examine relationships between disease severity and stand age, site quality, and physiography. One underlying purpose of the third objective was to identify promising factors for classifying vulnerability and risk in oak stands.

Description of Oak Decline

The disease generally progresses slowly over several years. It begins with a long-term predisposing stress such as prolonged drought or advanced age. Stressed trees are often subsequently damaged by short-term inciting factors such as insect defoliation, spring frosts, or acute drought. In their weakened condition, the trees may be attacked by insects and diseases that normally do not invade healthy trees (Manion 1981). At this point, classic decline symptoms appear. The most visible symptom of decline-affected trees is progressive dying back from the ends of branches, beginning at the top and outside of the crown and proceeding downward and inward. Less noticeable is a reduction, in radial. growth that may precede crown symptoms by years or even decades (Tainter and others 1990). Dieback may continue for several years and often terminates in mortality of affected trees. Local physiography and tree species composition may influence the patterns of damage in affected areas. The most important underlying factor when resource damage is severe may be a tree population dominated by senescent overstory oaks lacking in vigor (Mueller-Dombois and others 1983).

Oak decline can be distinguished from other diseases by: (1) relatively slow but progressive terminal branch dieback; (2) branch and bole sprouts and stagheaded crowns; (3) patterns of mortality related to site features, tree stress, and attacks of secondary insects and diseases; and (4) tree mortality usually peaking 2 to 5 years after stress (Wargo and others 1983). These characteristics were used by FIA crews to identify oak decline. Only dominant and codominant trees were considered in order to eliminate symptoms resembling decline but caused by suppression.

Met hods

FIA crews routinely collect damage data on live trees and determine cause of mortality for dead trees. The standard FIA damage code that correlates closest with oak decline is dieback when it occurs in dominant and codominant oak (USDA Forest Service 1985). Pest management specialists provided supplemental training to field crews to ensure proper and consistent diagnosis. Normal damage coding procedures were followed, and dieback was not given priority over other concurrent damages. Determining the primary cause of mortality was often difficult in trees that had other damage in addition to dieback. If trees surrounding a dead oak displayed decline symptoms, the mortality was coded as dieback-associated.

The geographic scope of this analysis was limited to the Northern Mountain, Southern Mountain, and Northern Piedmont Survey Units. Although a complete statewide evaluation would have been desirable, the remaining Coastal Plain and Southern Piedmont Survey Units were omitted because they were surveyed during the dormant season, when identification of dieback is putatively less reliable. Nevertheless, most of Virginia's hardwood forest is found in the study area. Sixty percent of the State's merchantable hardwood volume grows there. Softwood volume comprises only one-sixth of the total inventory in the study area, compared with one-half of the total in the Southern Piedmont and Coastal Plain Units (Bechtold and others 1987).

After data collection, plots with forest types dominated by oaks were segregated from the overall data base. The type groups of interest were oak-hickory and oak-pine. The specific types included white oak-red oak-hickory, chestnut oak, yellow-poplar-white oak-northern red oak, shortleaf pine-oak, Virginia pine-southern red oak, white pine-northern red oak-white ash, and mixed hardwoods. Forest types dominated by pines and northern hardwoods, such as white pine, shortleaf pine, and maple-beech-birch, may also contain oaks subject to decline. These types were excluded from the analyses because of their relatively small proportions of oak. From the designated types, plots with damage and mortality codes attributable to oak decline were isolated. Decline symptoms were found on 273 plots. Symptoms ranged from very light (one oak on the plot with dieback) to very severe (high incidence of mortality and advanced crown decline). Decline incidence was used to determine distribution, while the volume loss associated with oak mortality was used to assess relative severity. Since subjective evaluation of dieback was considered the greatest potential source of error, Forest Pest Management specialists field-checked 10 percent of the plots with decline taken by each field crew. This field check revealed that the crews were proficient in identifying decline areas; 92 percent of the plots diagnosed as decline-affected were correctly classified.

Results

Estimates of oak decline impacts throughout Virginia would have been desirable, but our methods do not permit such estimates. Damage is reported here only for forested land in the Northern Piedmont, Northern Mountain, and Southern Mountain Survey Units of Virginia. Live-tree volume, as used in this discussion, includes the volume from a l-foot stump to a 4-inch-diameter top (outside bark) for all living trees 5 inches d.b.h. and larger.

Distribution, Incidence, and Volume Losses

Oak forest types were widely distributed across the study area. Overall, 85 percent of the forested land was in oak forest types. The Northern Piedmont Unit had the lowest percentage of oak types (77 percent). The two Mountain Units had approximately equal proportions (89 percent in the Northern Mountains; 87 percent in the Southern Mountains). Overall, there were 6.7 million acres of oak forest types in the three Survey Units.

Oak decline occurred on an estimated 1 .1 million acres in the study area, but it was not uniformally distributed (fig. 1). More than half of the plots with oak decline were in the Northern Mountains. Over 650,000 acres, or 30 percent of the area in oak forest types in this Survey Unit, had decline symptoms. The Southern Mountains had only 9 percent incidence, despite having a greater acreage of oak forest. The Northern Piedmont had the smallest oak forest area (1.8 million acres) and a decline incidence similar to the Southern Mountains (11 percent).

Annual mortality in oak forests was high for counties with concentrations of decline (fig. 2). Oak stands in Shenandoah County in the Northern Mountain Unit sustained an average annual loss of 24.9 cubic feet per acre from 1977 to 1986, the highest in the study area. Oak stands in the surrounding counties of Frederick, Warren, Page, and Rockingham had annual volume losses between 14 and 19 cubic feet per acre (fig. 2). The only county outside the Northern Mountain Unit with a similar level of mortality was Montgomery County in the Southern Mountain Unit. Mortality volume was low in oak stands in most of the Northern Piedmont Unit. Only four counties there had annual mortality volume greater than 3 cubic feet per acre, and they were all clustered in the northeastern portion of this Unit.

Affected areas differed from unaffected areas in several attributes (table 1). They had higher basal area and volume, were composed of a higher percentage of oak, and had nearly twice the annual mortality of unaffected areas. These differences were expected. High basal area and high volume in affected areas could be caused by

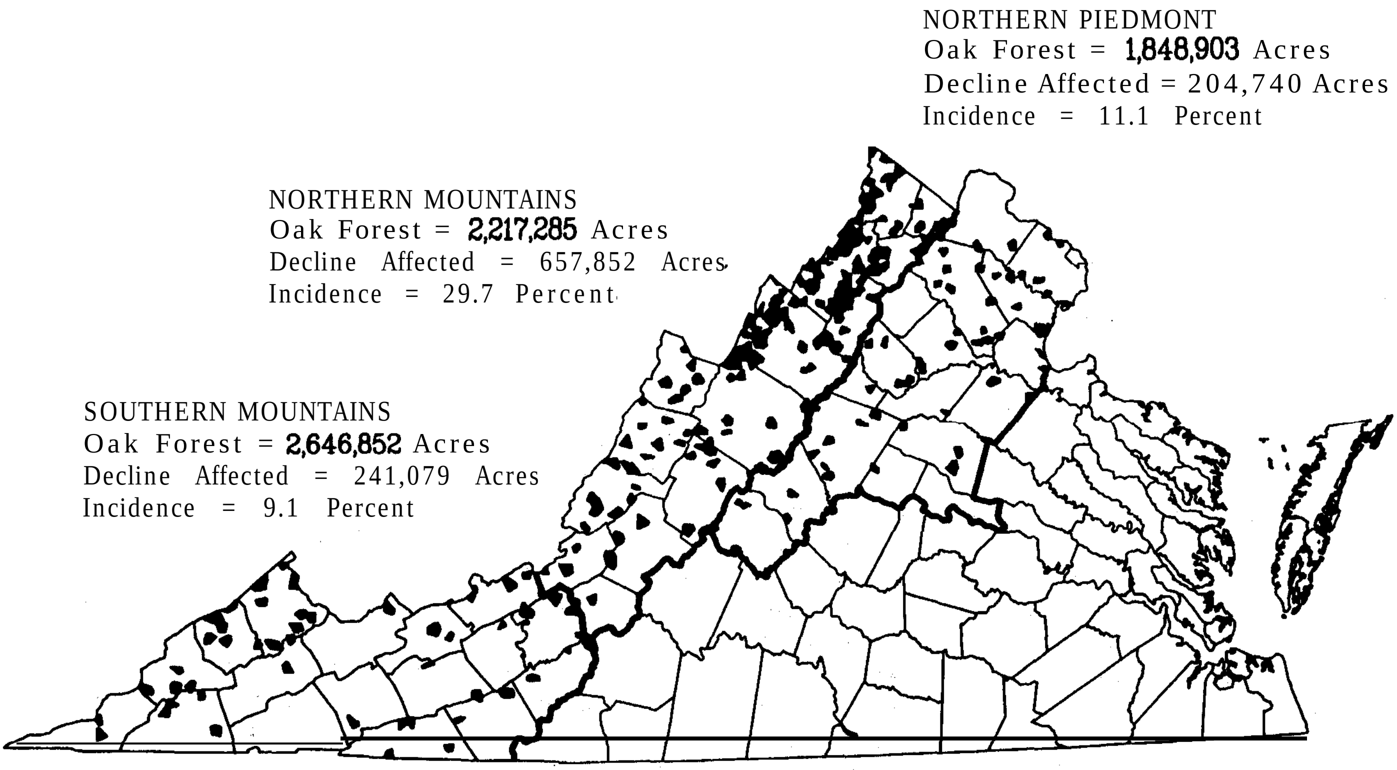

Figure l-Distribution and incidence of oak decline in the Mountain and Northern Piedmont Survey Units of Virginia, 1986.

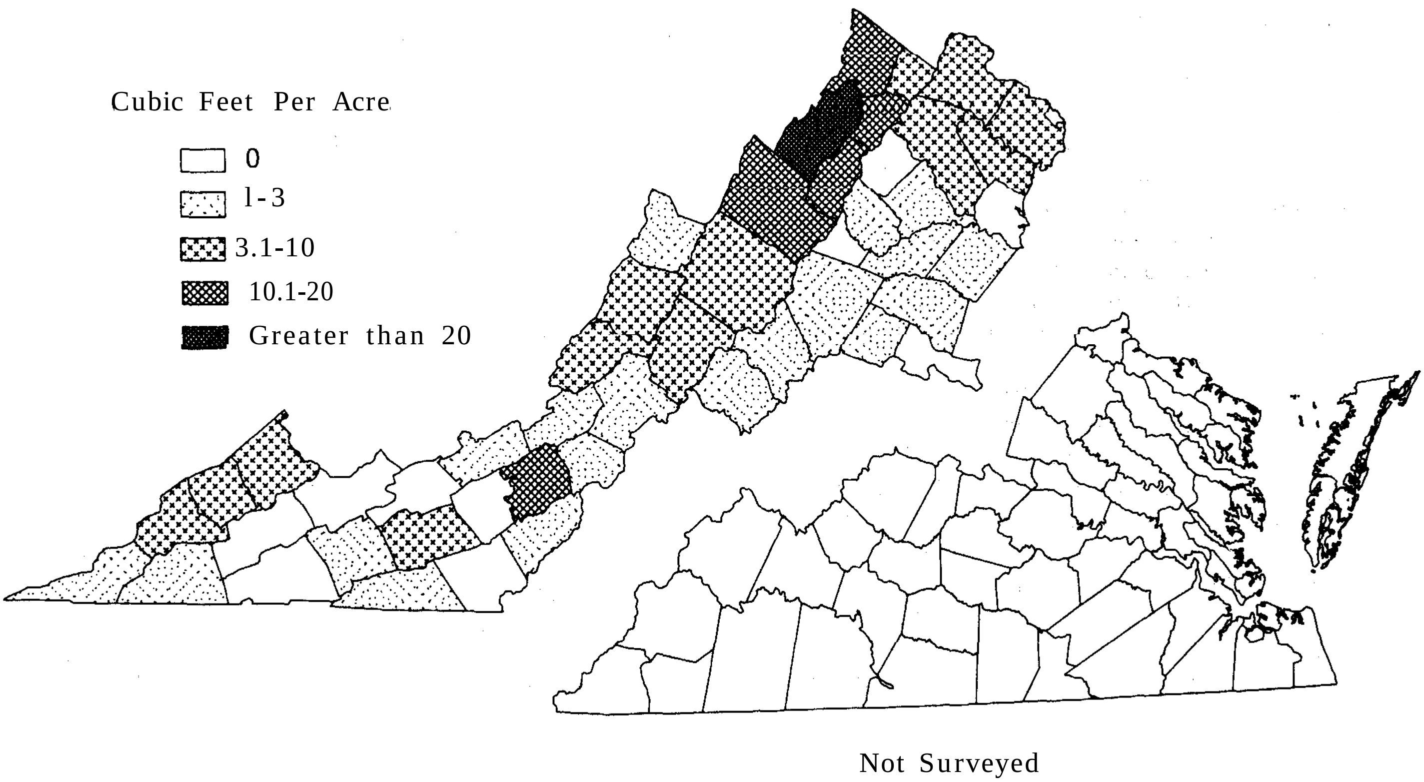

Figure Z-Annual oak decline mortality *volume* per acre on oak forest types, by county, for the Mountain and Northern Piedmont Survey Units of Virginia, 1977-1986.

age or stand density, or both. Oak decline is more common in mature overstory trees (usually larger) than in immature trees (usually smaller), and affected stands generally are older and have higher volume than unaffected stands. Basal area **and** volume differences could reflect an association between oak decline and stand density. Decline is stress-mediated and trees in stands with high basal area and volume may endure more intense competition for resources during times of stress. Effects of age, stand density, site quality, and physiography on decline incidence and severity will be more fully explored later in this paper.

Oak composition and total annual mortality volume were closely linked. Nearly all the difference in annual mortality between affected and unaffected areas was accounted for by higher oak mortality. Similar amounts of mortality among non-oak species occurred in affected and unaffected areas (7.6 and 8.5 cubic feet per acre per year, respectively), while oak mortality volume was three times as high in affected as in unaffected areas. Non-oak species were not dying at higher rates in affected areas like oak species were.

Large volume losses were associated with oak decline in the Mountains and Northern Piedmont of Virginia between 1977 and 1986. The total volume loss in affected areas was over 29 million cubic feet in the three Survey Units, with oaks accounting for 20.6 million cubic feet. However, not all of this total can be attributed to oak decline. The loss caused by oak decline can be estimated by deducting the oak mortality volume expected if decline had not occurred. The difficulty, of course, is that we do not know how much oak mortality would have occurred in the absence of oak decline. One estimate of this figure is the oak mortality volume in unaffected areas. If one assumes that oak mortality volume per acre in affected areas would have been the same as in unaffected areas, the annual loss caused by oak decline in the Mountain and Northern Piedmont Survey Units during the survey interval was 13.8 million cubic feet. This assumption, however, ignores the large difference in initial oak inventory between affected and unaffected areas. If one assumes that the percentage loss of oak volume in the absence of oak decline would have been the same in affected and unaffected areas, annual decline loss was 7.4 million cubic feet. This estimate does not account for differences between affected and unaffected areas in age and site quality that could influence mortality rates. The actual oak decline loss was probably somewhere between 7.4 and 13.8 million cubic feet per year.

There were clear differences in oak decline incidence among land ownership classes. Most of the 1.1 million acres of decline-affected oak forest was privately owned, but the incidence of decline was much higher on National Forests than on other ownerships (table 2). About one-fourth of the oak stands on National Forest land had decline damage. Incidence in other public and private oak stands was 16 and 14 percent, respectively.

The severity of oak decline was also greatest on National Forest land (table 3). Annual oak mortality on National Forests in affected areas was 26.9 cubic feet per acre. This was three-fourths of the total annual mortality volume on affected National Forest land. Other public and private ownerships had much lower total annual mortality than did National Forests, and only two-thirds of it was oak. Thus, a disproportionately large amount of the oak mortality in the study area occurred on National Forests. Forty-two percent of the annual oak mortality (8.7 million cubic feet) came from the 29 percent of decline-affected acres that occurred on National Forest land. The variation among ownerships in the percentage of annual gross growth (annual mortality volume + net annual volume growth) lost in decline-affected areas was large. National Forests lost 44 percent of gross growth, and other public ownerships lost 24 percent. In contrast, the percentage of gross growth lost in unaffected areas varied little among ownerships.

Predicting Oak Decline

Six factors that show promise for predicting oak decline are species composition, site quality, age, site index/age, physiography, and stand density. In prediction, two factors must be accounted for: vulnerability and risk of loss. Vulnerability is the probability of occurrence in a given stand. The incidence of oak decline by category provides a measure of relative vulnerability. Risk is the probability of volume loss if oak decline occurs. Mortality volume by category provides a measure of relative risk. We have not attempted to merge these two components into an oak decline rating system, but we believe that additional research could lead to such a system.

Species composition-Individual oak species vary in their susceptibility to decline. Therefore, it is reasonable to assume that species composition affects vulnerability and risk. For analysis, oak forest types were placed in three type groups: oak-pine, oak-hickory, and chestnut oak.

In terms of total acreage, most of the oak decline occurred in the oak-hickory forest type group because it was by far the most prevalent type group in the surveyed units (table 4). The chestnut oak type group, however, was clearly the most vulnerable. Decline occurred in 28 percent of chestnut oak stands, compared with only 16 percent of oak-hickory stands. Oak-pine types had the lowest incidence. Low vulnerability in oak-pine types was somewhat unexpected because oak decline is common under the relatively harsh site conditions (Starkey and others 1989) typical of oak-pine stands. The amount of oak within forest type groups influenced vulnerability. The percentage of volume made up by oaks was consistently higher in affected than in unaffected stands (table 5).

Although chestnut oak stands were the most vulnerable, they did not carry the highest risk of loss when decline occurred (table 5). The oak-hickory type group had the highest annual oak mortality overall. Further, oak mortality volume was not much greater in affected than in unaffected chestnut oak stands. Oak mortality volume was much larger in affected than in unaffected oak-hickory stands. Oak-pine types had the lowest overall loss for affected areas. These results are in general agreement with those of Stringer and others (1989) and Starkey and others (1989), who reported low mortality in oak-pine and chestnut oak stands, and greatest losses in red oak-white oak and oak-hickory stands.

Site quality—Oak decline is usually more prevalent on somewhat dry upland sites, which have relatively low site indices. This relationship was confirmed by the analysis of decline incidence by site index (SI) class, which showed that oak decline vulnerability was inversely related to SI (fig. 3). Below-average site qualities (SI $<$ 70 feet) were twice as likely as average and better sites to be affected (23 vs. 10 percent incidence). Over one-third of poor-quality sites (SI $<$ 50 feet) had decline.

Despite low vulnerability, high-quality sites had the highest risk of loss when decline did occur (table 6). Annual oak mortality on SI $>$ 90 land with decline was over 30 cubic feet per acre. This loss was over 2 percent of the total 1977 oak volume, and almost 10 times as high as the annual oak mortality on unaffected high-quality sites. Average and better sites (SI $>$ 70 feet) accounted for about 36 percent of the oak mortality in affected areas and 33 percent of the affected acreage.

Age-The incidence of decline increased as age class increased (fig. 4). Decline was present in only 3 percent of the stands $<$ 40 years old, but was in 29 percent of the stands $>$ 80 years. The average stand age in unaffected areas was 54 years, while that in affected areas was 70 years.

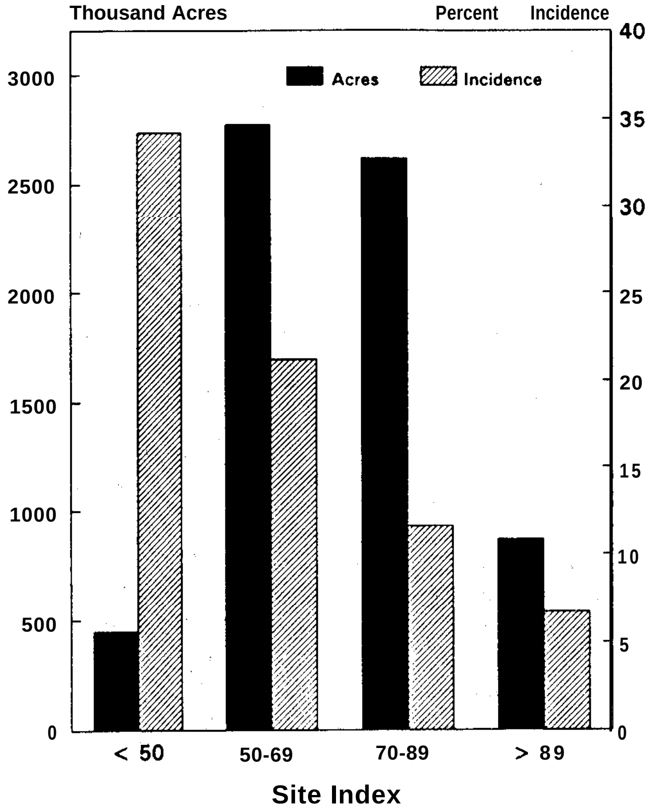

Figure 3—Acres and percentage of oak decline incidence by site index class in the Mountain and Northern Piedmont Survey Units of Virginia, 1986.

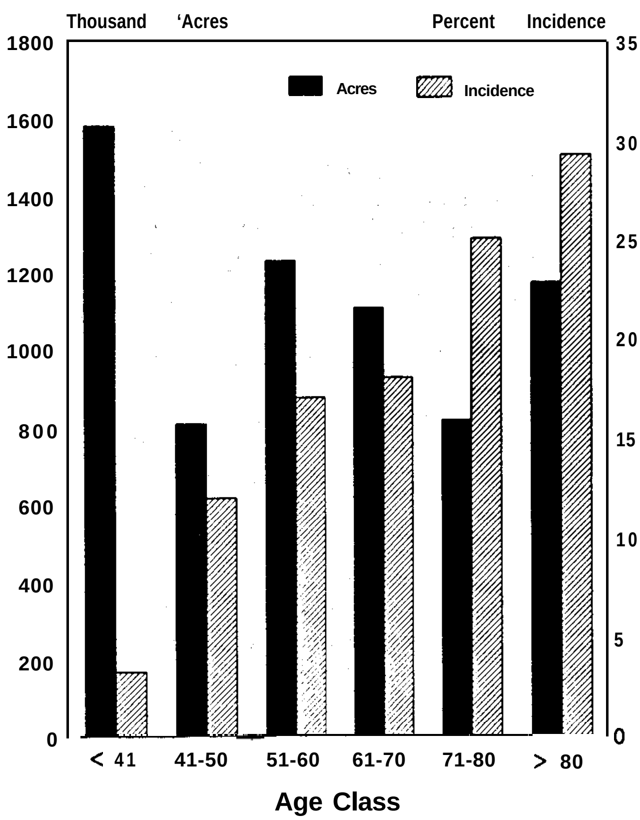

Figure 4—Acres and percentage of oak decline incidence by age class in the Mountain and Northern Piedmont Survey Units of Virginia, 1986.

Decline was observed in 4 percent of the area in the 0- to lo-year age class (grouped with other young stands in fig. 4). Trees of this age are not affected by oak decline, but stands in this age class often contain some large trees remaining from the previous mature stand. Decline symptoms presumably occurred in the scattered old individuals left after an earlier harvest. This condition was confirmed by comparing initial (1977) total volume and initial (1977) basal area for the youngest age classes. For affected areas, initial volume per acre and initial basal area per acre in the 0- to lo-year age class were 431 cubic feet and 52 square feet, respectively. In the 11- to 20-year age class, both total volume and basal area per acre were lower (106 cubic feet and 20 square feet), reflecting the loss of large residual overstory trees.

Old stands carried the highest risk for annual oak mortality, but the connection between increasing age and increasing risk did not appear to be as strong as it was for vulnerability (table 7). Volume losses were unexpectedly high in the < 40-year age class (again due to mortality of scattered old residuals), but they were also higher for the 51- to 60-year age class than for either the 61- to 70-year or the 71- to 80-year classes. Chronological age may not accurately reflect the physiological condition of trees that are prone to decline (Manion 1981).

Site Index/Age-Hyink and Zedaker (1987) characterized senescence as the result of changes in the efficiencies of water transport and translocation, hormone balances, and the balance between photosynthesis and respiration. They described physiological age as the progression toward critical levels of these relationships. They detailed the limitations of chronological age for characterizing senescence and suggested that a measure of physiological age would be of greater biological significance than chronological age. We created an index of physiological age by dividing SI (an indirect measure of moisture availability and stress in southern upland hardwood stands) by chronological age. Thus, 50-year-old oaks growing on poor SI 50 land (SI/age = 1.0) would be more mature physiologically than 80-year-old oaks growing on productive SI 90 land (SI/age = 1.1), despite having a lower chronological age.

The distributions of acres by SI/age classes were very different for affected and unaffected areas (fig. 5). Unaffected areas were nearly equally partitioned among the four classes, whereas affected areas were much more likely to have relatively low ratios. Nearly 60 percent of the affected acres had a ratio less than 1.0, and 84 percent had ratios less than 1.4.

Low SI/age ratios were associated not only with high vulnerability but also with high risk of mortality. Where ratios were < 1.4, annual oak mortality volume was much higher in affected than in unaffected areas (table 8). However, the greatest difference in oak mortality volume between affected and unaffected areas occurred where ratios were 1.4 - 2.0. For that SI/age class, mortality volume was 3.5 times greater in affected than in unaffected areas.

There was evidence that the low incidence of decline in the high-ratio classes was due more to young age than to high SI. Initial basal area and volume were lower for areas with ratios > 2.0 than for areas with lower ratios, especially in unaffected areas. If high site quality was the predominant influence, somewhat higher initial volumes would have been expected (see table 6).

Physiography-As expected, dry sites had higher incidence and vulnerability than did more moist sites (table 9). Forty-four percent of all decline-affected acres were classed as xeric, though these areas comprised only 30 percent of the area. Mesic landforms had about half the incidence rate of xeric sites. Mesic sites include moist mountaintops and slopes (usually coves with north-to-east aspects and relatively deep, fertile soils), floodplains, natural stream levees, and valley bottoms.

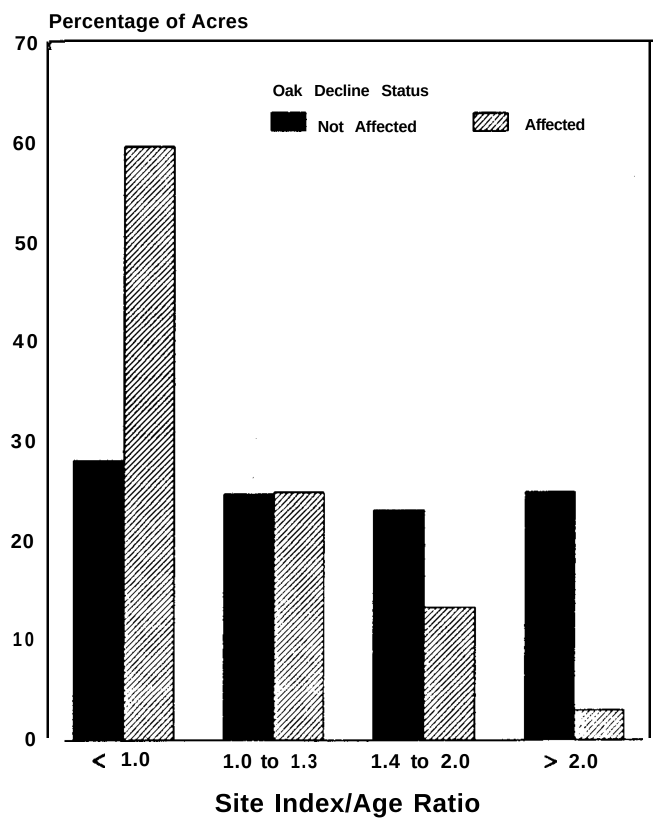

Figure 5-Percentage distribution of acres, by site index/age ratio, for oak decline-affected and-unaffected areas in the Mountain and Northern Piedmont Survey Units of Virginia, 1986.

Physiography did not appear to have a great influence on mortality risk, but the difference in annual oak mortality volume between affected and unaffected areas was greatest on mesic landforms (table 10). As with the analyses of losses by forest type, SI, and SI/age, oak decline losses were greatest when they occurred on more favorable sites (more mesic landforms).

No decline was detected on hydric landforms, and only a small amount of oak forest type was found there. Oak mortality was high on unaffected hydric sites, but dead trees did not display evidence of prolonged dieback.

Density-Decline is a stress-mediated condition. If intertree competition is an important contributor to decline etiology, one would expect affected areas to have higher initial (1977) basal area and total volume than unaffected areas. In general, basal area and volume were higher on affected than on unaffected areas (table 1). However, prediction of decline incidence and severity from basal area or volume has limited value because these stand characteristics depend on many factors, including stand age, site quality, and previous treatment. An association between decline vulnerability and stand density might be indirectly revealed by examining density characteristics within age and SI categories. Of the factors included in this work, age class would be expected to have the greatest effect on density (table 7). In most age classes, there were only slight differences in initial basal area and total volume between affected and unaffected areas. The differences were substantial only for the < 40-year age class. This result is probably attributable to decline occurring in a residual overstory component from an older age class. While intertree competition may well contribute to occurrence of decline in individual trees, we conclude from these data that stand basal area is not a useful predictor of where decline will occur. However, stand density cannot be dismissed as a factor until its influence has been isolated from those of other closely associated variables.

Conclusion

In the Mountain and Northern Piedmont Survey Units in Virginia, oak decline was the leading cause of mortality between 1977 and 1986. Our best estimate is that annual losses due to oak decline averaged between 7.4 and 13.8 million cubic feet during the period. Bechtold and others (1987) reported that hardwood mortality increased in Virginia as a whole by 59 percent since the previous statewide inventory, and that two-thirds of that increase occurred in the Mountain Units. Our results show that oak decline is a primary cause for that increase.

There seems little doubt that drought in the early and middle 1980's predisposed the oaks to decline. In the last few years, rainfall has been adequate, and that is comforting. We believe, however, that it would be foolish for forest managers and forest policymakers to ignore the implications of these findings. There have been droughts in the past in western Virginia, and there will be droughts in the future. When they occur, heavy losses of maturing oaks can be anticipated.

Oak stands on National Forests were particularly prone to damage, probably because stands there are older, overall, than other publicly and privately owned stands. Bechtold and others (1987) reported that public lands supported a large proportion of the upland hardwood stands where growth is slow and risk of mortality is high. The present management direction for National Forests in the South appears to be toward longer rotations and less frequent timber harvests. While this direction may be reasonable given recent public comment on National Forest Land Management Plans, it should be recognized that it will lead to very large losses of oak timber in the long run.

Since this inventory, gypsy moths have overspread most of the Northern Mountain and Northern Piedmont Survey Units in Virginia. Area of defoliation has increased more than a hundredfold from 5,200 acres in 1985 (USDA Forest Service 1986) to 594,000 acres in 1990 (USDA Forest Service, In press). Gypsy moths attack oaks preferentially (McManus and others 1989), and defoliation predisposes oaks to decline. The probability of mortality is especially high for oaks that are defoliated after decline has begun (Herrick and Gansner 1987). Thus, losses of oaks in the study area are likely to continue and even increase.

Our results give no clear indication of how forest managers should respond to oak decline. Certainly, oaks are valuable for timber, and they may be even more valuable for wildlife. Specific research should be conducted to determine whether oak regeneration occurs beneath declining trees. We do know, however, that decline can cause major reductions in the quantity and quality of acorns produced by affected trees (Gysel 1957; Oak and others 1989). We also know that reproducing red oaks on good sites requires considerable care and skill (Loftis 1990). In the absence of specific information, it may be reasonable to assume that without management intervention, oak decline and gypsy moth defoliation will reduce the proportion of oak in the hardwood stands of western Virginia. We think that forest managers should address that probability.

Our analyses indicate that a system can be developed for identifying stands that are vulnerable to oak decline. Factors that create high vulnerability include: (1) a high proportion of oak in the stand, (2) xeric landforms and accompanying low SI, and (3) physiological maturity as expressed by SI/age ratio. In our study, 80 percent of the declining stands had an SI/age ratio lower than 1.4.

While identification of vulnerable stands appears possible, devising a biologically and socially acceptable way of treating them will be difficult. Introducing age diversity would seem prudent. Uneven-aged management systems are currently favored by most of the vocal publics, but limited observations of some partial cuts in vulnerable or damaged stands have revealed continued or even accelerated decline. When adequate advance oak reproduction is already present, clearcutting results in a high proportion of oaks in the new stand (Loftis 1990). Clearcutting is rejected by many as a management option, however, particularly on public land. Studies monitoring the effects of management practices on decline and oak regeneration are needed.

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Table l--Basal area, volume, and annual mortality per acre, by oak decline status, in the Mountain and Northern Piedmont Survey Units of Virginia

Stand condition	Unaffected areas	Affected areas	All oak forests
Initial (1977) basal area	73 ft^2	90 ft^2	76 ft^2
Initial (1977) total volume	1,399 ft^3	1,735 ft^3	1,455 ft^3
Initial (1977) oak volume	657 ft^3	1,271 ft^3	759 ft^3
Total annual mortality	14.7 ft^3	26.3 ft^3	16.6 ft^3
Oak annual mortality	6.2 ft^3	18.7 ft^3	a.2 ft^3
Oak mortality (percent)[a]	.94	1.47	1.08

[a](Oak annual mortality/Initial oak volume) x 100.

Table 2--Acres in the Mountain and Northern Piedmont Survey Units of Virginia with oak decline, by ownership

Ownership	Total (all forest types)	Oak forest types[a]	Area affected by oak decline	Oak decline incidence
	- - - - - - - - -	Thousand acres	- - - - - - - - -	Percent
National Forest	1,468.5	1,342.6	323.6	24
Other public[b]	229.0	199.8	31.2	16
Private[c]	6,180.8	5,165.8	748.9	14
All ownerships	7,878.3	6,708.2	1,103.7	16

[a]Includes oak-pine, oak-hickory, and chestnut oak forest types.

[b]Small sample size.

'Includes forest industry.

Table s--Initial (1977) volume per acre and annual mortality per acre for oak decline affected and unaffected areas in the Mountain and Northern Piedmont Survey Units of Virginia, by ownership

Decline status	Ownership	Initial basal area	Initial volume		Annual mortality	
			Total	Oak	Total	Oak
		Square feet	- - - - - - - Cubic feet - - - - - - -			
Unaffected	National Forest	77	1,434	972	16.4 (28)	10.4
	Other public	79	1,441	722	13.3 (21)	5.0
	Private	72	1,389	583	14.4 (22)	5.2
	All ownerships	73	1,399	657	14.7 (23)	6.2
Affected	National Forest	89	1.675	1.313	35.1 (44)	26.9
	Other public	98	1,741	1,265	10.6 (24)	6.1
	Private	90	1,760	1,254	22.9 (30)	15.5
	All ownerships	90	1,735	1,271	26.3 (34)	18.7

Numbers in parentheses are percentage of annual volume of gross growth lost to mortality.

Table &-Acres in the Mountain and Northern Piedmont Survey Units of Virginia with oak decline, by forest type group

Forest type group	Oak forest types	Acres affected by oak decline	Oak decline incidence
	---- Thousand acres	---	Percent
Oak-pine	677.1	78.4	12
Oak-hickory	51673.7	925.2	16
Chestnut oak	357.5	100.1	28
All types	6,708.3	1,103.7	16

Table s--Initial (1977) volume per acre and annual mortality per acre for oak decline affected and unaffected areas in the Mountain and Northern Piedmont Survey Units of Virginia, by forest type group

Decline status	Forest type group	Initial basal area	Initial volume		Annual mortality	
			Total	Oak	Total	Oak
		Square feet	----- Cubic	feet	----	
Unaffected	Oak-pine	71	1,319	494	14.4	5.1
	Oak-hickory	72	1,394	634	14.6	5.9
	Chestnut oak	92	1,673	1,462	18.0	12.8
	All types	73	1,399	657	14.7	6.2
Affected	Oak-pine	75	1,326	666	17.5	11.9
	Oak-hickory	91	1,780	1,298	27.5	19.5
	Chestnut oak	94	1,608	1,450	21.3	16.2
	All types	90	19735	1,271	26.3	18.7

Table 6--Initial (1977) volume per acre and annual mortality per acre for oak decline affected and unaffected areas in the Mountain and Northern Piedmont Survey Units of Virginia, by site index

Decline status	Site index	Initial basal area	Initial volume		Annual mortality	
			Total	Oak	Total	Oak
		Square feet	----- Cubic feet -----			
Unaffected	< 50	60	855	554	7.3	5.2
	50-69	69	1.237	763	13.0	7.2
	70-89	74	1,466	641	16.1	6.2
	≥ 90	86	1,829	460	18.0	3.5
	All site indices	73	1,399	657	14.7	6.2
Affected	< 50	82	1,355	1,065	21.1	16.7
	50-69	89	1,691	1.343	26.0	18.2
	70-89	92	1,875	1,224	24.4	18.4
	≥ 90	107	2,428	1,320	54.8	31.1
	All site indices	90	1,735	1,271	26.3	18.7

Table T--Initial (1977) volume per acre and annual mortality per acre for oak decline affected and unaffected areas in the Mountain and Northern Piedmont Survey Units of Virginia, by age class (1986)

Decline status	Age class	Initial basal area	Initial volume		Annual mortality	
			Total	Oak	Total	Oak
		Square feet	------ Cubic feet -----			
Unaffected	≤ 40	41	675	250	6.5	1.8
	41-50	76	1,375	447	13.0	2.4
	51-60	83	1,607	665	17.3	6.2
	61-70	86	1,681	833	19.0	9.4
	71-80	89	1,785	990	18.4	9.3
	> 80	92	1,910	1,149	20.8	11.7
	All age classes	73	1,399	657	14.7	6.2
Affected	≤ 40	62	1,100	752	15.2	11.3
	41-50	78	1,431	757	18.7	17.6
	51-60	91	1,721	1,252	26.3	20.7
	61-70	90	1,739	1,306	26.3	15.9
	71-80	87	1,700	1,156	24.3	13.9
	> 80	98	1,950	1,562	31.3	25.2
	All age classes	90	1,735	1,271	26.3	18.7

Table 8--Initial (1977) volume per acre and annual mortality per acre for affected and unaffected oak decline areas in the Mountain and Northern Piedmont Survey Units of Virginia, by SI/age ratio

Decline status	SI/age ratio	Initial basal area	Initial volume		Annual mortality	
			Total	Oak	Total	Oak
		Square feet	Cubic feet			
Unaffected	< 1.0	84	1,600	1,033	17.8	10.5
	1.0-1.3	88	1,742	808	17.5	7.1
	1.4-2.0	77	1,487	480	15.8	4.5
	> 2.0	43	755	251	7.5	1.9
	All classes	73	1,399	657	14.7	6.2
Affected	< 1.0	91	1,728	1,362	27.9	20.0
	1.0-1.3	92	1,833	1,311	24.4	19.0
	1.4-2.0	87	1,691	867	27.3	15.6
	> 2.0	65	1,262	967	5.2	4.1
	All classes	90	1,735	1,271	26.3	18.7

Table g--Acres in the Mountain and Northern Piedmont Survey Units of Virginia with oak decline, by physiographic class

Physiographic class	Oak forest type	Acres affected by oak decline	Oak decline incidence
	---- Thousand acres	----	Percent
Xeric[a]	1,998.6	484.2	24
Mesic[b]	4,701.8	619.5	13
Hydric[c]	7.8	0	0
All classes	6,708.2	1,103.7	16

[a]Includes dry mountain tops and slopes and other xeric.

[b]Includes rolling uplands, mesic mountain tops and slopes, narrow flood plains, and other mesic.

'Includes deep swamps and small drains that are poorly drained except during periods of extended drought.

Table lo--Initial (1977) volume per acre and annual mortality per acre for affected and unaffected oak decline areas in the Mountain and Northern Piedmont Survey Units of Virginia, by physiographic class

Decline status	Physiographic class	Initial basal area	Initial volume		Annual mortality	
			Total	Oak	Total	Oak
		Square feet	----- Cubic feet -----			
Unaffected	Xeric	71	1,230	837	15.7	9.3
	Mesic	74	1,461	590	14.2	4.9
	Hydric[a]	84	1,616	657	62.9	44.2
	All classes	73	1,399	657	14.7	6.2
Affected	Xeric	87	1,536	1,226	27.6	20.0
	Mesic	92	1,887	1,306	25.3	17.6
	Hydric[b]	--	--	--	--	--
	All classes	90	1,735	1,271	26.3	18.7

"Small sample size.

[b]No decline-affected area in this class.

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Data collected in consecutive forest surveys of Virginia show that losses to oak decline from 1977-1986 were between 7.4 and 13.5 million cubic feet per year in the Northern Piedmont and Mountain Survey Units. Losses were greatest in the Northern Mountain Unit. The ratio of site index/age appears promising as a predictor of oak decline occurrence after severe stress caused by factors like drought.

Keywords: Quercus, mortality, volume loss, forest management, tree age, stand condition, decline.

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