SURVEY OF HARDWOOD DECLINE/MORTALITY ON THREE NATIONAL FOREST RANGER DISTRICTS IN THE SOUTHERN REGION

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ABSTRACT

Stratified double sampling using aerial photo and ground survey methods was used to estimate hardwood decline and mortality on three National Forest Ranger Districts and to examine stand and site relationships. Results showed that damage was widespread but variable. Hardwood forest types encompassed 75 percent or more of the forested area on each District with 28 to 55 percent of this host type affected. The Lee Ranger District, George Washington National Forest had the highest hardwood decline incidence. Ground survey confirmed that oaks were pre-eminent among affected species with members of the red oak group more prone to mortality than members of the white oak group. Among non-oak species, only hickories showed appreciable decline. Mortality and advanced decline averaged between 10 and 16 percent of the overstory in the most severely damaged sampling stratum. Four-year periodic mortality volume in affected strata varied among Districts from 5,621 mbf to 12,845 mbf with an additional 183 to 21,116 mbf at immediate risk based on advanced symptoms. Ecosystem changes wrought by oak decline and mortality at a landscape scale may be more important than wood volume losses.

INTRODUCTION

Oak decline is a disease of complex etiology involving the interactions of predisposing factors such as climate, site characteristics or tree age; inciting stress such as drought or insect defoliation; and contributing organisms of secondary action such as armillaria root disease or the two-lined chestnut borer (Manion 1991). Organisms of secondary action are not normally aggressive pests of vigorous trees but can successfully attack trees that have been physiologically altered by stress. The sequence of occurrence of predisposing factors, inciting stress and attack by secondary organisms is important yet variable. Decline symptoms are characterized by a progressive dieback from the tips of the branches. Mortality commonly results but usually not until after dieback has been manifest for a few years.

From the early 1900's to the present, oak decline or mortality has been reported from locations representing nearly the entire range of oak in the U.S. (Ammon et al. 1989, Millers et al. 1989). Widespread occurrence of oak decline in the 1980's in the southeast prompted a survey to determine impacts and site and stand factors associated with declining stands (Starkey et al. 1989). Thirty-eight sites in upland forests were surveyed from Virginia to Arkansas and included Missouri and Illinois. The survey documented growth loss, mortality, differential species susceptibility, and associations between damage and certain site and stand factors. Potentially detrimental changes in wildlife habitat for mast-dependent species is another likely result (Oak et al. 1988).

While previous reports demonstrate the wide-spread spatial and temporal distribution of oak decline and have contributed greatly to an understanding of its etiology, estimates of acres affected by host type, severity class and geographic region are mostly lacking. This survey was designed to provide such estimates for a representative cross section of upland hardwood forests in the southeast. Presentations of much of these results have been previously made (Oak et al. 1990, Starkey and Oak 1988, Starkey and Oak 1989).

MATERIALS AND METHODS

Three National Forest (NF) Ranger Districts (RD) in the Southern Region were selected for survey; the Buffalo RD of the Ozark NF in north-central Arkansas, the Wayah RD of the Nantahala NF in western North Carolina and the Lee RD of the George Washington NF in northern Virginia (Figure 1). These were selected for survey because the forest cover on these RD's consists of primarily hardwood forest types (77, 75 and 86 percent respectively, Table 5), because oak decline is known to occur there, and because they represent much of the regional diversity in climate, physiography, soils, and species composition.

Stratified double sampling (Wear et al. 1966) was used to estimate acres with oak decline and average number of affected trees within various damage strata. Similar methodology was used in a survey of hardwood tree health in Vermont (Kelley and Eav 1987). Briefly, this method included:

(1) acquisition of aerial photography,
(2) delineation of photo sample blocks,
(3) photointerpretation (PI) by:
    (a) stratification of photo grid cells into vegetation type, tree size and damage classes,
    (b) validation of stratification with detailed PI,

(4) ground sampling to:
   (a) verify species affected were primarily oak,
   (b) validate PI counts of dead and declining trees,
   (c) estimate the proportion of affected trees, volume loss, and collect site and stand data.

Aerial Photo Specifications

Color infrared aerial film transparencies (Kodak 2443) were acquired over each RD at an approximate scale of 1:8,000 during late summer of 1986 using a U.S. Forest Service Aero Commander 680-F aircraft equipped with a Wild RC-10, 9x9 inch (23x23 cm) format camera with a 6-inch (15 cm) focal length lens. Flight lines were spaced at 3 mile intervals and were continuous strips with 70% endlap.

Photo Sample Selection and Block Delineation

Every 5th frame was selected for a photo sample block unless the NF ownership was below about 70 percent of the photo. In such cases, adjacent photos with a higher proportion of National Forest ownership were used. There were 54 photo sample blocks selected on the Buffalo RD, 34 on the Lee RD and 44 on the Wayah RD.

The scale of each photo sample block was determined as accurately as possible from photo and map measurements. A square, 360 acre indexed grid of matching scale was established in the center of each photo sample. The grid was comprised of 144, 2.5 acre grid cells (Figure 2). The sum of the area of all photo sample blocks was targeted to be about 8-10 percent of the total area of each RD.

Photointerpretation

PI was performed using either an Old Delft scanning stereoscope on a Richards GFL-3040 light table or a Bausch and Lomb Zoom 240 stereoscope on a Richards MIM-4 light table. PI was performed in two steps; (1) an initial stratification of each grid cell into a vegetation/size/damage class, and (2) detailed counts of dead/declining trees in a subsample of grid cells to verify the initial stratification.

Stratification - Each grid cell was quickly scanned and assigned to a vegetation/size/damage class utilizing the following criteria:

Vegetation/Size Class:

P = Hardwood poletimber - all grid cells where 70% or more of the grid cell area consisted of hardwood forest cover and the majority of the canopy was poletimber (that is, crown size indicated that the estimated mean d.b.h. is < 10 inches but larger than seedling/sapling size).

S = Hardwood sawtimber - all grid cells where 70% or more of the grid cell area consisted of hardwood forest cover and the majority of the canopy was sawtimber (that is, crown size indicated that the estimated mean d.b.h. is > 10 inches.

NO = Non-forest (agricultural areas, water etc.)

FO = Other forest (conifers, regeneration, seedling/sapling, etc.)

CC = Cloud cover - all grid cells where clouds or cloud shadows obscured more than 30% of the grid cell area.

Damage Class:

1 = No dead or declining trees within the grid cell

2 = A single dead/declining tree within the grid cell

3 = Two to 4 dead/declining trees within the grid cell

4 = Five or more dead/declining trees within the grid cell

Dead and declining trees were identified using guidelines developed by Ciesla et al. (1985) and modified for southern conditions by Starkey and Ciesla (1986). Figures 3 and 4 illustrate the natural color and color infrared photo signatures of the crowns of such trees. For example, a grid cell stratified in the S-2 class contained trees with large crowns indicative of large stem diameter) would have a single dead or declining tree within its boundaries. It was not possible to determine the species of tree with symptoms from PI alone. However, prior experience suggested that oaks were the principle species affected.

Validation of Stratification - Because of the rapidity of the stratification procedure there was an inherent risk of error, especially for the more subtle crown signatures of living trees with crown dieback but no chlorosis (Figure 4, damage types E, F, and G). Validation was accomplished through detailed PI counts of affected trees in a subsample of grid cells within each hardwood size and damage class. Cells were selected at random from all scanned cells within a stratum according to the following intensities:

Percent of Forested Cells in Stratum	Sampling Intensity
0-2	100%
3-10	50%
11-25	10%
25+	5%

The number of cells in each stratum and the sampling intensity used for PI counts is found in Table 1. Trees affected by decline/mortality were identified using Figures 3 and 4 and tallied in three categories - recent dead, declining, and older dead.

Damage types included in these categories were:

Declining - damage types C, F and G
Recent dead - damage types D and H
Older dead - damage type I

Ground Sampling

A subsample of grid cells with tree counts was randomly selected for collection of ground plot data. All strata were represented on each RD by no fewer than 2 grid cells up to a targeted maximum of 30 total grid cells for the RD. Damage classes 3 and 4 were more heavily sampled than damage classes 1 and 2. The actual number of grid cells selected for field sampling and the sampling intensity are displayed in Table 2.

Grid cells were sampled in the field during the summer of 1987, one year after aerial photos were acquired. Each cell was located by traversing to one corner from a known ground point after scaling and orienting the photo in the field using identifiable landmarks. A portable stereo transparency viewer facilitated accurate navigation in the field.

Validation of PI Tree Counts - A complete count of dead and declining trees on the ground was necessary to correlate PI damage estimates and actual ground conditions. Due to time constraints, not all grid cells randomly selected for ground sampling received complete counts. We concentrated complete counts in grid cells with the highest damage classes (3 and 4) and where we had a very high level of confidence in cell boundary location. Dominant and codominant trees that were dead or had 1/3 or more crown dieback were included in the count. The number of cells receiving such counts was 19, 9, and 12 for the Buffalo, Lee and Wayah, respectively.

Site and Stand Data - In all grid cells selected for ground sampling, five basal area factor (BAF) 10 prism plots were systematically established according to the configuration in Figure 5. Trees above 5" d.b.h. were tallied and rated for crown position, crown condition, size, and other characteristics (Table 3). Data collected on site characteristics are listed in Table 4.

Data Analysis

The distribution of RD area among strata was determined by applying estimates and standard errors derived from PI stratification to total RD area obtained from timber inventory records. PI accuracy was estimated in the validation process and used to interpret the accuracy of RD area estimates among strata. Validation of PI tree counts was accomplished through correlation analysis of dead and declining trees alone and combined for the cells receiving complete tree counts. Prism plot data were averaged and standard errors calculated for each stratum within RD's to obtain estimates of affected trees and volume per acre. Tree condition data were related to site characteristics collected on ground plots. In all analyses utilizing tree condition, only dominant and codominant tree data were used.

RESULTS

Photointerpretation

The number of interpreted photo sample blocks varied for each RD but the sampling intensity was fairly consistent, averaging 8.3 percent of the actual ground area (Table 5).

Stratification was highly accurate (Table 6). Overall, 94 percent of grid cells with detailed PI tree counts were correctly classified, with a range of 91 (Wayah RD) to 97 percent (Lee RD). When errors did occur, detailed PI tree counts showed a greater tendency to underestimate decline damage; there were nearly 4 times the number of underestimated grid cells (96) than overestimated (25). Errors were rarely more than a single damage class, that is, it was rare for a grid cell stratified as damage class 2 to be found a class 4 by PI validation. Grouping of damage classes 1 & 2 into unaffected, and 3 & 4 into decline-damaged would, therefore, result in an even higher stratification accuracy. Only those grid cells stratified in damage class 2 that were actually damage class 3 and vice versa would be stratification errors. The accumulated errors for all strata and RD's under this grouping resulted in 98 percent overall accuracy.

Area Affected

The estimated area within strata on each Ranger District are presented in Table 7. Over 90 percent of the hardwood forest type was covered with sawtimber-sized trees; less than 10 percent were covered with poletimber. The distribution by stratum varied among RD's. The Buffalo RD had the highest proportion of damage-free area (51 percent; P1 + S1 = 100,797 acres). The Lee RD had the highest proportion of damage class 4 area (26 percent of hardwood type; 36,844 acres), followed by the Wayah (8 percent; 10,250 acres) and the Buffalo (6 percent; 10,952 acres).

We considered damage classes 1 and 2 to represent areas unaffected by decline and damage classes 3 and 4 to represent affected areas. Making these combinations results in 28 percent incidence in host type on the Buffalo, 55 percent on the Lee and 35 percent on the Wayah (Figure 6).

Ground Sampling

Photo vs. ground correlation - PI counts gave excellent estimates of the number of dead trees actually present, but not the number of live declining trees (Table 8). The correlation between PI and complete ground counts was significant for mortality on all RD's but not for live declining trees. The lack of correlation for live declining trees underscores the difficulty in detecting this type of damage on aerial photos. The correlation of PI counts with complete ground counts of dead and live declining trees combined was significant for the Lee and Wayah RD's, but not for the Buffalo RD. A larger photo scale and longer camera lens (less image distortion) would improve individual tree resolution, improving accuracy in identification of living trees with decline. Patterns inherent in stratification - i.e. a stepwise increase in trees damaged with damage class - were generally evident in all RD's (Figure 7). This pattern was most evident for mortality and reflects the strong correlation of PI and ground mortality counts. Thus, sampling with BAF 10 plots provided acceptable estimates of dead and live declined trees when complete ground counts were not possible.

Volume - Since the cordwood volume in poletimber strata has a very low monetary value, only sawtimber volume data are presented. Sawtimber volumes in poletimber strata were much lower than for sawtimber strata, as would be expected (Table 9). Overall timber volumes were highest on the Wayah, and lowest on the Buffalo mainly due to differences in site quality. Volume of dead trees was also highest on the Wayah (S4 stratum) and also had the highest volumes in moderate/severe decline (S2, S3 and S4). Similarly, dead and declining volumes were lowest on the Buffalo, with very little declining volume (only in S4). Mortality as a percent of total stratum volume was highest in S4 on the Wayah and generally increased with damage stratum on all RD's except for a relatively high proportion in S1 on the Lee (Figure 8). Total mortality volume for all RD's was 25,019 mbf for decline-damaged strata (P3+P4+S3+S4; Table 10), with nearly half of this occurring on the Lee. Trees with moderate or severe decline totaled an additional 31,280 mbf. Monitoring has shown that trees with moderate or severe decline usually die within 5 years. Volume of trees in advanced decline was very low on the Buffalo (183 mbf) and highest on the Lee (21,116 mbf). These volumes actually represent periodic mortality and decline. We tallied trees that were judged to have died <= 4 years prior to survey. If the period of mortality volume accumulation is assumed to be 4 years, then the average annual mortality volume for the period ranged from 1,405 mbf/yr for the Wayah to 3,211 mbf/yr for the Lee.

Trees Affected - Mortality and advanced decline of dominant and codominant trees were most severe where decline incidence was highest. For example, the Lee RD had the highest incidence of affected acres (P3+P4+S3+S4=56.2 percent; Table 7) and the highest overall damage in classes 3 and 4 (12.5 and 15 percent, respectively; Figure 7). Mortality in the higher damage classes was similar among RD's. Advanced decline (>1/3 crown decline) did vary; it was substantially higher on the Lee and Wayah RD's compared with the Buffalo.

Species Affected - Species in the red oak group had consistently higher incidence of mortality and advanced decline, even though they did not always predominate (Figure 9). On all RD's, white oak incidence was less than half that of red oaks. This was true even on the Lee where white oaks were more than twice as common in the overstory compared with red oaks. The only non-oak species with appreciable decline symptoms were hickories. Greater species diversity on the Wayah RD did not translate into less damage. Non-oak species accounted for 51 percent of the overstory (compared with 16 and 21 percent for the Lee and Buffalo, respectively) but incidence of affected area was intermediate (Figure 6) and affected volume was greatest (Table 9).

Stand Age - Hardwood forests on these RD's are overwhelmingly sawtimber-sized (Table 7) with most of this in the older age classes (Figure 10). More than half of all sawtimber cells were >70 years old with over 95 percent >50 years old. This age structure reflects the history of wide-scale logging 50 or more years ago, prior to Forest Service acquisition and very low rates of regeneration since. Wayah sawtimber cells were somewhat older than elsewhere with 63 percent >70 years old. The Buffalo was youngest overall, with about 2/3 of all sawtimber cells in the 50-69 year age class. The imbalanced age distribution in all RD's will have important decline implications in the future as the forest continues to age and the area in regeneration remains small.

Poletimber cells on the Buffalo and Wayah were relatively young (67-100 percent <70 years) compared to the Lee (only 10 percent <70 years). Crown size on aerial photos did not correlate well with poletimber age on the Lee RD since it was much older than crown size indicated.

Associated Site Factors - Mortality and decline were, on the average, more common where xeric site conditions prevailed, although there was quite a bit of variation among RD's. These relationships were previously noted in a southwide survey of decline-damaged stands (Starkey et al. 1989). Ridge and slope topographic positions (Figure 12), shallow soils (Figure 13), and relatively low site (Figure 14) index tended to have the greatest damage.

SUMMARY AND RECOMMENDATIONS

Oak decline was confirmed as a widespread and sometimes locally severe disease on the surveyed RD's. This survey not only provides a detailed view of conditions within the RD's but a window to conditions on similar areas within the physiographic regions they represent. Other National Forests and nearby areas in the Southern Appalachian and Ozark Mountains are most closely comparable. Based on other survey data (Oak et al. 1991), it is known that NF's generally have higher incidence than other ownerships and that the Lee RD is in a region of Virginia with the highest oak decline incidence and severity.

Oak decline is a normal part of ecosystem processes in aging upland hardwood forests. Dieback and death is an expected result when physiologically mature oaks come under stress. It is a normal function of root disease fungi like *Armillaria mellea* and insect pests like the two-lined chestnut borer to preferentially attack, kill, and decompose weakened members of the tree canopy. As expected and natural as these results may be, many forest values including wildlife, timber, and recreation will be influenced by oak decline. These effects will occur on large scales, given that incidence ranges from 28 to 57 percent in landscapes dominated by vulnerable hardwood forest types. Whether these effects are positive, negative, or neutral depends on the importance that oaks are deemed to have in the ecosystem.

On lands devoted to forest uses in perpetuity and where species composition is unimportant, oak decline has little effect. Tree cover will re-establish itself and oaks will probably persist as a component, albeit reduced in abundance, diversity, and importance.

Other influences may be viewed as positive. These include the creation of small openings, reduced canopy density, short-term stimulation of understory species, increased diversity of cover types, more denning and cavity-nesting sites and an increase in some old-growth attributes such as increased structural diversity and increased coarse woody debris. Species composition shifts to non-oak species may be desirable in some locations.

If oaks are considered a highly desirable component of the forest, then the consequences of oak decline are decidely negative in the short run and probably negative in the long run. Mortality results in lower stocking overall, lower oak stocking, and lower oak species richness and diversity as more susceptible red oaks die and are replaced by other, usually non-oak, species. Living oaks with decline will produce fewer and lower quality acorns (as food and as potential propagules for regeneration) with the net result of smaller and less consistent mast crops. This is a negative consequence for wildlife that use acorns as food and where substitutes are not available or are less desirable. Oak regeneration capacity is reduced due to the reduced capacity of declined trees to sprout after cutting and from fewer and lower quality acorns. Long term monitoring is in early stages but to date we have seen few situations where understory oaks are recruited into the upper crown positions vacated by dead oaks. To the contrary, other species such as red maple and black gum are more often positioned to occupy the available space. Others have noted similar species composition changes after decline and mortality induced and enhanced by repeated gypsy moth defoliation (Feicht et al. 1993, McGee 1986).

No data exist to suggest particular future trends in the occurrence or severity of oak decline. Historically, oak decline has been reported in the literature in every decade of the 1900's except the 1940's, and nearly every eastern state has been affected (Ammon et al. 1989, Millers et al. 1989). Stress will be a certain, though unpredictable, element of future conditions. Oak decline can, therefore, be expected to continue as a significant forest health issue. Then, to the extent that oak forests continue to age without the introduction of new age classes, the landscape becomes more uniformly susceptible to the effects of oak decline. Incidence and severity will likely increase, especially where drought stress is compounded by repeated defoliation by advancing gypsy moths.

No direct control methods are currently available for oak decline. Drought and frost are recurring phenomena which cannot be controlled and are difficult to predict. Epidemics of defoliating insects (epecially gypsy moth) can and have been controlled by chemical means (Doane and McManus 1981) but control is temporary, expensive, difficult to coordinate and generally limited in scope. Research is needed to develop effective, feasible methods for managing the effects of such pests as *Armillaria* spp. and *Agrilus bilineatus*.

Sound preventive techniques are also lacking for oak decline. Periodic thinning of young healthy stands might help shape species composition and retain vigor of oaks into older age classes (Sonderman 1984, Dale and Sonderman 1984, Graney 1983), although stem quality can be reduced unless careful stocking control is maintained. Unfortunately, early thinning is economically unattractive unless subsidized by sources outside of timber sales receipts.

Wood volume losses could be mitigated through salvage of recently dead and severely declining trees. In addition to the benefit gained by utilization, residual trees stand to benefit from additional growing space, moisture, and nutrients. While this response seems logical, it is difficult to justify economically except on better sites. Here, salvage volume and residual volume are more likely to be sufficient to justify the entry and the partial cut. Based on this and other surveys (Starkey et al. 1989, Oak et al. 1991), oak decline infrequently occurs on above average sites. Use of salvage is further complicated by the risk of increased severity and incidence in residual trees due to the exposure of the forest floor and root disturbance from machinery (Mason et al. 1989, Wargo and Harrington 1991).

The introduction of new age classes through harvest and regeneration seems a prudent course to reduce oak decline effects on landscapes. The functional upland hardwood forest ecosystem will always have a component that is suceptible to, or actively declining. Land managers must decide how much area will be involved and how it will be distributed on the landscape. Selection of a cutting method and other treatments to achieve regeneration objectives requires careful consideration of desired future condition; composition, abundance, and competitive ability of regeneration; and the mixture of resource values to be emphasized. Clearcutting, group selection, and various shelterwood applications can be used successfully to regenerate upland hardwoods if adequate advance reproduction is present. The public at large has grown less tolerant of clearcutting, particularly on public lands. The age and condition of the residual stand must be considered where shelterwood or group selection methods are more desirable. As with salvage discussed earlier, these regeneration methods carry a risk of continued or increased decline in the residual stand. The results of this and other oak decline surveys are being used to develop methods to assist land managers in classifying upland hardwood stands for decline status (hazard rating) using standard inventory data. Preliminary results indicate that the most vulnerable stands are physiologically mature, have a large oak component (especially in the red oak group), and grow on sites of average and lower productivity. A measure of physiologic maturity has been suggested (Oak et al. 1991) that combines site index (a surrogate for the propensity to suffer drought stress) and chronological age in a ratio. The stands where actions are most urgently indicated are those with a large red oak component growing on average and lower sites where stand age exceeds the site index (SI/age ratio < 1.0). Likewise, leaving large or physiologically mature red oaks for extended periods after partial cuts in stands with these characteristics is a risky practice.

Taking no action is also an option. It implies the land manager's willingness to emphasize non-timber resources and acceptance of the effects that accompany the shifts in species composition away from oaks pointed out by McGee (1986) and Feicht, Fosbrooke, and Tweery (1993).

The findings of this survey and the interpretation of decline effects raise several questions. They include:

- Will oak replace itself in decline areas without intervention in the long run?

- What are the consequences of reduced oak diversity and richness for upland hardwood forest ecosystems?

- Are there plant or animal species dependant on these forests and are they threatened by oak decline?

- Should the apparent trend away from oak under the present disturbance regime be reversed?

- Should attempts be made to restore oak to areas where it has been eliminated by the combined effects of decline and gypsy moth defoliation?

- What are effects of harvest methods on residual overstory health and regeneration?

- What role might fire play in encouraging oak reproduction in upland hardwood stands?

Some of these are researchable questions while others are more value-based with social connotations. Land managers should be aware of oak decline in their decision making while answers are pursued through scientific inquiry and social debate.

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APPENDIX

Figure 1. -- National Forest Ranger Districts surveyed for hardwood decline.

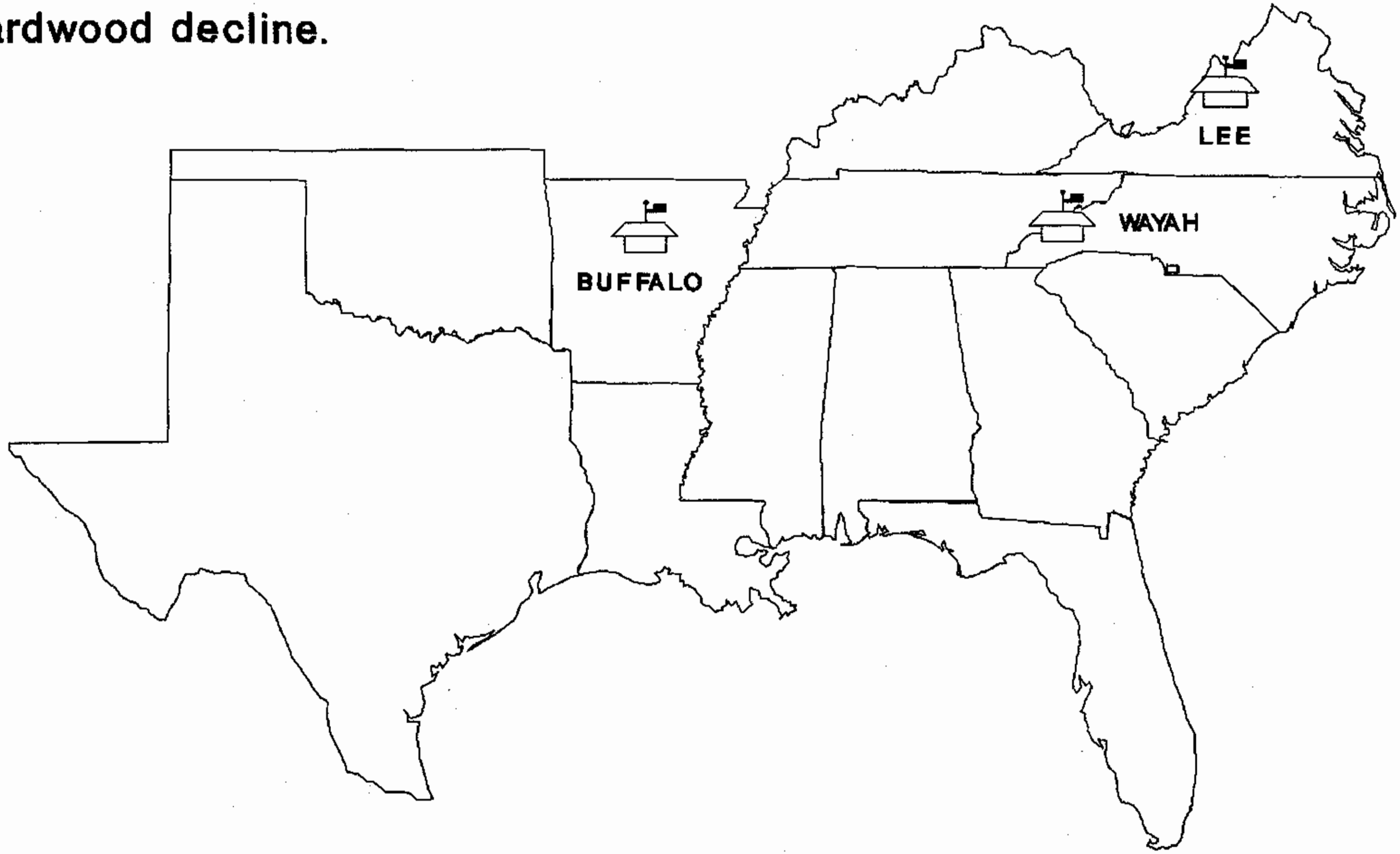
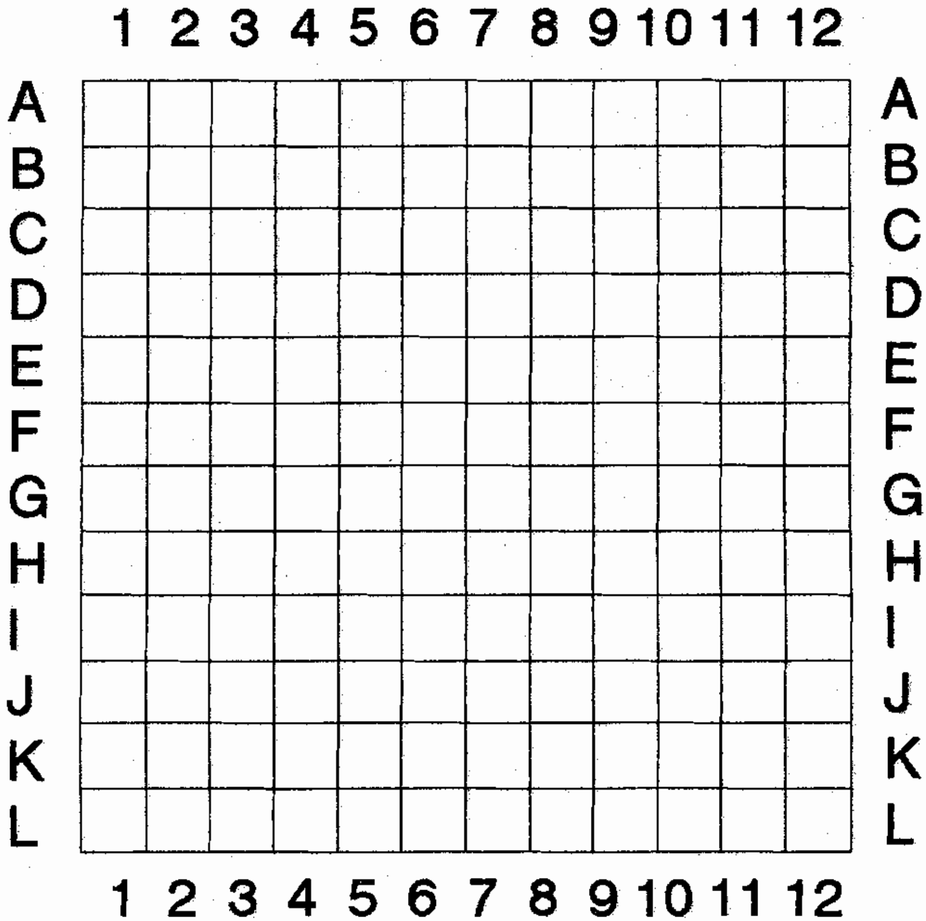
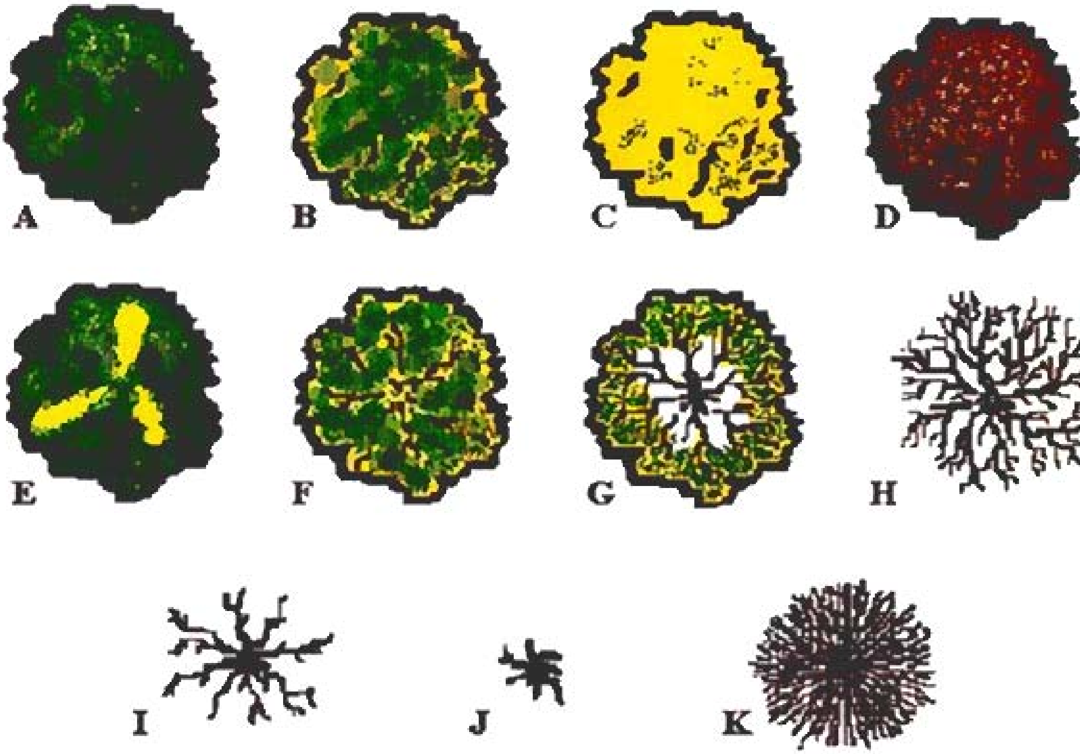


Figure 2.--Sampling grid for color-infrared aerial photography.



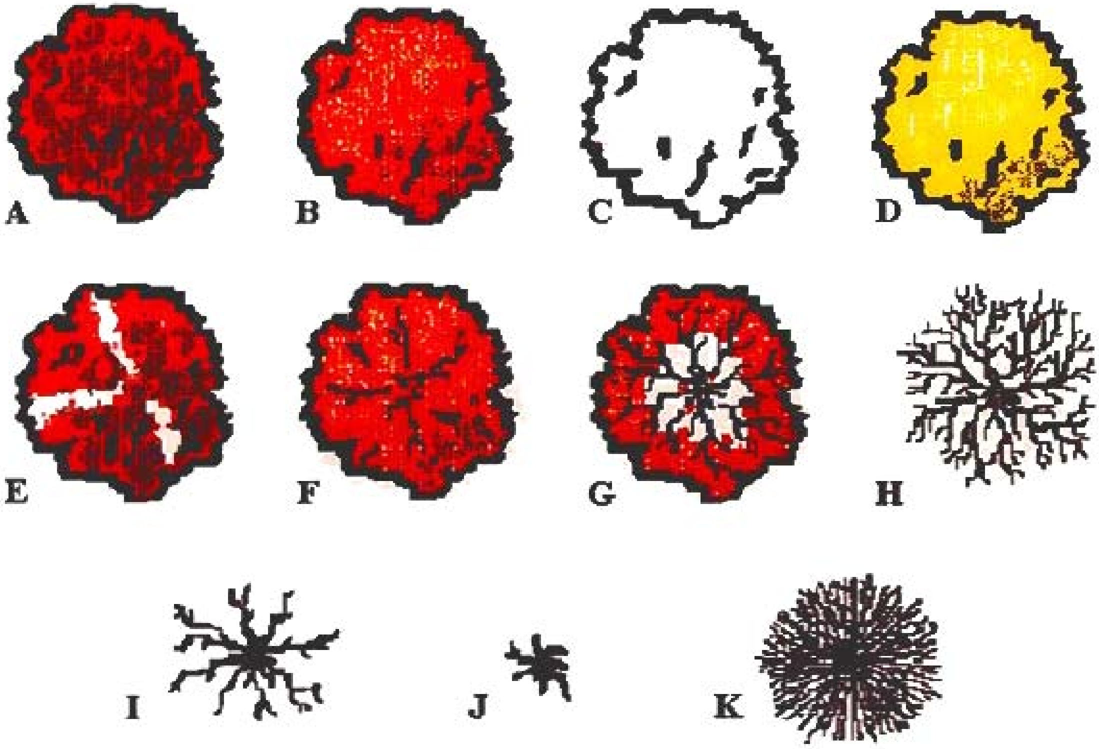
1:8500

Figure 3. - - Crown damage types - approximate natural color.



A - Healthy crown
B - Slightly chlorotic crown
C - Acutely chlorotic crown
D - Crown with dead foliage
E - Crown with chlorotic, " flagging " branches
F - Slightly chlorotic crown with slight dieback
G - Slightly chlorotic crown with severe dieback and foliage loss
H - Recently dead crown with no foliage
I - Older dead crown with fine twigs missing
J - Very old dead snag
K - Dead conifer

Figure 4. - - Crown damage types - approximate color on color - infrared aerial film.



- -

A - Healthy crown
B - Slightly chlorotic crown
C - Acutely chlorotic crown
D - Crown with dead foliage
E - Crown with chlorotic, " flagging " branches
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H - Recently dead crown with no foliage
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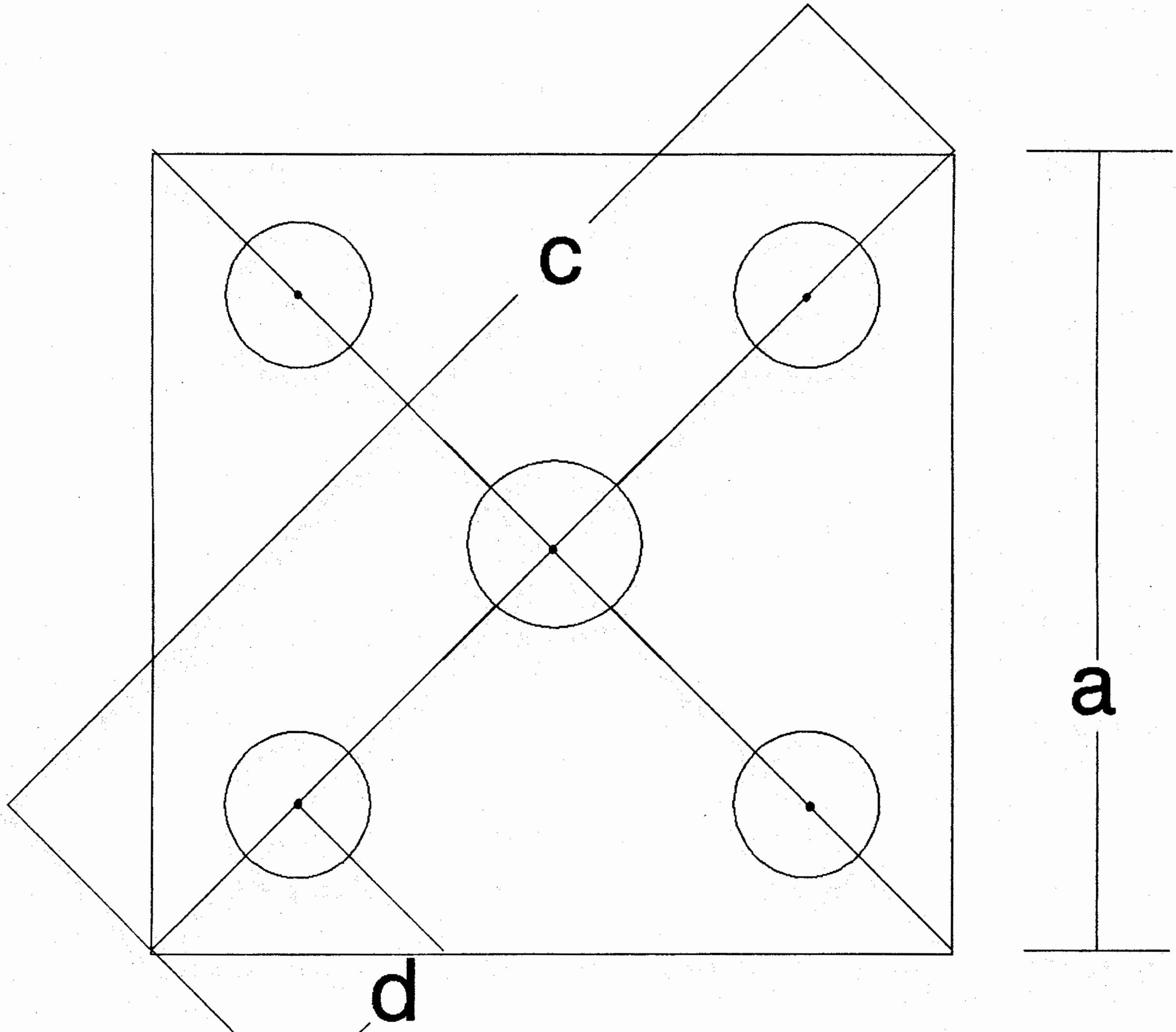
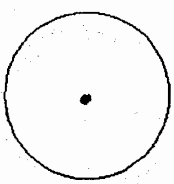
J - Very old dead snag
K - Dead conifer

Figure 5.--Grid cell diagram with ground and plot locations and dimensions.



For 2.5 ac cell at target scale of 1:8000:

a = 330.0' c = 466.7' d = 116.7'



Location of BAF-10 prism plot

Figure 6.-- Percent of hardwood acres in affected and unaffected strata by Ranger District.

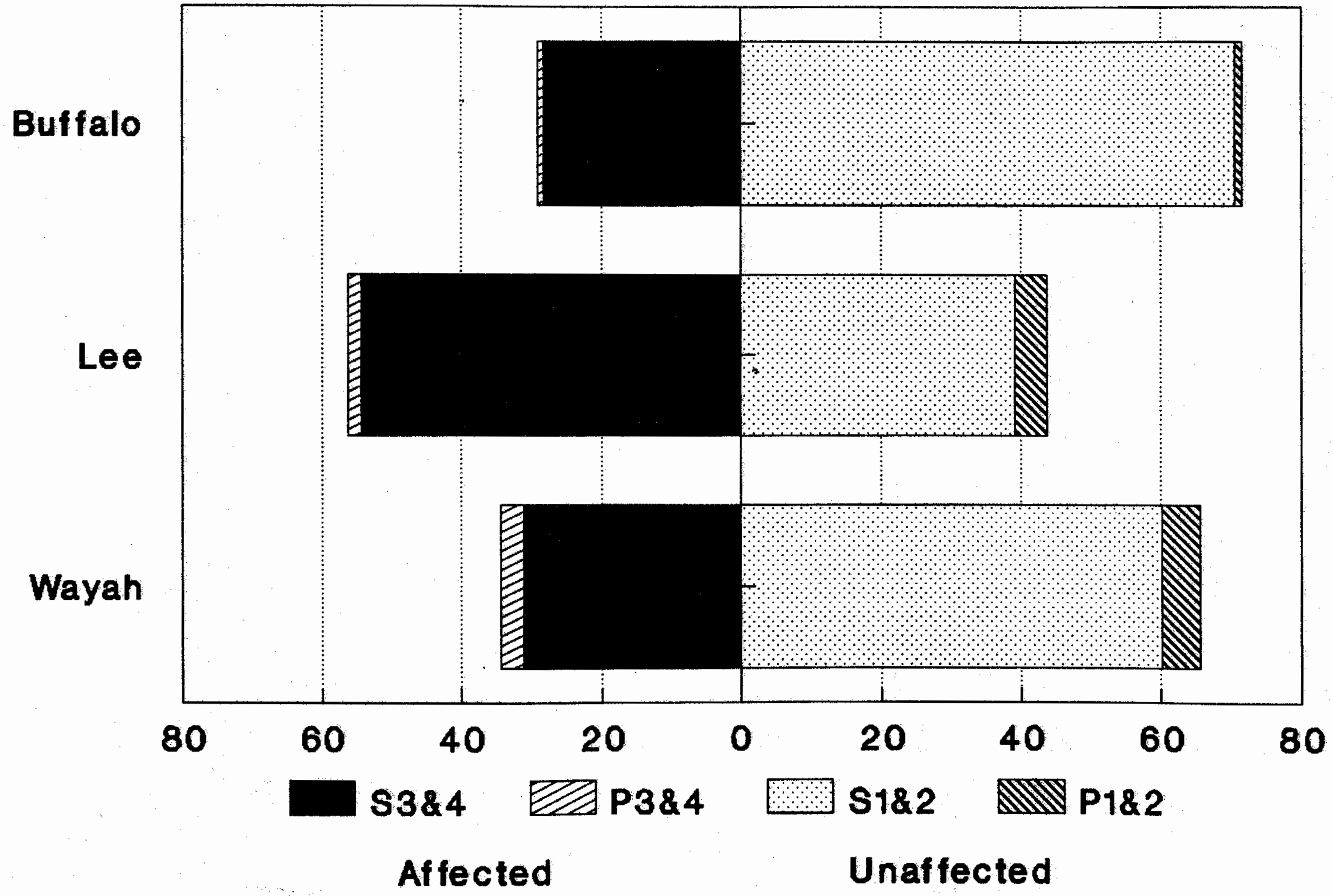


Figure 7.--Oak decline damage estimates obtained from ground sampling for photointerpreted damage strata by Ranger District (dominant and codominant trees only).

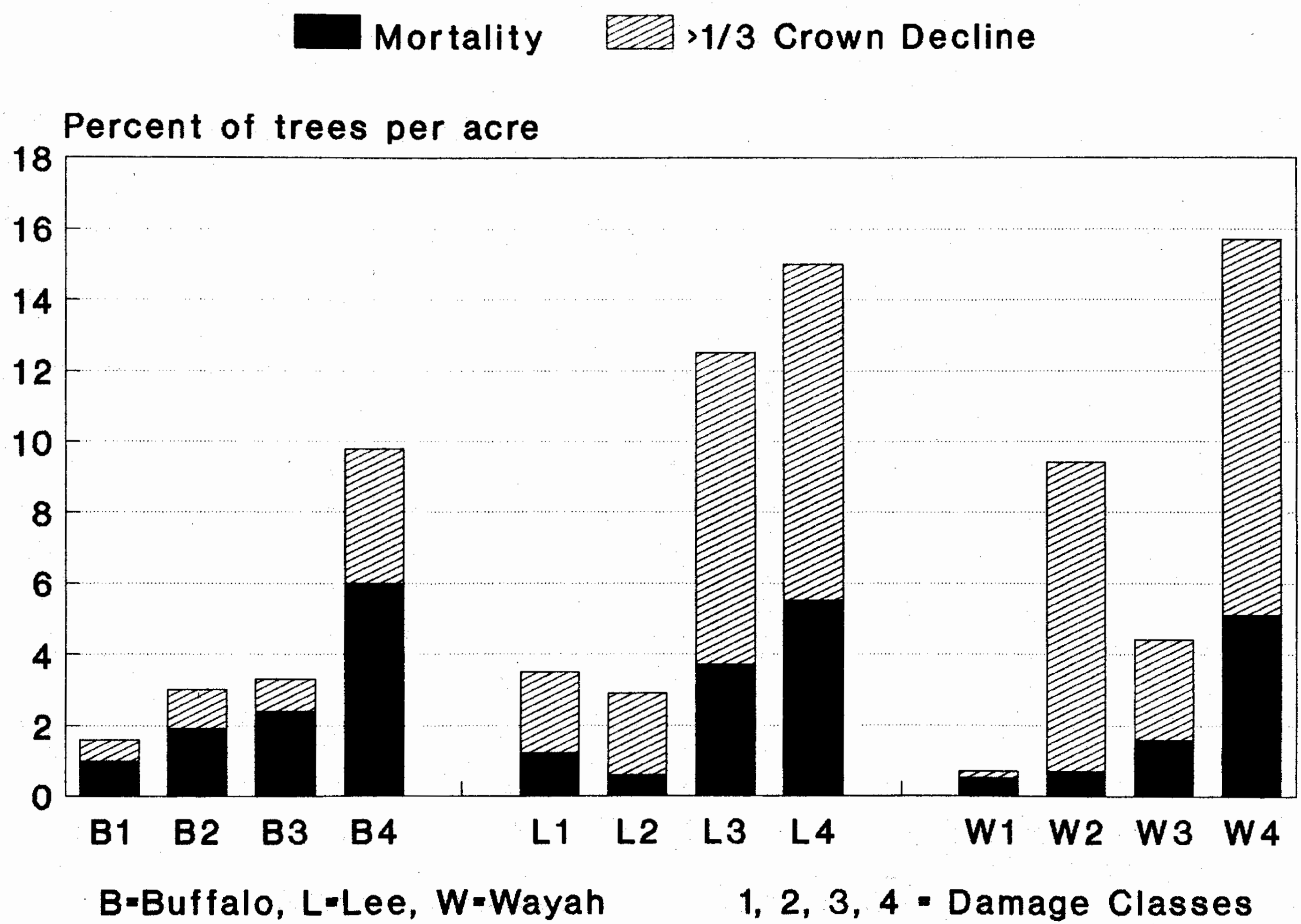


Figure 8.--Average percent cumulative mortality volume of dominant and codominant trees in sawtimber strata by Ranger District.

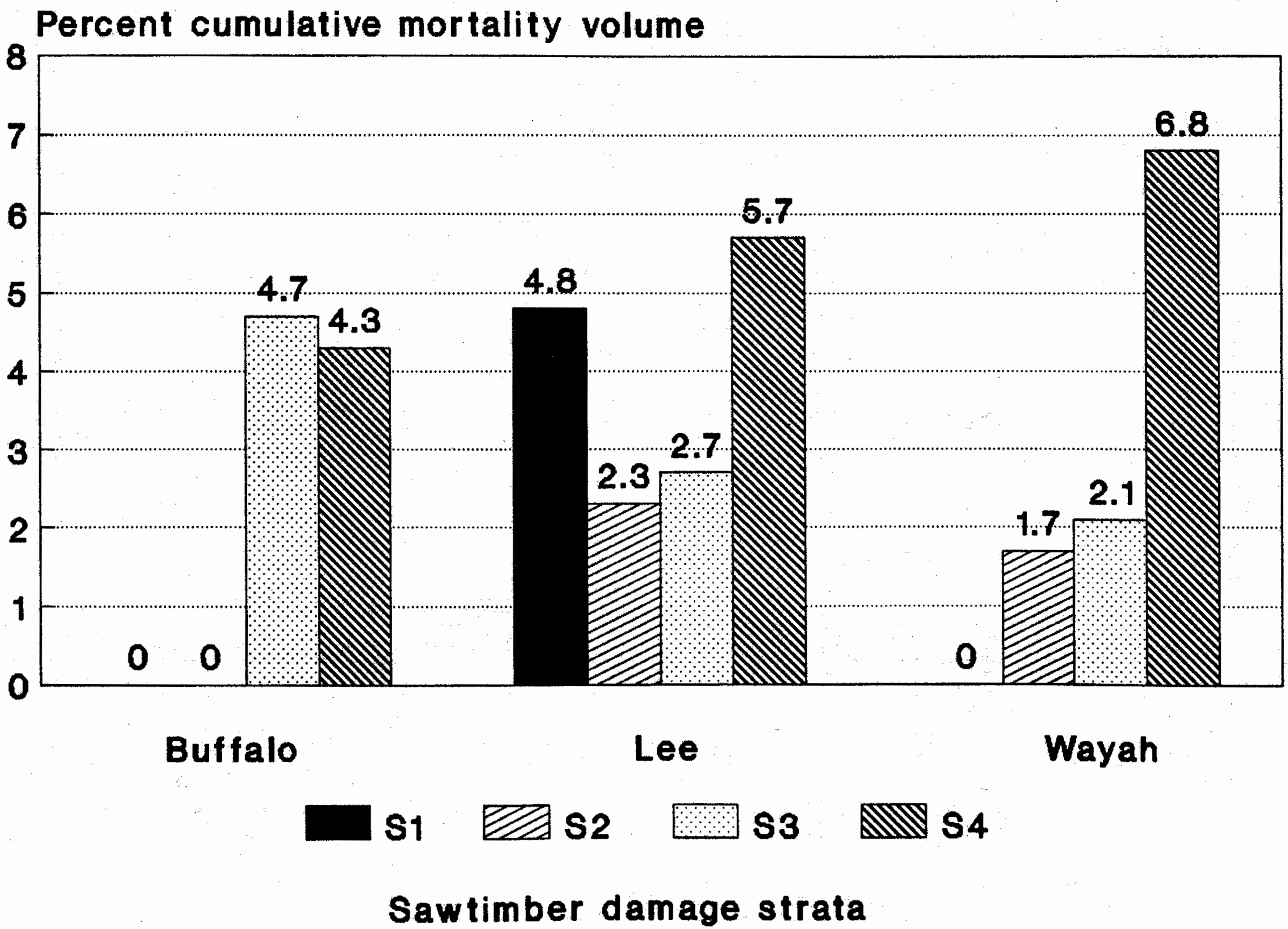


Figure 9.--Percent of dominant and codominant trees by crown condition, species group and Ranger District (from ground plot data).

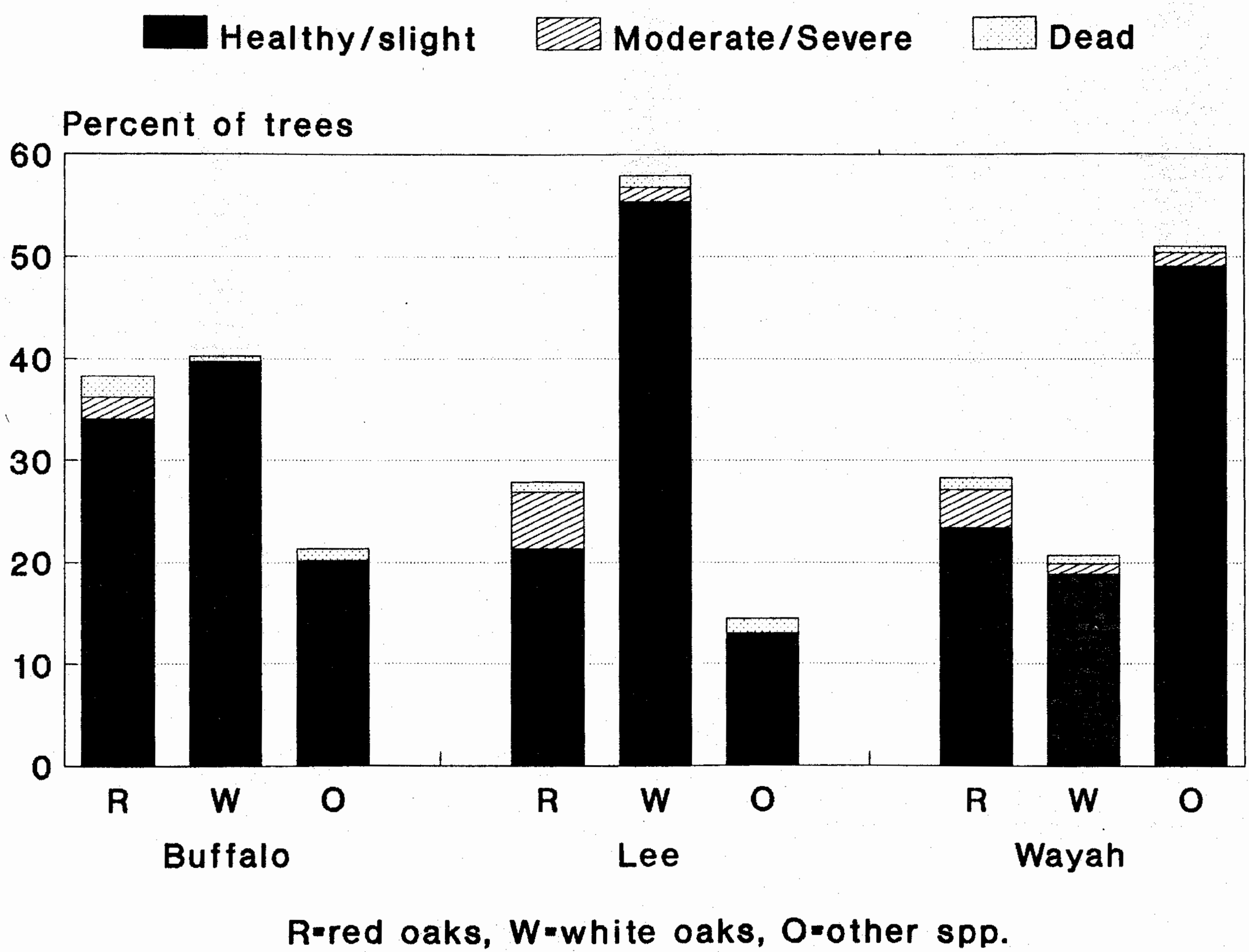


Figure 10.--Percent of sawtimber grid cells by age class class for all Ranger Districts combined.

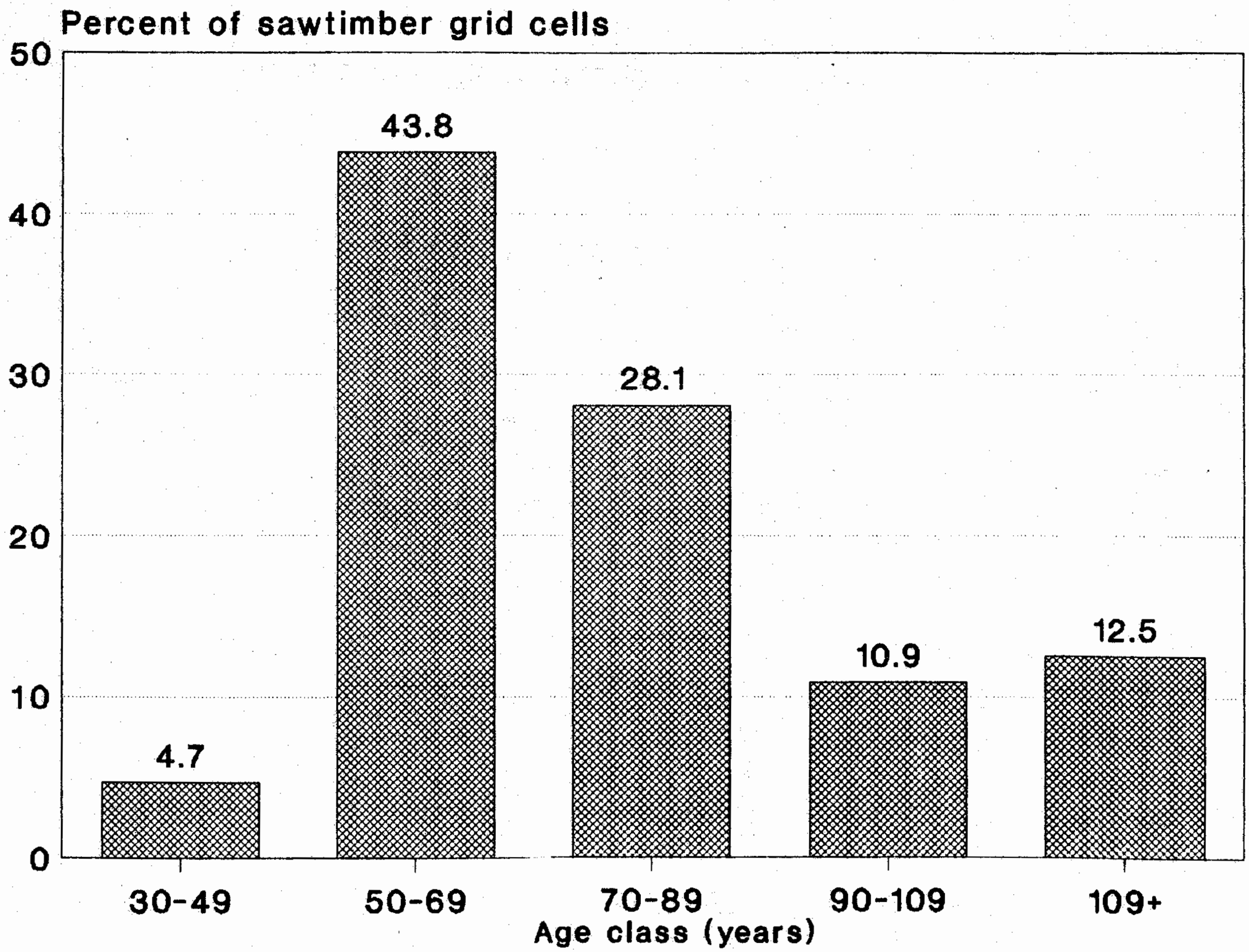


Figure 11.--Percent of sawtimber grid cells by age class and Ranger District.

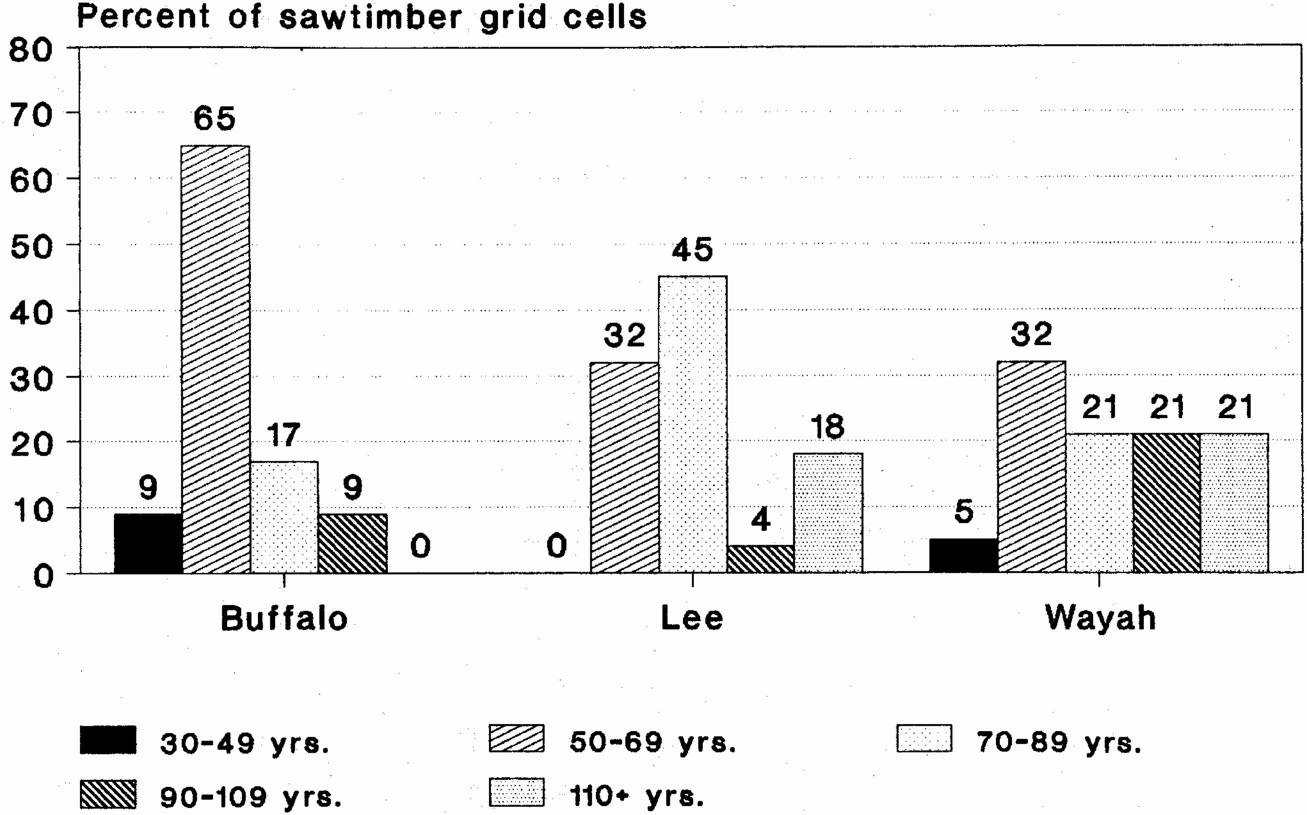


Figure 12.--Average percent of dead or declining, dominant and codominant trees per acre by topographic position for all Ranger Districts combined.

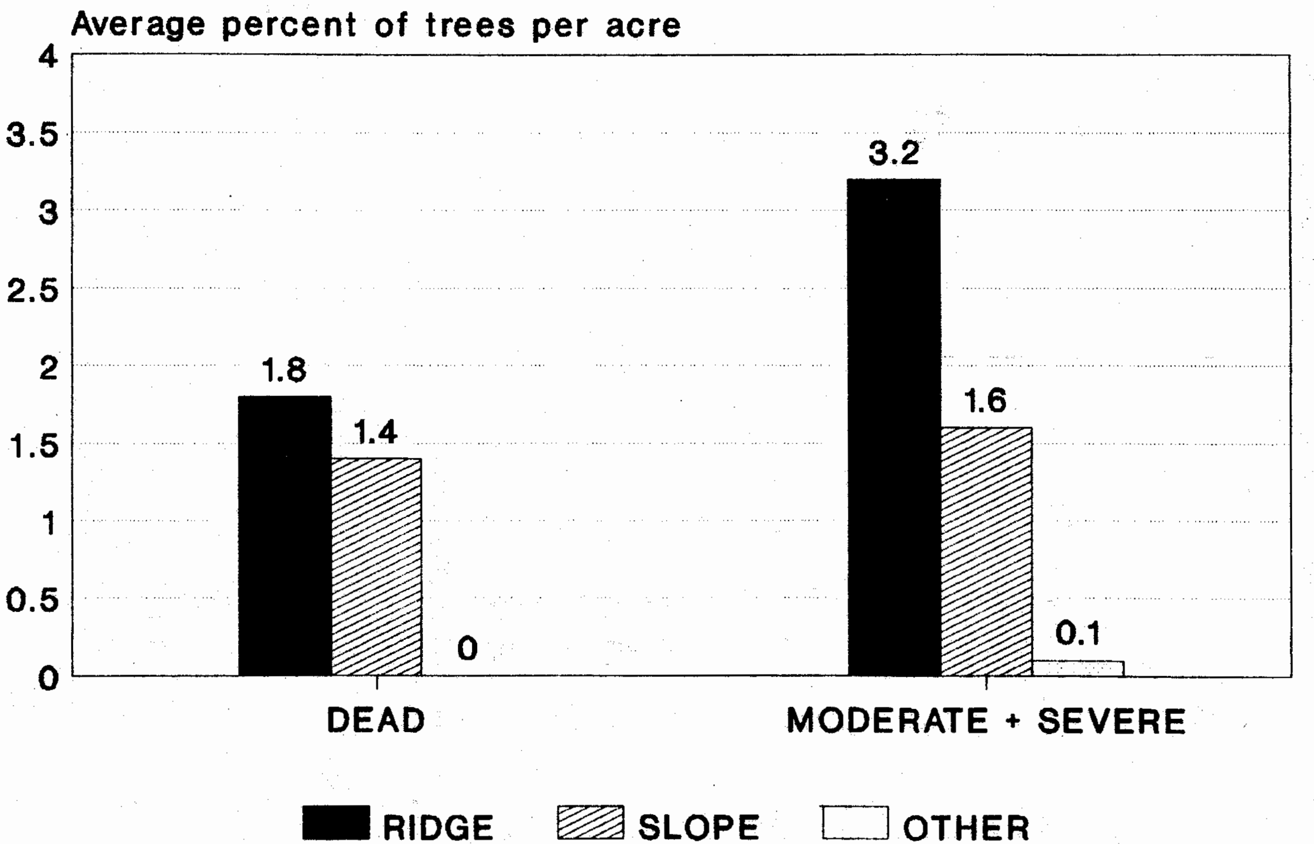


Figure 13.--Average percent of dead or declining, dominant and codominant trees per acre by soil depth category for all Ranger Districts combined.

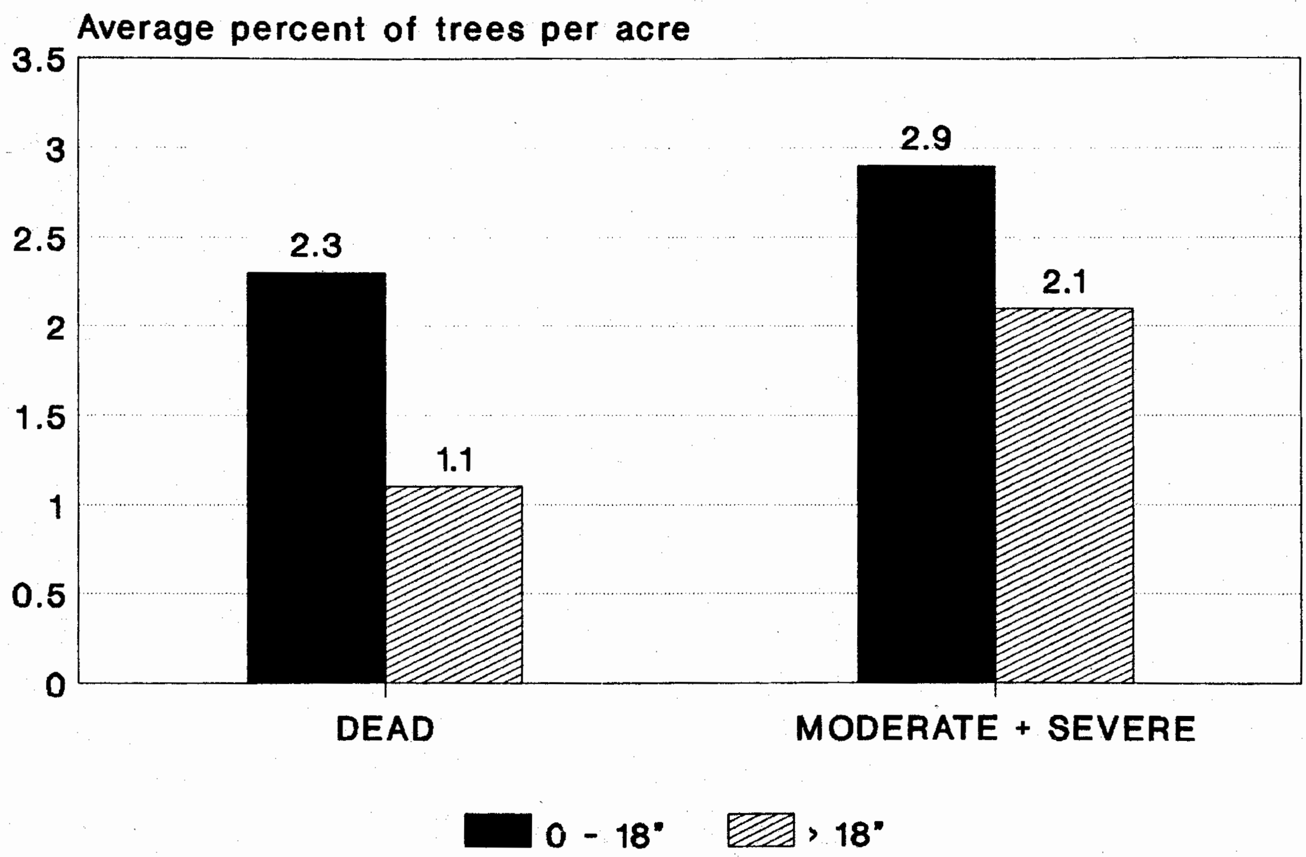


Figure 14.--Average percent of dead or declining trees per acre by site index class for all Ranger Districts combined.

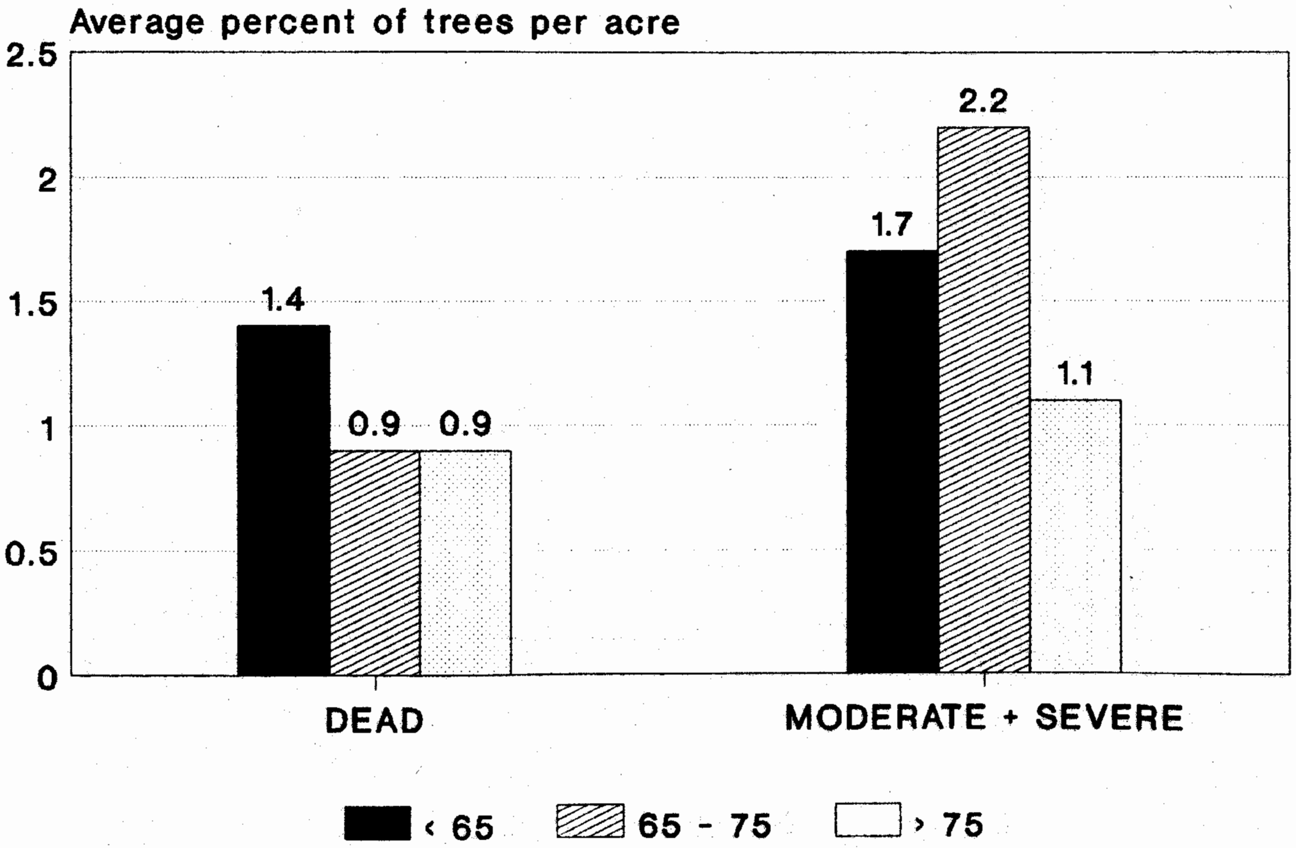


Table 1.--Stratification, sampling rate and number of grid cells receiving validation tree counts.

Stratum	No. Cells in Stratum	Sampling Rate	No. Cells with Validation Counts
BUFFALO RD			
P-1	57	100%	57
P-2	8	100%	8
P-3	12	100%	12
P-4	5	100%	5
S-1	3037	5%	160
S-2	1194	10%	121
S-3	1336	10%	153
S-4	328	50%	174
Total	**5077**	---	**690**
LEE RD			
P-1	183	50%	92
P-2	38	100%	38
P-3	65	100%	65
P-4	26	100%	26
S-1	1328	10%	133
S-2	555	10%	56
S-3	1373	10%	137
S-4	1151	10%	115
Total	**4719**	---	**662**
WAYAH RD			
P-1	167	50%	84
P-2	67	100%	67
P-3	97	50%	47
P-4	49	100%	49
S-1	1577	5%	79
S-2	935	10%	94
S-3	1013	10%	101
S-4	309	50%	155
Total	**4214**	---	**676**

Table 2.--Number of grid cells with tree counts and grid cells selected for ground sampling.

Stratum	No. Cells with Tree Counts	No. Cells with Ground Plots
BUFFALO RD		
P-1	57	2
P-2	8	2
P-3	12	2
P-4	5	2
S-1	160	4
S-2	121	4
S-3	153	6
S-4	174	9
Total	**690**	**31**
LEE RD		
P-1	92	3
P-2	38	2
P-3	65	4
P-4	26	2
S-1	133	4
S-2	56	2
S-3	137	8
S-4	115	7
Total	**662**	**32**
WAYAH RD		
P-1	84	2
P-2	67	2
P-3	47	3
P-4	49	3
S-1	79	3
S-2	94	3
S-3	101	6
S-4	155	9
Total	**676**	**31**

Table 3.--Sample data collected on all trees >5" d.b.h. on ground sample plots.

FACTOR	MEASURE
Species	Species
Diameter breast height	Inches
Pulpwood products	Trees 5-9 inches d.b.h.; estimated number of 5-foot sticks to a 4-inch d.b.h. top
Sawtimber product	Trees $\geq$ 10 inches d.b.h.; estimated number of 16-foot logs to a 9-inch d.o.b. top
Crown position	(1) Dominant (2) Codominant (3) Intermediate (4) Suppressed
Crown condition (dieback)	(1) Healthy - no dieback (2) Slight - <1/3 of crown dead (3) Moderate - 1/3-2/3 of crown dead (4) Severe - >2/3 of crown dead (5) Dead - died this year (6) Dead - died last year (7) Dead - died 2-4 years ago

Table 4.--Site data collected on ground sample plots.

FACTOR	MEASURE
Elevation	Feet; obtained from topographic maps
Topographic position	(1) Ridge (2) Slope - upper 1/3 (3) Slope - middle 1/3 (4) Slope - lower 1/3 (5) Cove (6) Upland flat or bench (7) Lowland flat - stream terrace or bottom
Soil depth	(1) 0-6" to parent material or impervious layer (2) 7-12" (3) 13-18" (4) 19-24" (5) 25-30" (6) 31-36" (7) >36"

Table 5.--Photo sample statistics and PI stratification by Ranger District.

	Buffalo RD	Lee RD	Wayah RD
Forested Acres[1]	243,248	189,986	137,701
# Photo Sample Blocks	54	44	34
PI Acres	19,521	15,420	12,040
% PI Sample[2]	8.02	8.12	8.74
PI STRATIFICATION			
Hardwood (P+S)	77.0	74.6	85.7
Forested Other	18.3	24.3	11.4
Non Forested	4.7	1.1	2.3
Clouds & Shadows	0	0	0.6

[1] From RD timber inventory files (FY 89).

[2] PI Acres/Forested Acres.

Table 6.--Accuracy of photointerpretation stratification for cells with detailed tree counts by Ranger District.

Stratum	Cells Over[1]	Cells Under[2]	Total Cells	Percent Accuracy
BUFFALO RD				
P-1	-	2	56	96.4
P-2	0	0	8	100.0
P-3	0	0	13	100.0
P-4	0	-	5	100.0
S-1	-	9	160	94.4
S-2	3	8	121	90.9
S-3	4	3	153	95.4
S-4	6	-	174	96.6
Subtotal	**13**	**22**	**690**	**94.9**
LEE RD				
P-1	-	9	95	90.5
P-2	1	1	38	94.7
P-3	3	2	65	92.3
P-4	0	-	26	100.0
S-1	-	0	147	100.0
S-2	0	3	89	96.6
S-3	1	4	147	96.6
S-4	2	-	140	98.6
Subtotal	**7**	**19**	**747**	**96.5**
WAYAH RD				
P-1	-	9	84	89.3
P-2	3	11	67	79.1
P-3	1	5	49	87.8
P-4	0	-	49	100.0
S-1	-	3	79	96.2
S-2	0	11	94	88.3
S-3	0	16	101	84.2
S-4	1	-	155	99.4
Subtotal	**5**	**55**	**678**	**91.1**
Grand Total	**25**	**96**	**2114**	**94.3**

1 Rapid PI stratify damage class > PI tree count damage class.

2 Rapid PI stratify damage class < PI tree count damage class.

Table 7.--Estimated area in 8 hardwood size class/damage strata by Ranger Districts; from photointerpretation data.

Acres (percent) {standard error}

Stratum	Buffalo	Lee	Wayah
P1	1751 (0.89) { 452}	5387 (3.76) {1148}	4808 (3.96) {1017}
P2	251 (0.13) { 53}	1101 (0.77) { 235}	1899 (1.56) { 406}
P3	430 (0.22) { 91}	1920 (1.34) { 199}	2581 (2.12) { 361}
P4	162 (0.08) { 36}	776 (0.54) { 164}	1407 (1.16) { 195}
S1	99046 (50.39) {10193}	39532 (27.58) {3295}	46083 (37.92) {6474}
S2	39524 (20.11) { 4080}	16673 (11.63) {2333}	26903 (22.14) {3812}
S3	44611 (22.69) { 3036}	41900 (29.23) {2127}	29011 (23.87) {1979}
S4	10790 (5.49) { 494}	36068 (25.16) {2458}	8843 (7.28) { 400}
All hardwood (P&S)	196565 (100.0) { 2660)	143357 (100.0) {1857}	121535 (100.0) {1632}
Forested-other[1]	46679	46629	16166
Total area[2]	243248	189986	137701

[1] Includes conifer seedling/sapling, and recently harvested areas.

[2] Acres under Forest Service administration - FY89. Includes regulated and unregulated acres, but excludes water area and non-forest.

Table 8.--Correlation analysis of photointerpretation tree counts vs. complete ground counts of various damage types, by Ranger District.

Condition	Buffalo RD	Lee RD	Wayah RD
	(N=19 cells)	(N=9 cells)	(N=12 cells)
Mortality	**	***	***
Decline	ns	ns	ns
Total Damage	ns	**	*

*** Significant at P=.01
** Significant at P=.05
* Significant at P=.1
ns = non significant (P>.1)

Table 9.--Average board foot volume per acre of sawtimber trees by strata and tree condition by Ranger District.

	Average board foot volume per acre (standard error) Tree Condition			
	Moderate	Severe	Dead[1]	All Trees
BUFFALO RD				
P-1	0 (--)[2]	0 (--)	0 (--)	409 (08)
P-2	0 (--)	0 (--)	175 (11)	1,233 (12)
P-3	0 (--)	0 (--)	0 (--)	801 (08)
P-4	0 (--)	0 (--)	0 (--)	1,206 (13)
S-1	0 (--)	0 (--)	0 (--)	2,941 (15)
S-2	0 (--)	0 (--)	0 (--)	2,823 (13)
S-3	0 (--)	0 (--)	129 (24)	2,771 (11)
S-4	17 (03)	0 (--)	74 (05)	1,739 (07)
All	**5 (01)**	**0 (--)**	**59 (03)**	**2,015 (02)**
LEE RD				
P-1	0 (--)	0 (--)	0 (--)	1,640 (08)
P-2	0 (--)	0 (--)	0 (--)	636 (05)
P-3	85 (07)	0 (--)	0 (--)	1,709 (08)
P-4	91 (08)	71 (**)[3]	167 (16)	1,455 (11)
S-1	0 (--)	0 (--)	91 (07)	1,870 (08)
S-2	0 (--)	0 (--)	48 (07)	2,104 (09)
S-3	253 (17)	28 (08)	90 (06)	3,386 (12)
S-4	164 (11)	87 (18)	248 (10)	4,639 (15)
All	**112 (03)**	**28 (02)**	**98 (02)**	**2,669 (02)**
WAYAH RD				
P-1	102 (**)	0 (--)	0 (--)	2,022 (16)
P-2	477 (31)	125 (14)	276 (24)	2,608 (26)
P-3	0 (--)	85 (06)	118 (14)	2,455 (13)
P-4	102 (09)	96 (11)	0 (--)	2,058 (12)
S-1	0 (--)	0 (--)	0 (--)	3,446 (19)
S-2	527 (38)	108 (54)	65 (09)	3,854 (22)
S-3	176 (11)	25 (**)	97 (20)	4,690 (18)
S-4	320 (10)	93 (08)	283 (22)	4,152 (15)
All	**221 (03)**	**67 (02)**	**132 (05)**	**3,536 (03)**

[1] Volumes of dead trees represent the accumulation of about 4 years of mortality.

[2] Standard error not calculated.

[3] Too few observations to calculate a standard error.

Table 10.--Total volume of declining and dead sawtimber trees by Ranger District.

	Volume (mbf)[1]		
	Declining	Dead	Dead/yr.[2]
Wayah	9,981	5,621	1,405
Lee	21,116	12,845	3,211
Buffalo	183	6,553	1,638
Total	31,280	25,019	6,255

[1] Obtained by multiplying acres in Table 7 by volume/acre in Table 9 and summing P3 + P4 + S3 + S4.

[2] Annualized volumes obtained by dividing cumulative dead volume by 4 years.