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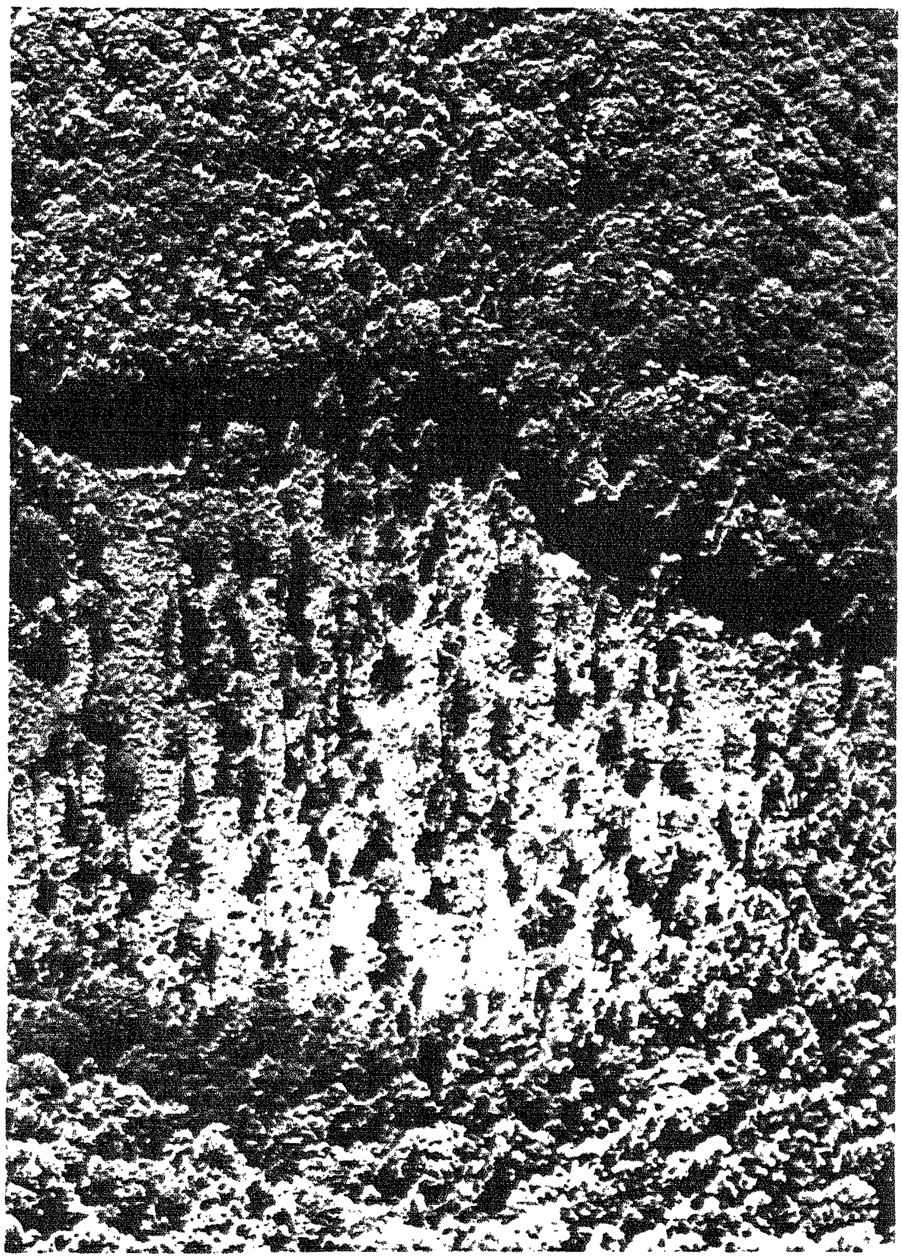

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For attending this conference, each registrant was eligible for 12 hours of Continuing Forestry Education (CFE) credit offered by the Society of American Foresters.

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ACKNOWLEDGMENTS

The editors would like to acknowledge and thank all of the people who served as manuscript reviewers for the Proceedings. The quality of the Proceedings has been improved due to your efforts. We would like to thank Becky Rosenberger for her assistance in typing the program, preparation of the table of contents, typing abstracts, proofreading, and in managing the manuscripts, reviews, and letters associated with the Proceedings. We thank Gary Miller for providing the cover photograph.

Cover Photo: This 1984 aerial photograph was taken from a helicopter three years after deferment cutting in 80-year-old central Appalachian hardwoods on the Fernow Experimental Forest near Parsons, West Virginia. (Photo by James N. Kochenderfer, USDA Forest Service.)

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10TH CENTRAL HARDWOOD FOREST CONFERENCE

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Edited by

Kurt W. Gottschalk and Sandra L. C. Fosbroke

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FOREWORD

This conference is the tenth in a series of biennial meetings that began in 1976 at Southern Illinois University. Other conferences have been hosted by Purdue University, University of Missouri, University of Kentucky, University of Illinois, University of Tennessee, Southern Illinois University with the North Central Forest Experiment Station (NCFES), Pennsylvania State University with the Northeastern Forest Experiment Station, and Purdue University with NCFES. The purpose of these conferences has remained the same: to provide a forum for the exchange of information concerning the biology and management of central hardwoods by forest scientists from throughout the Central Hardwood Region of the eastern United States. As with previous Proceedings, a wide range of topics that represent the broad array of research programs in this area is represented.

The social and biological characteristics of the Central Hardwood Region make it unique in comparison with other forest regions of the United States. For example, one-fourth of the United States human population resides in this region. Approximately 90% of the land is in private ownership and public lands tend to be small and fragmented with private inholdings. These and related conditions play critical roles in the practice of forestry in this region. The information presented in this Proceedings is important to the long-term management of the forest resources of this unique region.

REVIEW PROCEDURES

Each manuscript published in these proceedings was critically reviewed by at least two (usually three) scientists with expertise in disciplines closely aligned to the subject of the manuscript. Reviews were returned to the senior author, who revised the manuscript appropriately and resubmitted it in a diskette format suitable for printing by the Northeastern Forest Experiment Station, USDA Forest Service where they were edited to a uniform format and type style. Manuscript authors are responsible for the accuracy and content of their papers.

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POSTER SESSION

FOREST HEALTH IN WEST VIRGINIA: PAST, PRESENT AND FUTURE

Ray R. Hicks, Jr. and Darlene A. Mudrick[1]

Abstract: This report chronicles the status of forest health in West Virginia as of 1993. Primary data sources are the Forest Inventory and Analysis reports, West Virginia state forest pest reports, National Oceanographic and Atmospheric Administration weather records and numerous other publications. We attempted to describe primary stressing agents affecting the forest, including drought, defoliation, fire and overstocking and to relate the occurrence of stress to the performance of the forest (growth, mortality, etc.). Furthermore, we divided the state into zones representing the major cover types (mesophytic hardwoods, Appalachian oaks, northern hardwoods and spruce). Indexes to the health status of these types, such as growth and mortality, were examined, and comparisons were made between high and low stress zones, using the expected rates from published reports.

Forests in West Virginia are generally healthy, although certain areas have been subjected to fairly heavy stress loads over the past 10 years. Forest fires have severely impacted the southern West Virginia counties of Mingo, Logan and Boone. Drought has been severe in several areas of the state, including part of north central West Virginia and the Ridge and Valley Province of the Eastern Panhandle, extending into Pendleton County. Counties experiencing high stress loads showed growth rates about one third lower than areas experiencing lower stress. Appalachian oak forests seem most vulnerable to future stresses, since oaks are highly susceptible to defoliators and occur in drought-prone areas. oaks are also particularly vulnerable to decay, and numerous studies report that there is a lack of adequate oak regeneration in our present-day stands.

The area in spruce forests in West Virginia has decreased steadily over the past few hundred years, and the current rate of mortality in mature spruce exceeds that of other forest types in the state. Whether this is due to the relict nature of spruce, to natural processes, such as cohort senescence, or to anthropogenic influences, such as air pollution or global warming, cannot be determined. The encouraging news is that, in many areas, natural spruce regeneration is apparently healthy and thriving.

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SPATIAL TRENDS IN RELATIVE STOCKING POINT TO POTENTIAL PROBLEMS IN FOREST HEALTH

David A. Gansner, Susan L. King, Stanford L. Arner, Richard H. Widmann and David A. Drake[1]

Abstract: The term "forest health" means many things to many people and we do not know how to measure it. Baseline standards for conducting a physical examination of a stand of trees do not exist. One factor that can be considered when making judgments about the health of a particular forest tree species is change in the relative stocking of that species, that is the extent to which the species is gaining or losing ground in its ecosystem. The forest survey unit at the Northeastern Forest Experiment Station is using remeasured forest inventory plot data to estimate current average annual change in the relative stocking of common forest tree species in the Northeast. Spatial shifts in the relative stocking of individual species are being mapped. The procedure can be readily extended to other species in other regions. Information on shifts in relative stocking can provide a symptomatic guide to recognizing problems of forest health, and it gives us a better understanding of the complex workings of a dynamic ecosystem.

INTRODUCTION

The health of our Nation's forests has become a major issue. Unfortunately, the term "forest health" is vague. It means many things to many people and we do not know how to measure it. Baseline standards for conducting a physical examination of a stand of trees do not exist. The Northeastern Forest Experiment Station's Forest Health Monitoring Program and other organizations are working on how to assess the dimensions of forest ecosystem health and how to analyze and report health trends.

Until clearly defined baseline standards are developed, one factor that can be considered when making judgments about the health of a particular forest tree species is change in the relative stocking of that species, that is, the extent to which the species is gaining or losing ground in its ecosystem. This we can measure with the help of forest inventory plot records.

STOCKING AS A MEASURE OF SITE OCCUPANCY

Stocking is another term that means different things to different people. In this application, it is a measure of the extent to which trees utilize a plot of forest land. Stocking is expressed as a function of the number, size, and basal area of trees. Formulae for calculating stocking levels have been developed for a number of individual species. For example, the equation we use for sugar maple is : $s = .00694(DBH)^{1.86}$, which was obtained by translating the tree-area ratio developed by Stout and Nyland (1986) to a power function of diameter. Solving this equation for one tree on an acre of forest land tells us how much that tree contributes to stocking on the acre. When a stocking formula is not available for a particular species, the formula for a species with similar characteristics of growth and competitiveness is used.

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ESTIMATING CHANGE IN RELATIVE STOCKING

Stocking equations can be applied to remeasured forest inventory plot data to estimate the average annual change in relative stocking (RS) for any tree species on any acre. The following example demonstrates the process.

	Stocking (%)	
	1978	1989
Sugar maple	16	18
All species	64	90

The relative stocking of sugar maple on the acre for 1978 was 16/64 = 25%. The relative stocking of sugar maple for 1989 was 18/90 = 20%. The average annual change in relative stocking for sugar maple on the acre is:

$$[RS(1989) - RS(1978)]/\text{Years between inventories}$$

or

$$(20-25)/11 = -0.45\% \text{ per year}$$

Note, that even though the absolute stocking of sugar maple increased on this acre, the change in its relative stocking was negative. In other words, in a relative sense, sugar maple was losing ground to other species between inventories.

The USDA Forest Service updates timber-resource information statewide approximately every 10 years. For land that remains in forest, remeasured plot records provide a history of change in the inventory of all live trees 5 inches and larger in d.b.h. By design, each inventory plot represents a proportional share of the forest area in a state; so, appropriate weights can be assigned to plot data to derive statewide and regional averages of current annual change in relative stocking for individual species. We applied this procedure to Kentucky, Maryland, Ohio, Pennsylvania, and West Virginia where a network of approximately 6,000 permanent inventory plots were remeasured during the most recent inventories in each state (Alerich 1990, Frieswyk and DiGiovanni 1988, Griffith et al. 1993, Alerich 1993, and DiGiovani 1990).

OVERALL STOCKING IS UP

At the time of the most recent forest inventories, the stocking of all live trees 5.0 inches d.b.h. and larger per acre of forest land averaged about 59 percent in the five-state area (Table 1). At the time of previous inventories, stocking averaged only 51 percent. Obviously, growth on original trees plus ingrowth of new trees into the 5.0-inch size class more than offset losses to cutting and mortality between inventories. Stocking has increased an average of at least one percent per year in each of the five states.

Table 1. Change in stocking between inventories, by state.

State	Average Stocking Previous	Average Stocking Most Recent	Change(%)
	----------Percent----------		
Kentucky	44.4	52.2	7.8 (18)
Maryland	54.2	59.5	5.3 (10)
Ohio	43.0	52.3	9.3 (21)
Pennsylvania	57.3	63.4	6.1 (11)
West Virginia	54.8	65.3	10.5 (19)
All States	51.3	59.3	8.0 (15)

All but a few forest inventory subunits of the five-state area recorded healthy increases in average stocking (Figure 1). One of the exceptions was south-central Pennsylvania where gypsy moth defoliation, drought, cutting, bark beetles, root rot, deer browsing, and other agents took a heavy toll on the oak resource during the 1980's. Growth of residual oaks, maple, black gum, yellow-poplar, cherry, and other species counter balanced the oak loss. But, gains in average stocking for all species combined remained minimal. On the lower Eastern Shore of Maryland, declines in the relative stocking of oak were offset by increases in loblolly pine, red maple, black gum, beech, and other hardwoods. Thus, average stocking there remained about the same.

MAPLES AND YELLOW-POPLAR GAIN WHILE BLACK LOCUST AND OAKS LOSE GROUND

Red maple is a pioneer species--a shade tolerant, prolific seeder and sprouter that can occupy a wide variety of forest sites. So, it is no wonder that red maple has recorded significant gains in relative stocking throughout the five-state area (Figures 2-7). Overall, the annual gain in relative stocking of red maple averaged 0.31 percent between inventories.

There has been much recent concern over the demise of sugar maple. Not too long ago (12/7/86) an article in the New York Times suggested that sugar maple was becoming extinct because of damage from acid rain. Such news prompted establishment of The North American Maple Project and the installation of plots to measure annual trends in the condition of this valuable hardwood species. It is too soon to draw conclusions from that study. But, our analysis indicates that, on the whole, sugar maple is doing quite well. In terms of gaining ground, it ranks right behind red maple. Substantial increases in the relative stocking of sugar maple were recorded in all five states.

Another prevalent species that made significant regional gains in relative stocking was yellow-poplar. White pine also recorded significant increases in states where it is common.

At the opposite end of the scale were black locust and the oaks (particularly chestnut, black, white, and scarlet oak). Black locust lost ground at a rate of 0.30 percent per year across the region. And why not? Forest land in this area has undergone significant increases in average tree size and density in recent years. Black locust is sensitive to competition and intolerant of shade. Under stress, it falls easy prey to locust borers, leaf miners, heart rot, and other insects and diseases.

Much of the oak decrease can be associated with gypsy moth. But oaks are also losing ground in areas where the pest is not yet a problem. Sharp declines in the relative stocking of hard pines are noteworthy. Virginia pine in Maryland, Ohio, and West Virginia; pitch pine in West Virginia and Kentucky; and shortleaf pine in Kentucky are all losing ground at significant rates (Huntley 1990).

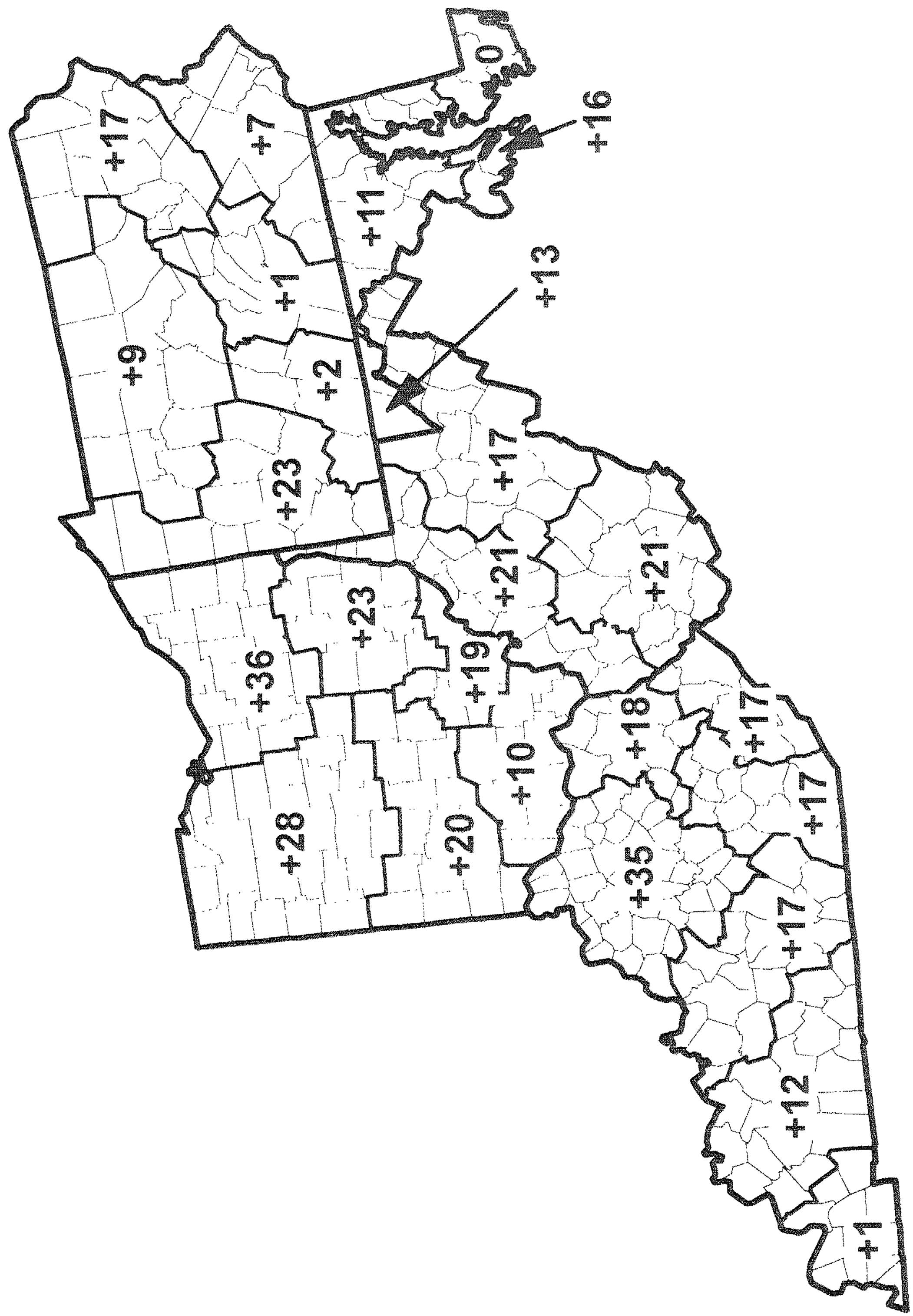

Figure 1. Percentage of change in stocking between inventories, by subunit.

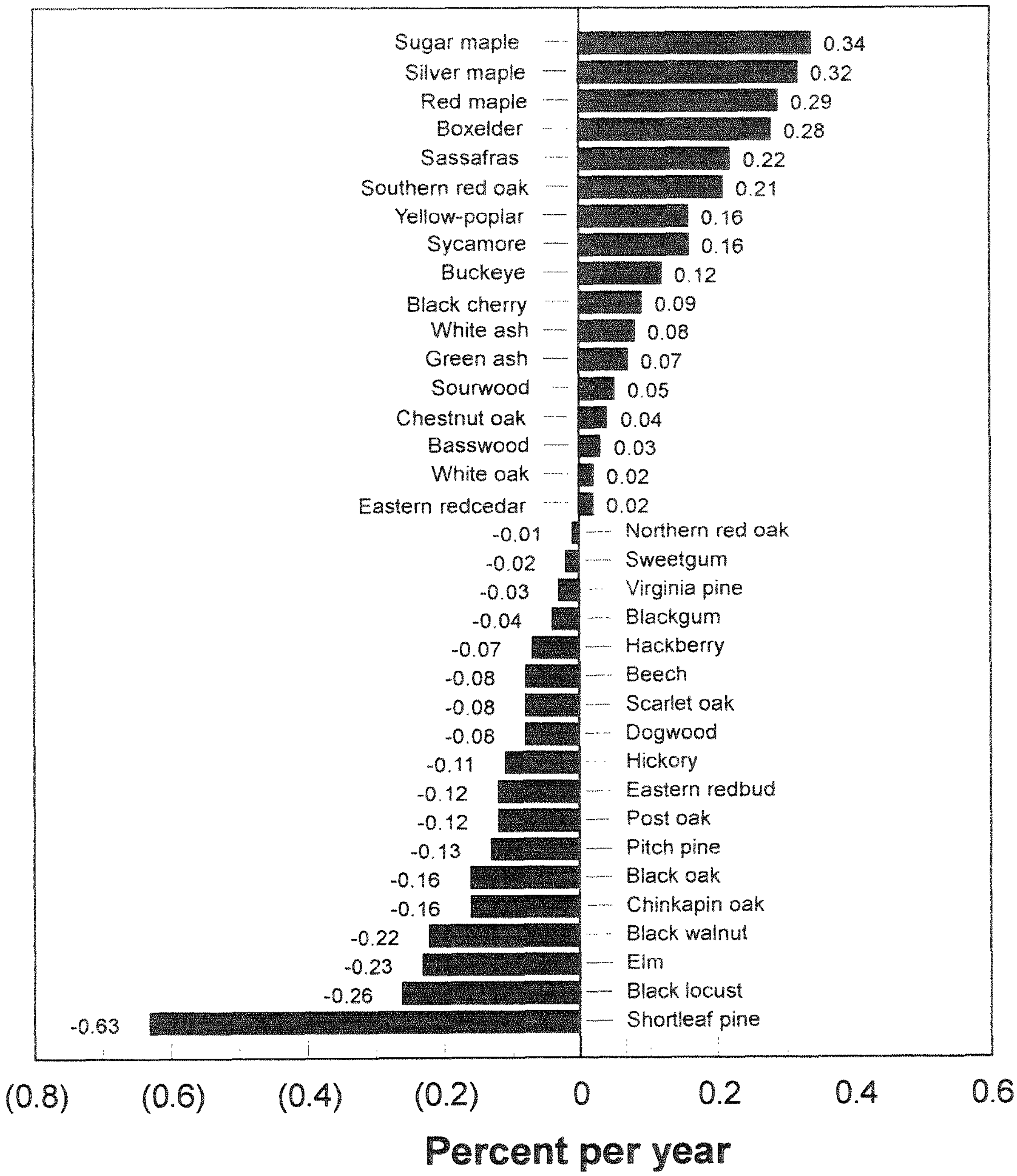

Figure 2. Average annual change in the relative stocking of some common forest tree species in Kentucky, 1975-1988.

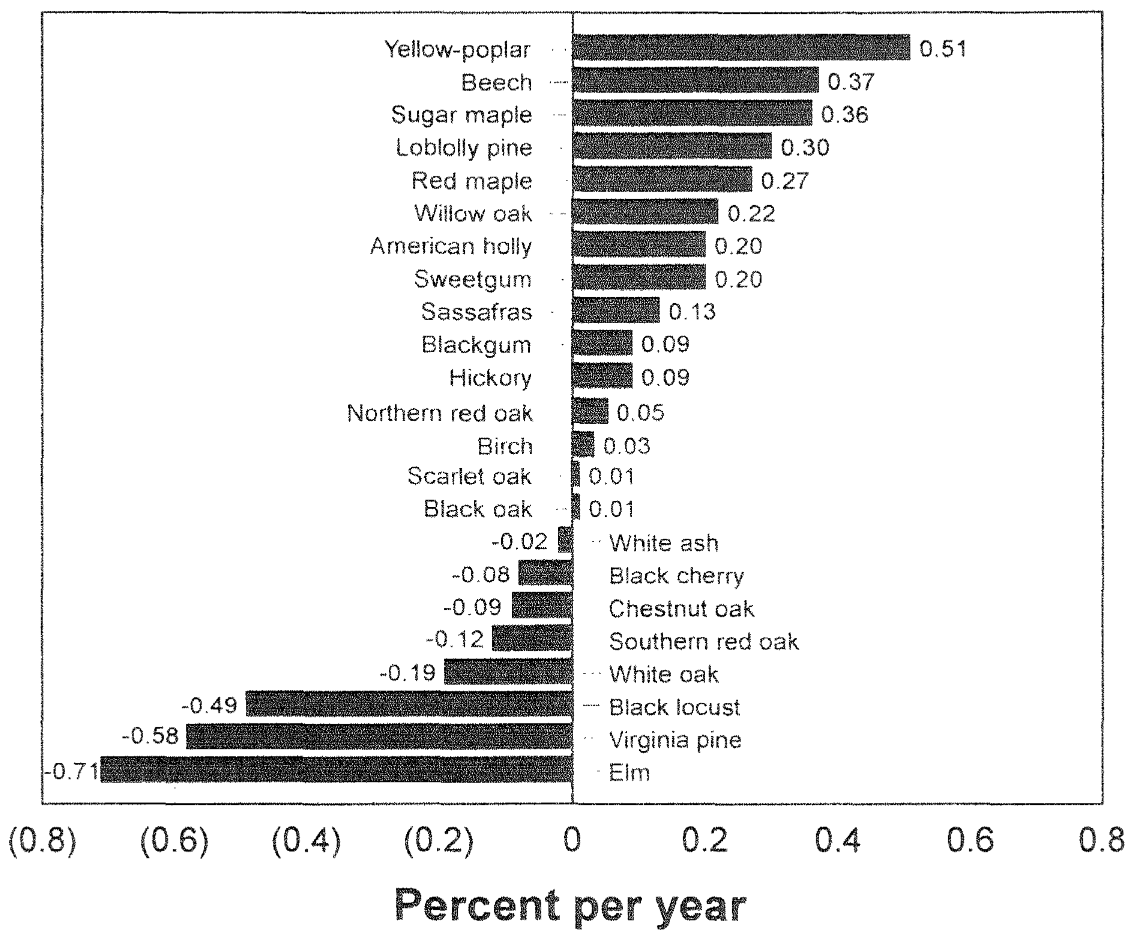

Figure 3. Average annual change in the relative stocking of some common forest tree species in Maryland, 1976-1986.

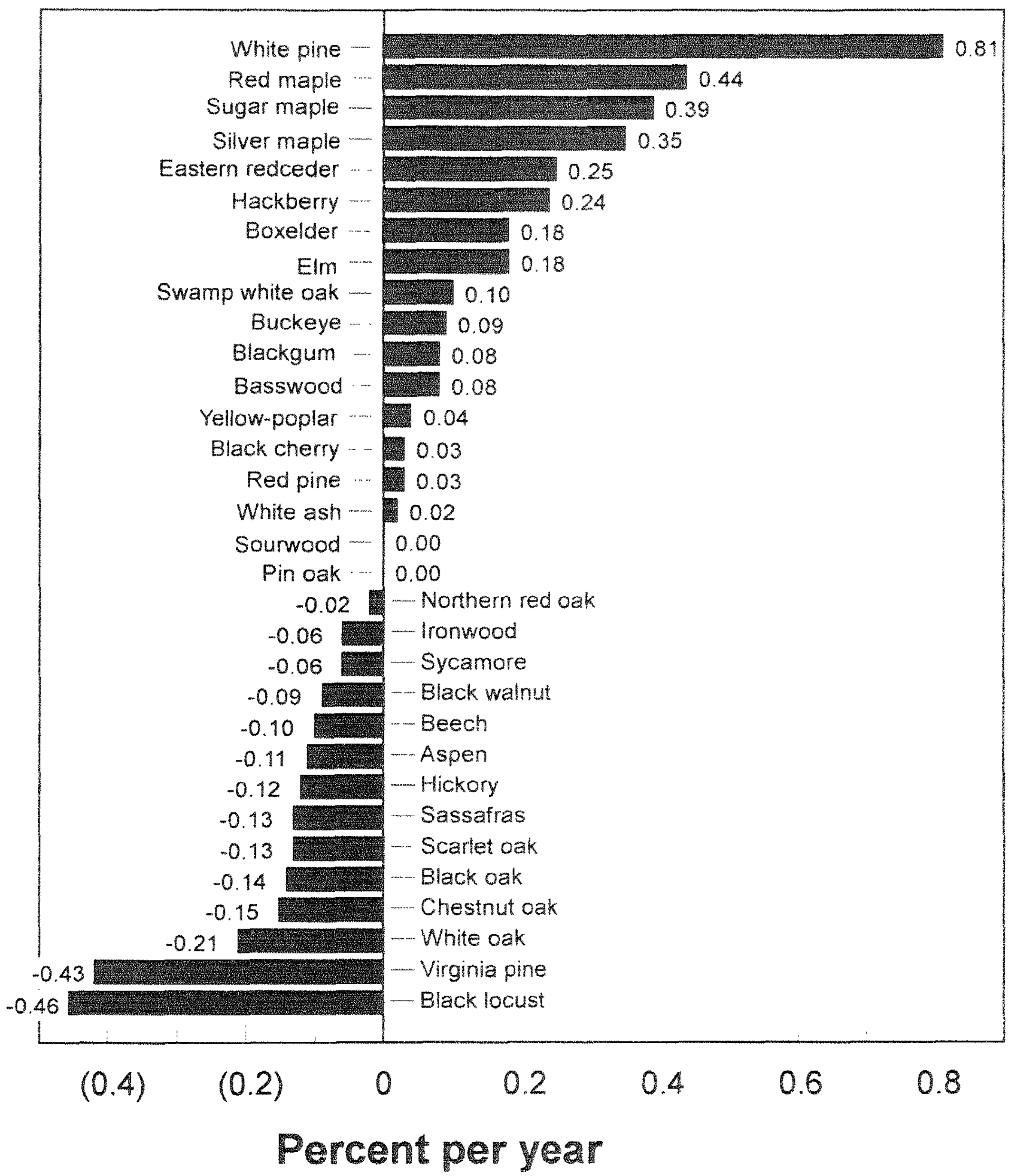

Figure 4. Average annual change in the relative stocking of some common forest tree species in Ohio, 1979-1991.

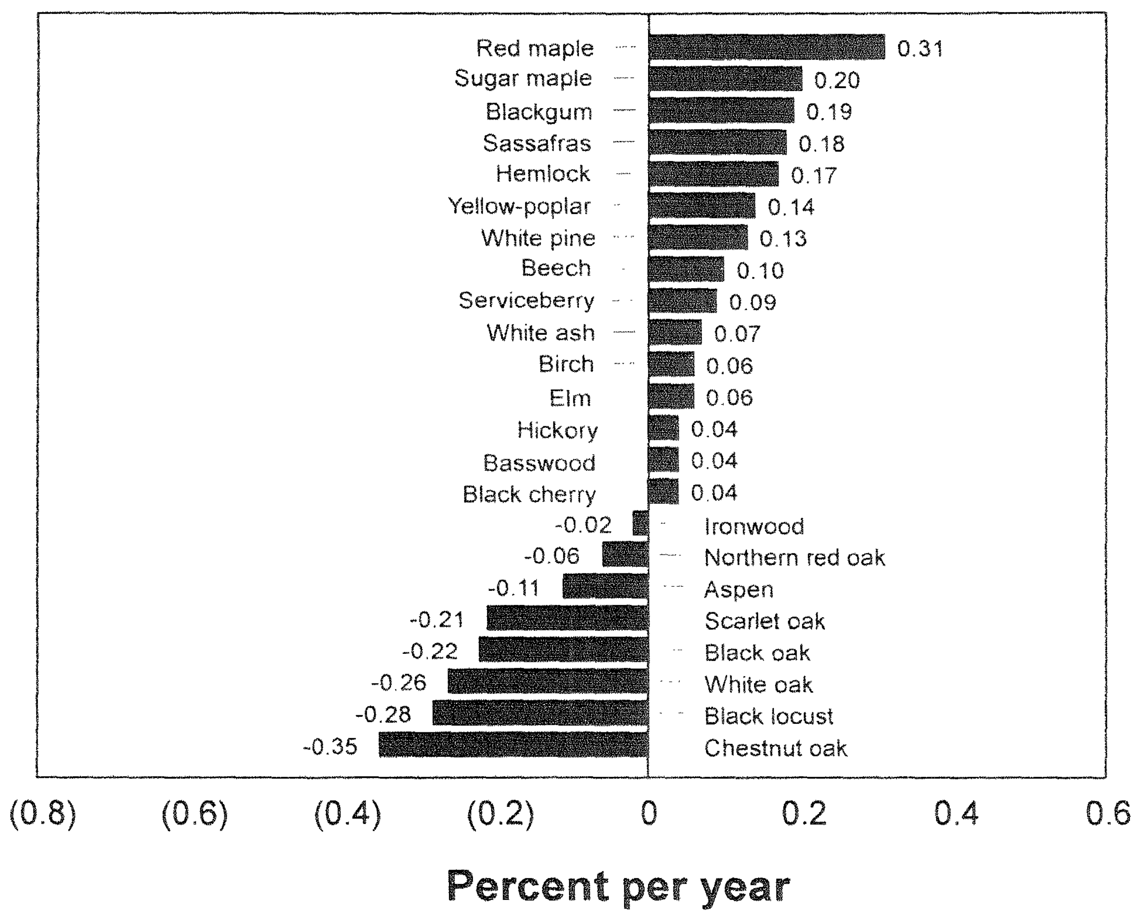

Figure 5. Average annual change in the relative stocking of some common forest tree species in Pennsylvania, 1978-1989.

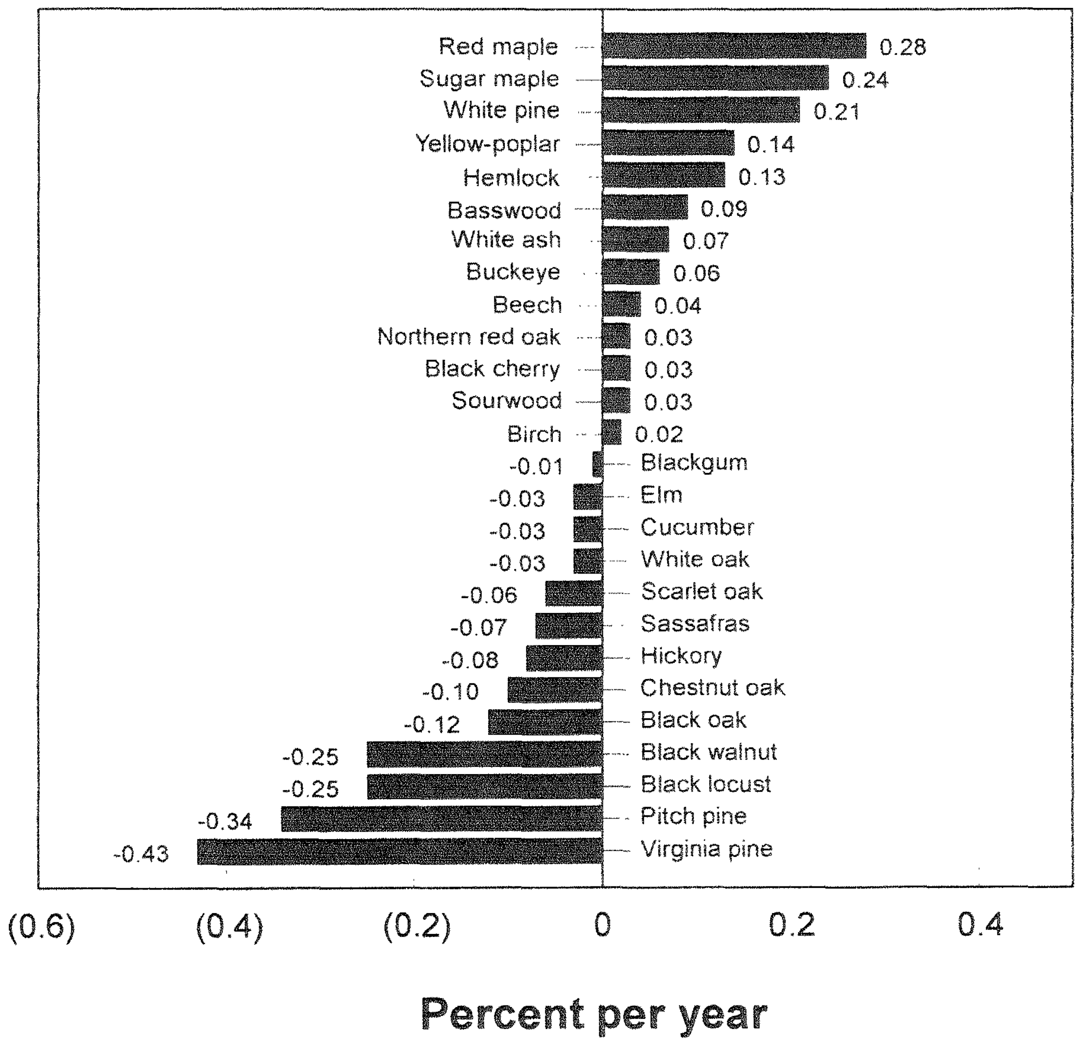

Figure 6. Average annual change in the relative stocking of some common forest tree species in West Virginia, 1975-1989.

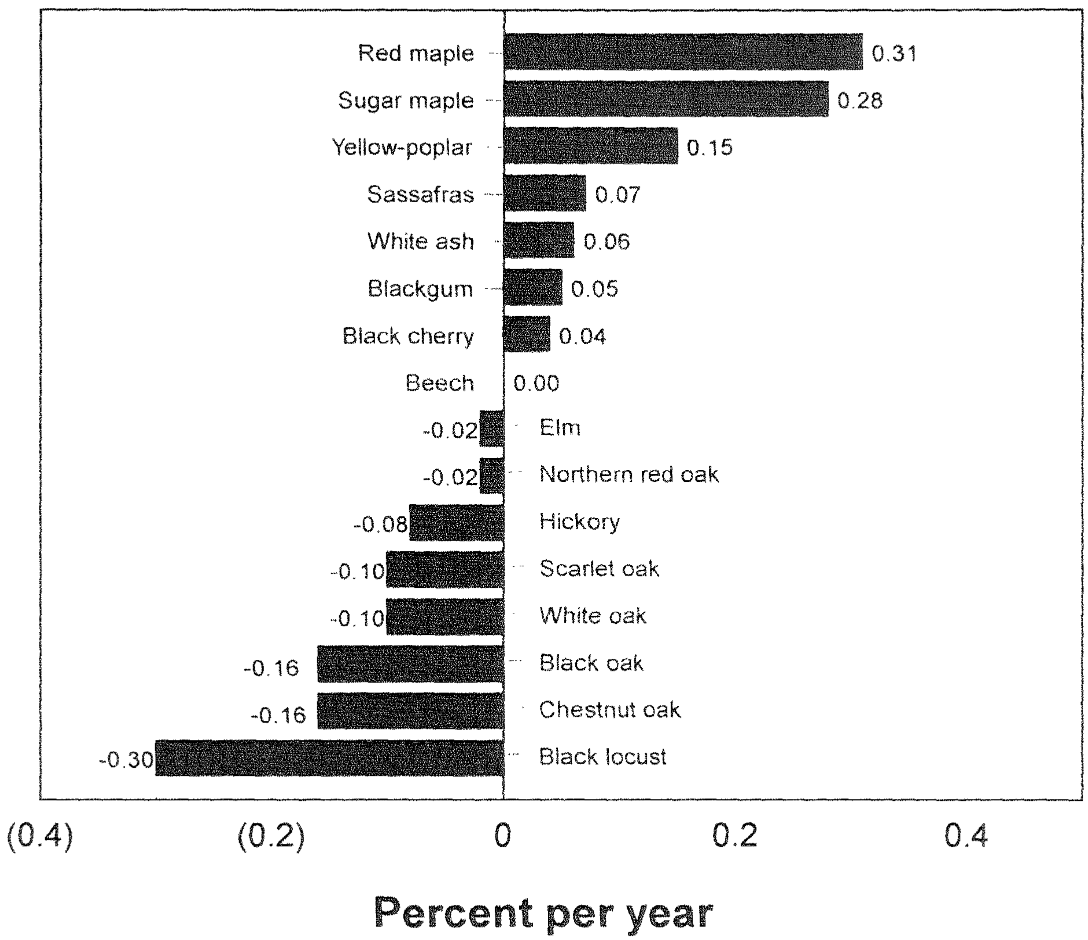

Figure 7. Average annual change in the relative stocking of forest tree species common in the five-state area.

TRACKING TRENDS AND SPOTTING PROBLEMS

Since each inventory plot represents a proportional share of the forest area in a county, appropriate weights can be assigned to plot data to derive average trends in relative stocking for individual species in each county. County averages can then be mapped to provide a closer look at where a species is gaining or losing ground. Maps showing county trends for three of the area's top gainers (red maple, sugar maple, and yellow-poplar) and three of its losers (black locust, chestnut oak, and black oak) are presented here (Figures 8-13).

Using county averages to gauge trends in relative stocking has its limitations. Some county averages, especially those for sparsely forested counties, are based on very few ground plots and may be subject to high sampling errors. Locations of individual ground plots have been digitized, so trends for each plot also can be mapped. These maps provide a more specific view of spatial shifts in relative stocking (Figures 14-15).

Together, maps showing trends for counties and individual plots can be used to detect areas where species are gaining or losing ground and, thus, help us locate potential problems in tree health. For example, figure 12 shows that chestnut oak has been losing ground in several of the region's counties. Figure 14 tells us that declines were especially noticeable in Pennsylvania where chestnut oak occurred on one-third of the remeasured plots and was losing ground on two-thirds of them. Bedford County in south-central Pennsylvania epitomizes the worst case. Here, change in the relative stocking of chestnut oak averaged
-0.86 percent per year. Dead trees and stumps recorded on Bedford County plots provide clear evidence of why. For a first-hand view of the situation, take a ride on the Pennsylvania turnpike and check out the landscape around Everett, Pennsylvania. Some good news here is that most of the oak stands that were devastated by gypsy moth, drought, cutting, and other agents during the 1980's have regenerated to a more diverse mix of species such as maple, birch, cherry, ash, and yellow-poplar that are less susceptible to the gypsy moth (Gansner et al. in press).

For a completely different scenario, take a look at sugar maple. Figures 9 and 15 indicate that this species recorded large gains in relative stocking in all five states. But the maps also show that while sugar maple was performing well regionwide, it was losing ground in some places such as the Allegheny Plateau in Elk, Forest, McKean, and Warren Counties, in northwestern Pennsylvania. Annual change in the relative stocking of sugar maple in these four counties averaged -0.12. The reasons for this change are not apparent.

IMPLICATIONS

The procedure used here to track shifts in relative stocking can be used for virtually any species anywhere. Results provide an extensive look at where each species is gaining or losing ground and, thus, a means for locating current and potential problems in tree health.

Findings of our analysis raise more questions than they answer. Will red maple continue its rapid gains in relative stocking and, if so, how will that affect the integrity of the region's forested ecosystems? Will oaks continue to lose ground or will they overcome the effects of gypsy moth and other stress that hit them hard during the last couple of decades? Why is sugar maple making significant gains regionwide but losing ground on the Allegheny Plateau of Pennsylvania--is it pear thrips, drought, overstocking, a combination of these factors, or none of the above? Many are hypothesizing that sugar maple just does not do well in dense maturing stands. Will black locust continue to disappear from the scene as overall stocking continues to improve? Is white pine on the verge of regaining the status it once held? What is happening to the hard pines? And what about hickory, especially in Kentucky, Ohio, and West Virginia?

Information on shifts in relative stocking can provide a symptomatic guide to recognizing problems of forest health. It definitely gives us a better understanding of the complex workings of a dynamic ecosystem. This information can help us make better decisions about the management and use of our precious forest resource.

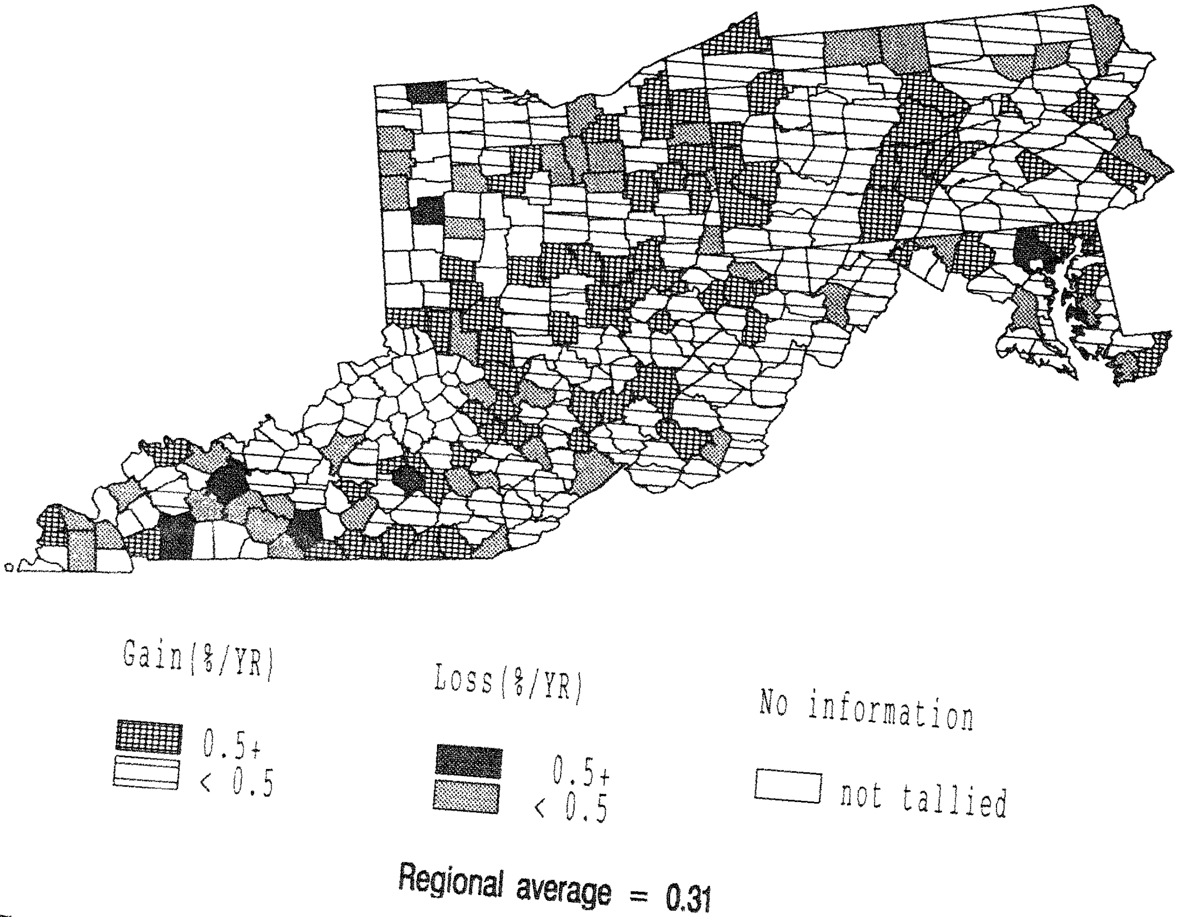

Figure 8. Average annual change in the relative stocking of red maple, by county.

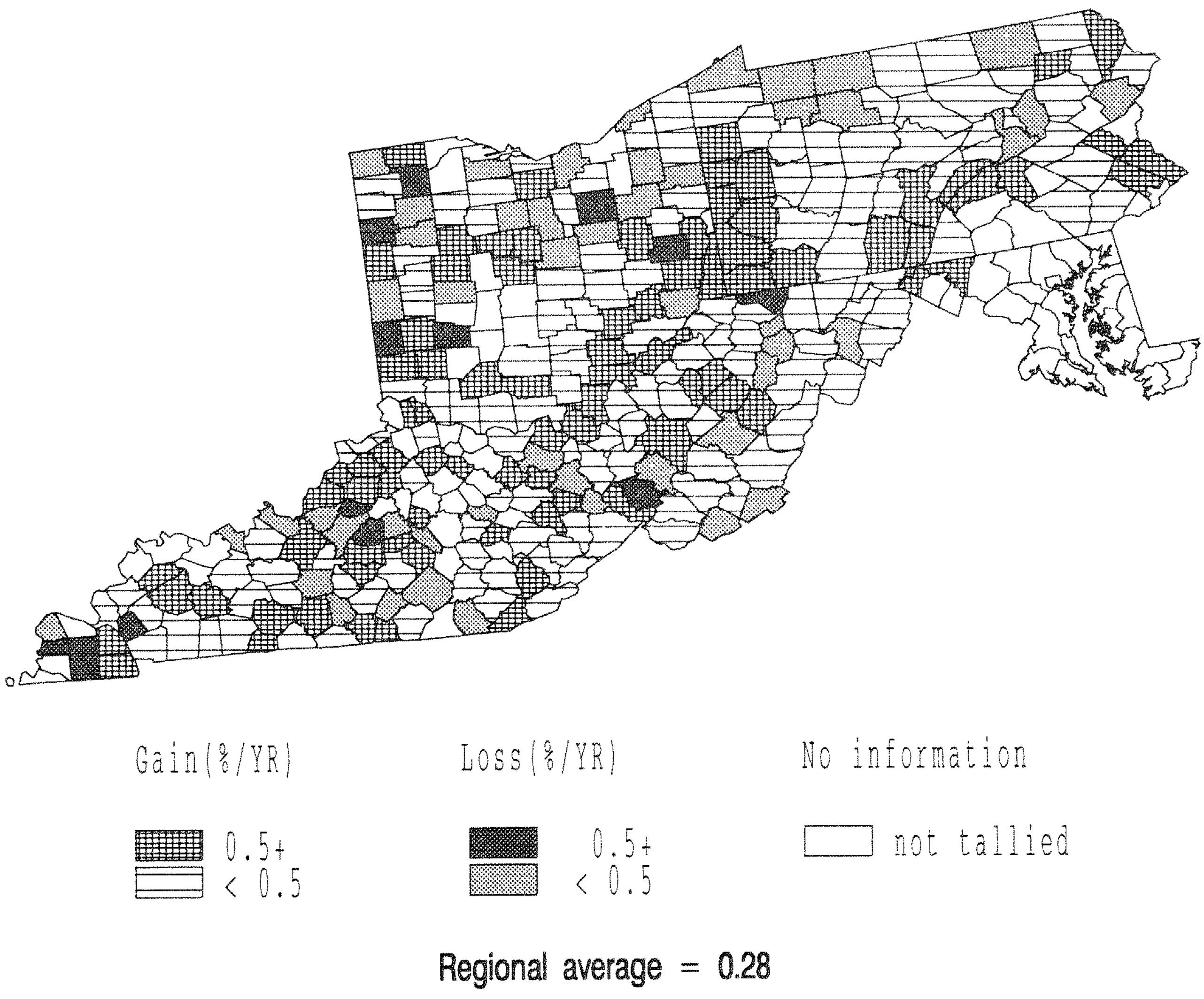

Figure 9. Average annual change in the relative stocking of sugar maple, by county.

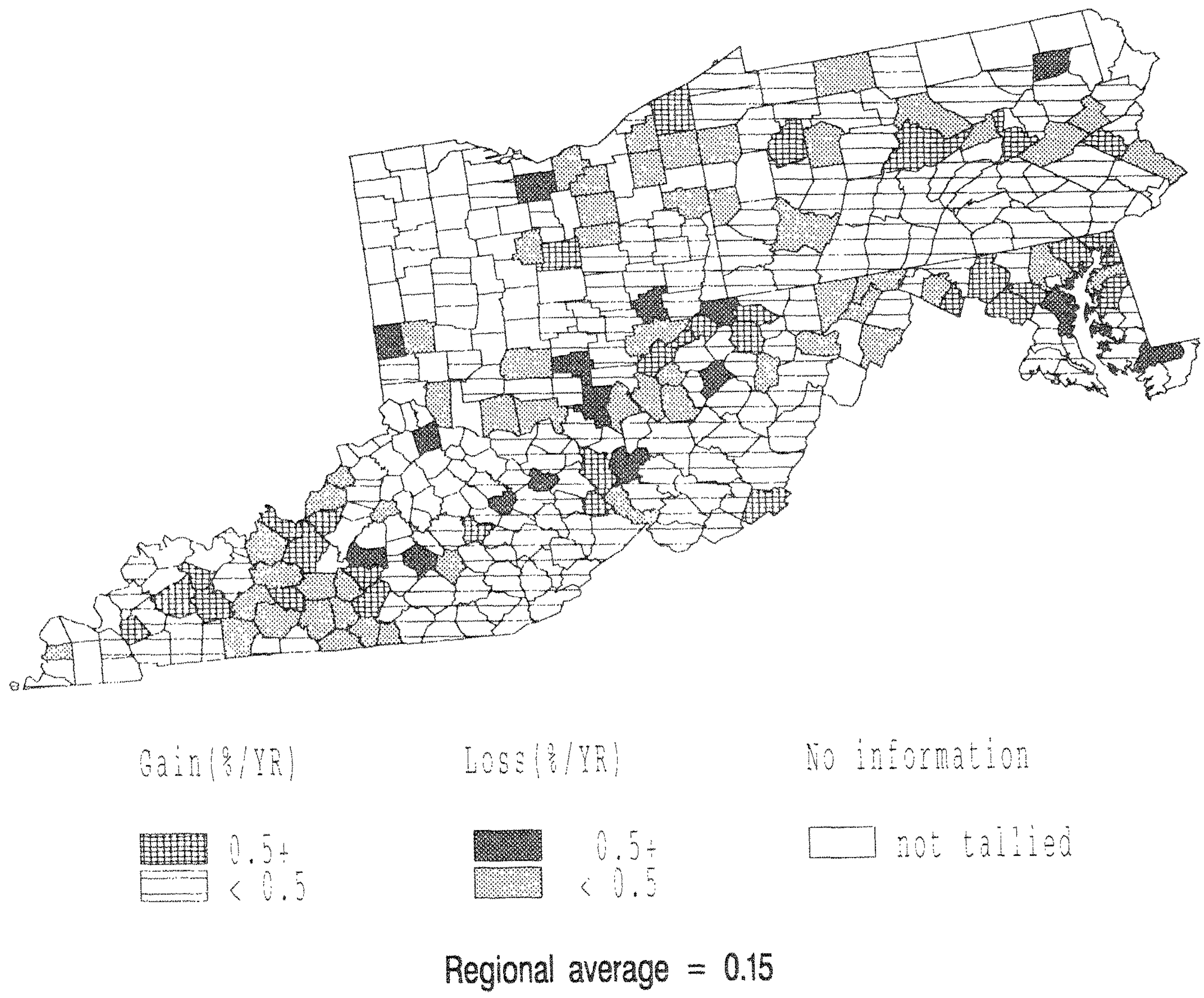

Figure 10. Average annual change in the relative stocking of yellow-poplar, by county.

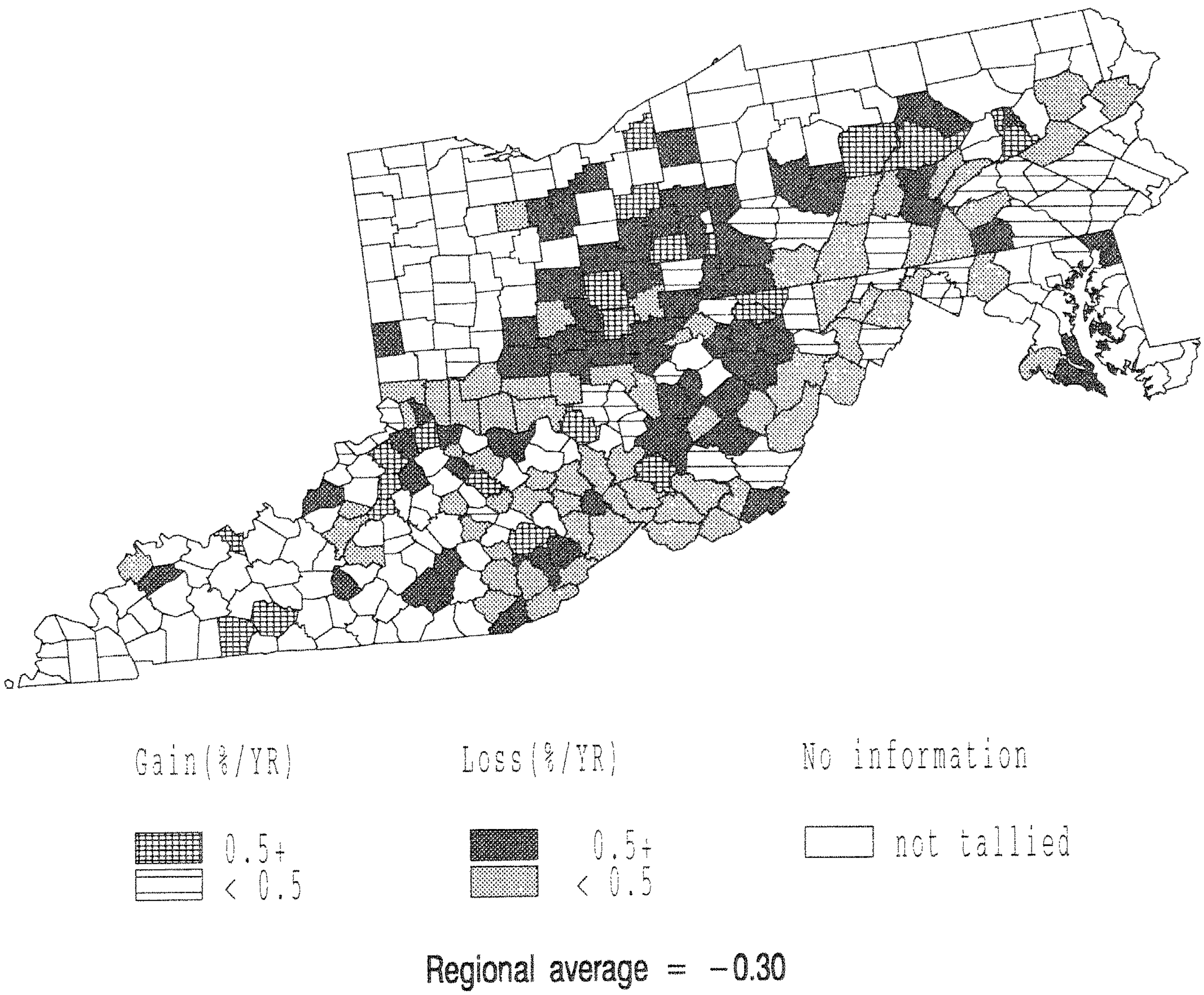

Figure 11. Average annual change in the relative stocking of black locust, by county.

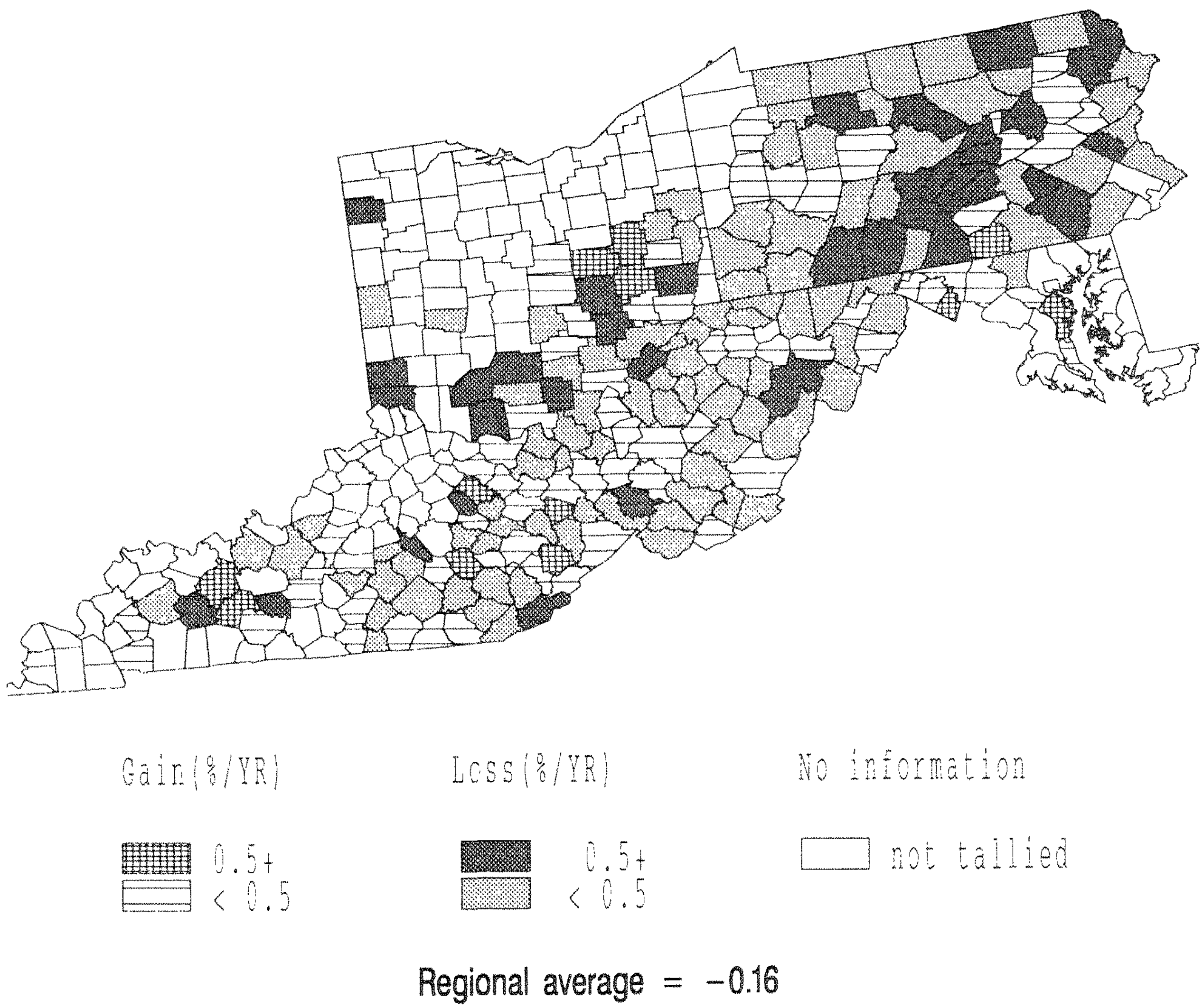

Figure 12. Average annual change in the relative stocking of chestnut oak, by county.

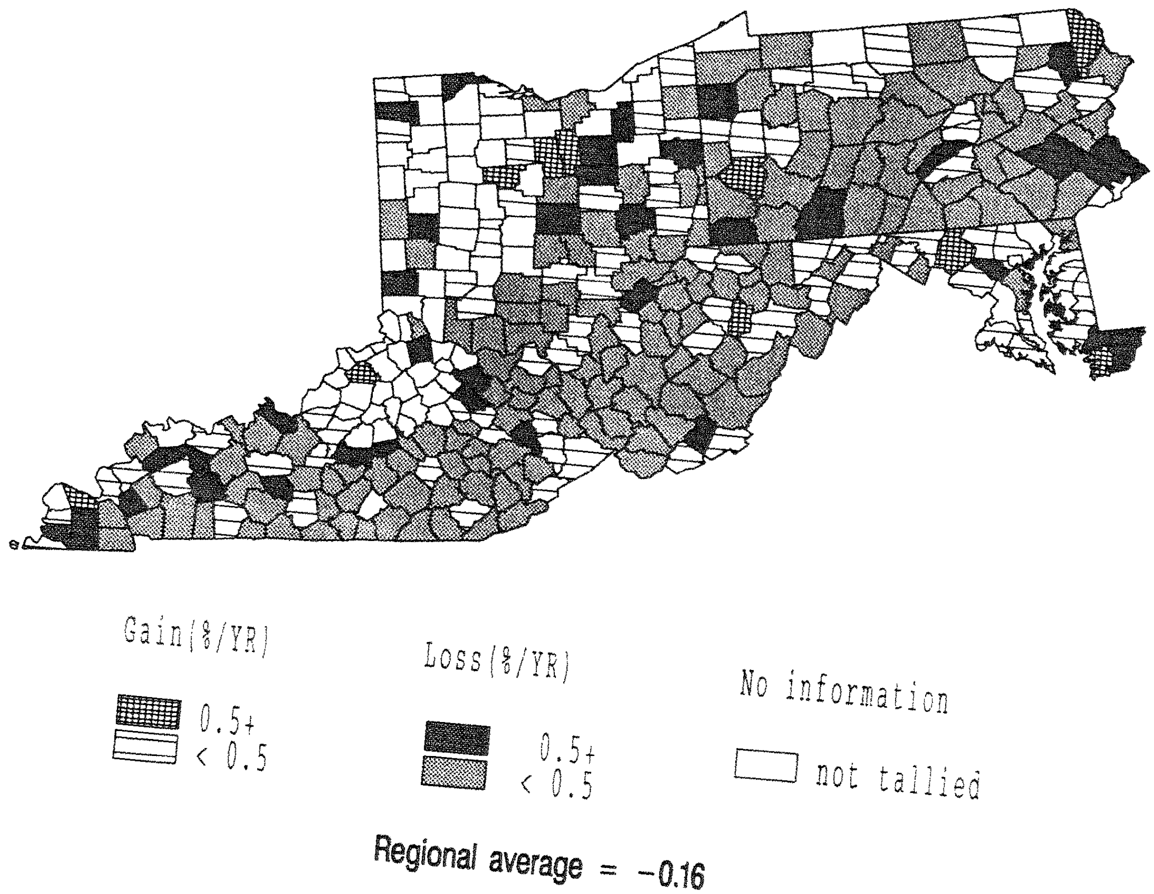

Figure 13. Average annual change in the relative stocking of black oak, by county.

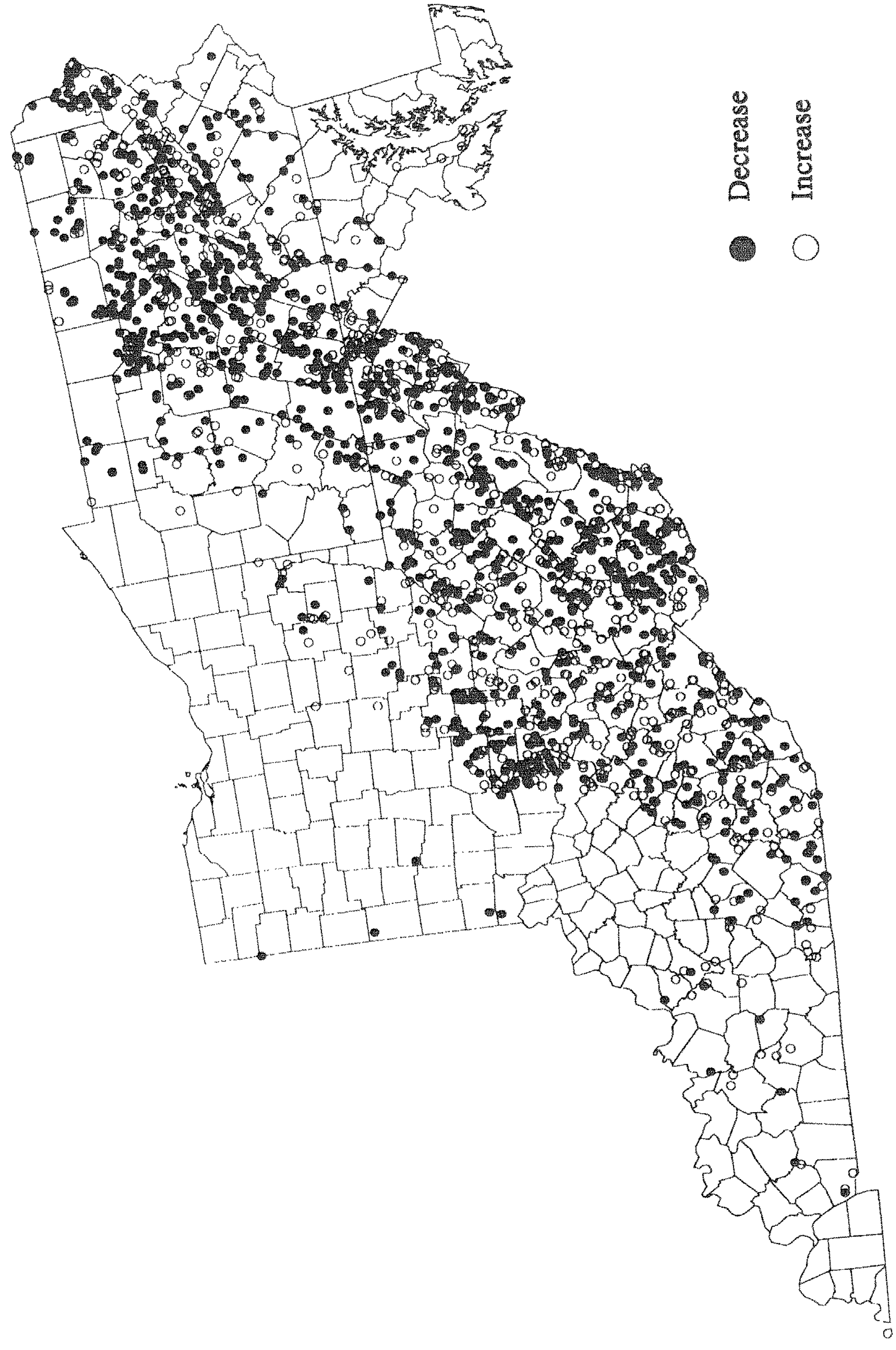

Figure 14. Change in the relative stocking of chestnut oak on plots between inventories.

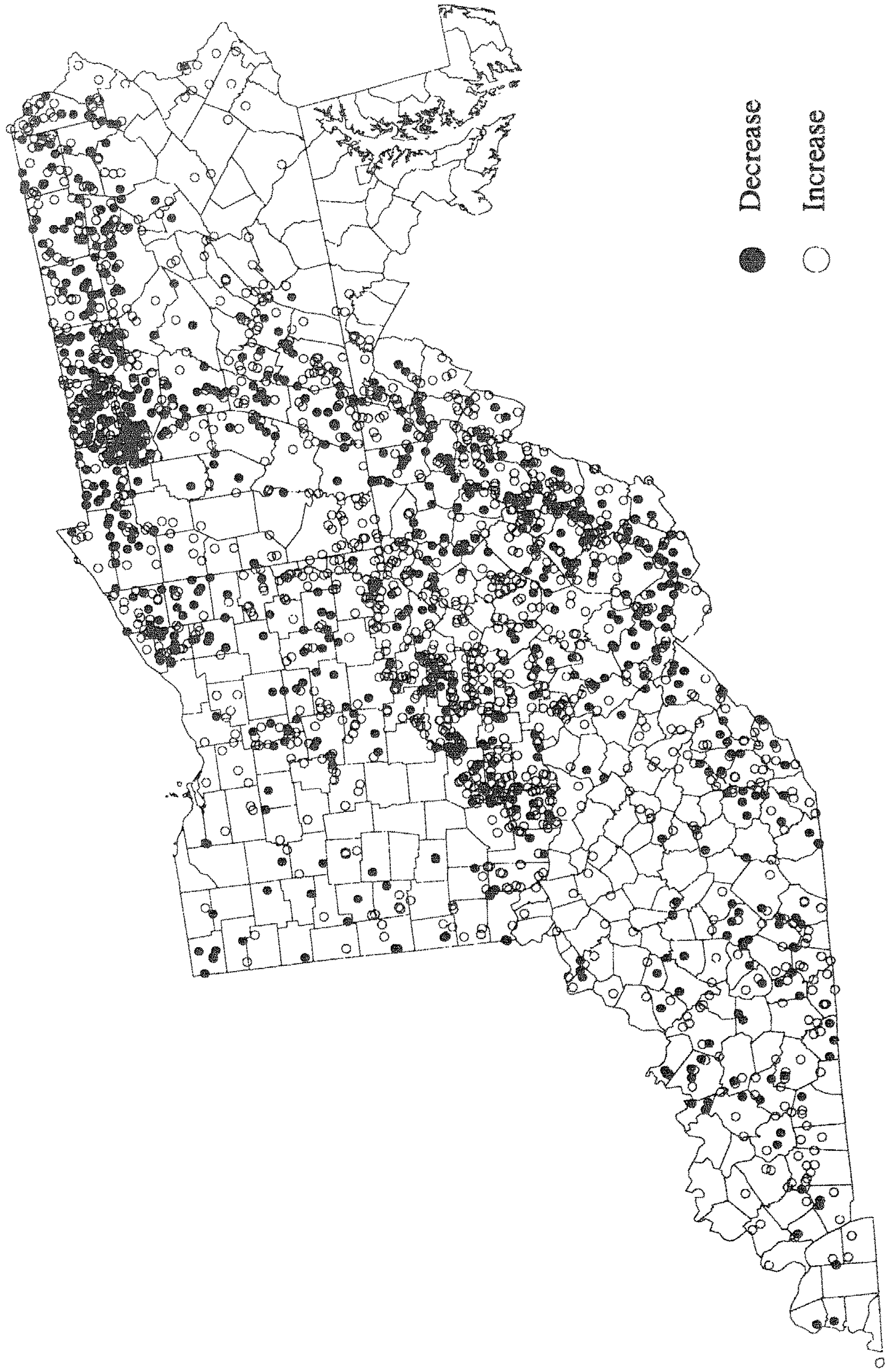

Figure 15. Change in the relative stocking of sugar maple on plots between inventories.

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DIMILIN EFFECTS ON LEAF-DECOMPOSING AQUATIC FUNGI ON THE FERNOW EXPERIMENTAL FOREST, WEST VIRGINIA

T. Dubey[1], S. L. Stephenson[2], and P. J. Edwards[3]

Abstract: Dimilin was applied to two watersheds on the Fernow Experimental Forest on May 16, 1992, as part of a study to evaluate its effect on non-target organisms. Data were obtained on the occurrence, conidial production, and leaf litter colonization of aquatic hyphomycetes 5 days prior to and 2, 10, 25, and 55 days following application in the two treated watersheds and two control watersheds. Two days after application, conidial numbers were higher in one treated watershed, while they remained relatively constant in the other treated watershed. Northern red oak (*Quercus rubra* L.) and sugar maple (*Acer saccharum* Marsh.) leaf bags placed in the weir ponds and streams of the treated watersheds prior to Dimilin application and retrieved 2 days after application were colonized by greater numbers of fungal taxa than bags retrieved later. This pattern suggests the possibility of an increasing influence of this pesticide on the occurrence and the litter decomposition activities of this group of aquatic fungi.

INTRODUCTION

Rapid deterioration of the quality of oak forests due to invasion of the gypsy moth (*Lymantria dispar* L.) has led to the widespread use of Dimilin (Diflubenzuron) as a method to control this introduced insect pest. Dimilin is a chitin synthetase inhibitor and affects immature insects during molting. It is ingested as the insect larvae feed on treated foliage. However, other non-target organisms also may be affected negatively.

Aquatic hyphomycetes dominate the assemblages of aquatic fungi associated with decaying leaves in lotic systems (Bärlocher and Kendrick 1974, Suberkropp and Klug 1976, Trisca 1970). Decomposition of leaf detritus and its exploitation by other members of stream detrital communities are largely dependent upon the activities of aquatic hyphomycetes, since hyphomycetes have the enzymatic capability to digest the structural polymers that comprise most dead plant tissue (Bjarnov 1972, Monk 1976). Thus, any change in the physicochemical or biological environment of a stream will influence aquatic hyphomycete activity. Consequently, concerns exist about how Dimilin might affect aquatic hyphomycetes.

The present paper compares aquatic fungal occurrence data in two watersheds treated with Dimilin and two other watersheds maintained as controls. Conidia in stream water samples were enumerated and fungal species colonizing northern red oak (*Quercus rubra* L.) and sugar maple (*Acer saccharum* Marsh.) leaves placed in the four watersheds were identified.

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[3]Hydrologist, USDA-Forest Service, Timber and Watershed Laboratory, Parsons, WV 26287.

METHODS

Site Descriptions

Four small watersheds (1, 4, 7, and 13) on the USDA Forest Service's Fernow Experimental Forest, near Parsons in Tucker County, West Virginia, were used for this study. The Fernow Experimental Forest is located in the Allegheny Mountain section of the unglaciated Allegheny Plateau (79° 0' 11" W, 39° 0' 05" N). Elevations range from 530 to 1100 m; slopes range from 10 to 60 percent. Mean annual precipitation is 147 cm, and the mean annual temperature is 9°C. Soils are derived from sandstone and shales of the Hampshire formation. All four watersheds were logged heavily between 1905 and 1910. However, since then their disturbance histories have been quite different.

All the trees on watershed 1 (30.1 ha), except for cull trees and trees less than 2.4-cm dbh, were harvested from May 1957-June 1958. A "logger's choice" method was used such that no specific road construction, harvesting, or skidding guidelines were required. Seventy-four percent of the original basal area was cut, with 24,527 bd ft ha^{-1} removed (Kochenderfer and others 1990). The current stand is 34 years old and is dominated by yellow-poplar (*Liriodendron tulipifera* L.), chestnut oak (*Q. prinus* L.), and red maple (*A. rubrum* L.). In 1986, watershed 1 was treated with Dimilin at a rate of 0.067 kg active ingredient ha^{-1} with a fixed-wing aircraft. This treatment was imposed to measure the persistence of Dimilin in stream water, sediment, organic matter, and throughfall (Jones and Kochenderfer 1987).

Watershed 4 (38.7 ha) has had negligible disturbance since 1910, except for salvage removal of dead American chestnut (*Castanea dentata* (Marsh.) Borkh.) during the 1940s following the chestnut blight (*Cryphonectria parasitica* (Murrill) Barr). Currently, the dominant stand is about 90 years old, though scattered residual trees left from the turn-of-the century logging are estimated to be 175 to 200 years old. The dominant overstory species are sugar maple, red maple, and American beech (*Fagus grandifolia* Ehrh.).

Watershed 7 (24.2 ha) was harvested in two halves in the 1960s. The upper 12.1 ha, comprising 49 percent of the basal area (80.2 m ha^{-1}), were clearcut from November 1963 to March 1964. This half was maintained barren of vegetation with herbicides, principally 2,4,5-T, until October 1969. The lower half of watershed 7 was clearcut (76.9 m ha^{-1}) from October 1966 to March 1967 and also maintained barren until October 1969 (Patric and Reinhart 1971; Kochenderfer and others 1990). Today, the overstory vegetation is dominated by black birch (*Betula lenta* L.), red maple, and sugar maple.

Less is known about the history of watershed 13 (14.2 ha) than of the other watersheds because it became an active research watershed only in 1984. A light selection cut is believed to have been performed in the 1960s, although the volume of wood or percent basal area removed is not known. The dominant overstory vegetation is yellow-poplar, northern red oak, and sugar maple. Stand age is approximately 65 years.

Dimilin Application

For the current study, watersheds 1 and 13 were treated with Dimilin and watersheds 4 and 7 were maintained as untreated controls. The Dimilin was applied at a rate of 0.03 kg active ingredient ha^{-1} on the morning of May 16, 1992. The application was made using a Bell 206 Jet Ranger helicopter. The spraying was done using protocols to ensure that the Dimilin application was confined to the treated watersheds (USDA Forest Service 1991).

Sampling Methods

Aquatic hyphomycete distributions in the four watersheds were studied by membrance filtration of stream water samples (Iqbal and Webster, 1973) and by leaf bag incubation in both streams and weir ponds (Musil and Shearer, 1982). For membrane filtration, 250-ml water samples were collected from each stream 5 days prior to and 2, 10, 25, and 55 days following Dimilin application. Ten samples were collected from each stream on the first three sampling dates; because of low water levels, only five samples were collected from each stream on the last two sampling dates.

Samples were filtered through Millipore 0.45-μm membrane filters in the field at the time of collection. In the laboratory, each filter was treated with 0.1 percent cotton blue and heated in lactic acid at 50-60°C to render it sufficiently transparent for conidial enumeration and identification. Filters were examined microscopically at 100x, and conidia were counted. Taxa were recorded for 40 noncontiguous fields-of-view (36.2 mm^2) on each filter.

For leaf bag incubation, mesh bags containing leaves from northern red oak and sugar maple were prepared in the manner described by Musil and Shearer (1982) and Chamier and others (1984). The leaves were collected in October 1991 shortly after leaf abscission, air-dried, and stored until leaf bags were prepared. Each bag contained approximately 2.0 g of dried leaves of either red oak or sugar maple. One set of four bags of each leaf type was tied to a perforated brick. These were placed in the streams and weir ponds of the four watersheds on May 11, 1992. Bags of each leaf type were retrieved on each of four visits following application of Dimilin (i.e., after 2, 10, 25, and 55 days). Upon retrieval, leaf bags were placed in plastic zipper-lock storage bags, partially filled with stream water, and returned to the laboratory. Leaves were removed from the mesh bags, gently washed in sterile distilled water, and cut into 1 x 1-cm squares. A few squares were examined microscopically to determine the presence of hyphomycetes. The remaining squares were incubated in aerated chambers filled with sterile distilled water, as described by Shearer and Webster (1991). After 24 hours, the water was filtered through a membrane filter, and conidia were identified by microscopic examination of the filter paper after treatment with cotton blue and lactic acid, described previously. Fungal specimens recovered from leaf bags were studied as living material and/or fixed and stained with cotton blue and mounted in lactophenol. Fungal species were identified using keys and description provided in Ainsworth and others (1973), Barnett and Hunter (1972), Ellis (1971), Nilsson (1964), Ingold (1975), and Subramanian (1983). Nomenclature used in this paper follows that given by these authors.

Data Analysis

Separate data sets were compiled for aquatic hyphomycetes recorded as conidia filtered from water samples and for those occurring on leaves. The four streams were compared using coefficient of community (CC) indices (Mueller-Dombois and Ellenberg 1974). The equation for this index, which is based solely on the presence or absence of taxa, is

$$CC = 2c/(a+b) \tag{1}$$

where a = total number of taxa in the first stream being considered, b = total number of taxa in the second stream, and c = number of taxa common to both streams. The CC value ranges from 0.0 (when no taxa are common to both streams) to 1.0 (when all taxa are common to both streams).

RESULTS

Water Filtration

Two days after the Dimilin application (May 18), the number of conidia in samples from watershed 1 was approximately twice that recorded 5 days prior to treatment (May 11) (Table 1). However, the number of conidia recorded in samples from the other treated watershed decreased from May 11 to May 18. In both treated watersheds, conidial numbers generally increased on subsequent sampling dates. Conidial numbers recorded from control watersheds 4 and 7 also declined from May 11 to May 18 and remained below the pretreatment levels throughout the subsequent sampling dates.

Numbers of fungal taxa recorded on May 18 did not differ significantly between the treated and control watersheds (Table 2). Fewer taxa generally were observed in June and July when compared to the May sampling periods for both treatment and control watersheds. This decline may be the result of the lower water levels or higher water temperatures common in these headwater streams during the growing season.

Table 1. Occurrence of aquatic hyphomycetes as indicated by the presence of conidia filtered from water samples prior to and after the Dimilin application to watersheds 1 and 13, with watersheds 4 and 7 serving as controls. Data are numbers of conidia per 1000 ml of water.

	Sampling Date				
Watershed	May 11	May 18	May 27	June 11	July 12
1	797	1660	359	304	407
13	684	485	262	314	347
4	860	498	414	213	543
7	1834	584	231	110	343

Table 2. Numbers of aquatic hyphomycete taxa recorded from filtered water samples prior to and after the Dimilin application to watersheds 1 and 13, with watersheds 4 and 7 serving as controls.

	Sampling Date				
Watershed	May 11	May 18	May 27	June 11	July 12
1	30	29	19	17	15
13	18	16	20	14	16
4	27	24	24	14	19
7	23	25	14	14	14

Overall, 108 fungal taxa were recorded by means of membrane filtration of water samples from all four watersheds on the five sampling dates. This total included 79 fresh water forms, or Ingoldian hyphomycetes; 24 terrestrial geofungi; and 5 aeroaquatic fungi, which typically occur in marshy environments. Only 25 taxa were common to all four watersheds.

The CC indices calculated from pooled filtration data for all sampling dates (Table 3) indicate that watersheds 1 and 4 were the most similar streams (CC = 0.687), even though watershed 1 was treated with Dimilin and watershed 4 was not treated. Watersheds 7 and 13 were the least similar (CC = 0.556). The average CC value for all possible combinations of streams was 0.638.

Table 3. Community coefficient indices calculated from water filtration data.

Watershed Comparisons	Coefficient of Community
1-13	0.672
1-4	0.687
1-7	0.631
4-7	0.630
4-13	0.654
7-13	0.556

Leaf Bag Colonization

Like the filtration data, leaf bag colonization data (Table 4) are quite variable. In general, more aquatic hyphomycete taxa were associated with red oak leaves than with sugar maple leaves in both the streams and the weir ponds. In most instances, the highest numbers of taxa for both leaf types were recorded on the first sampling date. The maximum number (28) was recorded for red oak in the weir pond of watershed 7 on June 11, whereas the minimum number (4) was recorded for the same leaf type in the weir pond of watershed 13, also on June 11. Overall, numbers of taxa recorded from the two types of ecological situations (i.e., weir ponds and streams) were remarkably similar.

A total of 64 fungal taxa colonized red oak leaves. Forty-six of these taxa were freshwater hyphomycetes. Fifteen species of terrestrial geofungi and 3 species of aeroaquatic hyphomycetes also were recorded. Nine taxa were present only in the treated watersheds, whereas 12 species were restricted to the control watersheds.

Colonization of sugar maple leaves was similar to that of red oak leaves. Sixty-five fungal taxa were recorded. Fifty-one of these taxa were fresh water hyphomycetes, 11 were terrestrial geofungi, and 3 were aeroaquatic hyphomycetes. Nineteen taxa were found only in treated watersheds, while 7 were restricted to the control watersheds. *Anguillospora crassa* and *Flagellospora curvula* were the only taxa recorded from both filtered water samples and leaf bags, with 100 percent consistancy.

Coefficient of community indices calculated from leafbag colonization data are summarized in Table 5. The highest CC value was 0.666, which was recorded for pairwise combinations of watersheds 1 and 4, 1 and 7, 4 and 7, and 1 and 13. Four of these involved red oak and three involved sugar maple. The lowest CC value (0.303) was recorded for sugar maple in watersheds 1 and 13.

Table 4. Aquatic hyphomycete colonization of red oak and sugar maple leaf bags.

Watershed	Leaf type	Stream May 11[a]	Stream May 18	Stream May 27	Stream June 11	Stream July 12	Stream Mean	Weir pond May 18	Weir pond May 27	Weir pond June 11	Weir pond July 12	Weir pond Mean
						Number of taxa						
1	Sugar maple		6	8	15	3	8.0	13	6	15	7	10.3
	Red oak		17	8	6	14	11.3	16	5	7	8	9.0
		19										
13	Sugar maple		23	12	6	8	12.3	27	6	11	15	14.8
	Red oak		19	19	12	17	16.8	21	9	4	18	13.0
		14										
4	Sugar maple		15	10	14	16	13.8	10	10	10	9	9.8
	Red oak		19	5	10	12	11.5	12	14	13	15	13.5
		13										
7	Sugar maple		16	13	15	9	13.3	16	13	11	12	13.0
	Red oak		14	16	21	12	15.8	15	5	28	9	14.3
		14										

[a]Present on natural substrates prior to Dimilin application.

Table 5. Coefficient of community (CC) indices calculated from red oak (RO) and sugar maple (SM) leaf bag colonization data obtained on four dates following Dimilin application.

	Sampling Date							
	May 18		May 27		June 11		July 12	
Watershed Comparisons	RO	SM	RO	SM	RO	SM	RO	SM
1-13	0.622	0.451	0.387	0.583	0.545	0.514	0.514	0.303
1-4	0.666	0.555	0.416	0.518	0.451	0.486	0.500	0.416
1-7	0.666	0.611	0.666	0.551	0.380	0.500	0.600	0.384
4-7	0.666	0.500	0.533	0.666	0.509	0.540	0.562	0.666
4-13	0.625	0.528	0.540	0.528	0.571	0.437	0.594	0.594
7-13	0.577	0.490	0.540	0.592	0.434	0.514	0.564	0.410
Average CC Value	0.637	0.522	0.513	0.573	0.481	0.498	0.555	0.462

DISCUSSION

Filtration data indicate that conidial numbers in watershed 1 increased following the Dimilin application, but a similar increase did not occur in watershed 13. In fact, numbers of conidia decreased from May 11 to May 18 for all watersheds except watershed 1. Although the decrease in watershed 13 was less than that observed in the two control watersheds, there is not enough of a difference to suggest that the application of Dimilin caused any sudden increase or decline in fungal occurrence in the treated watersheds.

Generally higher numbers of fungal taxa were observed in leaf bags from treated watersheds than in those from control watersheds. This difference was most obvious on May 18 and was more apparent in the weir ponds of treated watersheds than in streams of the same watersheds. Dimilin may have a greater opportunity to accumulate in weir ponds and thus influence growth and sporulation of litter-decomposing hyphomycetes. Ongoing investigations on residual analysis of Dimilin do indicate persistence of Dimilin in litter and soil within the treated area (Wimmer 1994).

Overall, numbers of fungal taxa recorded from filtration and leaf bag colonization in treated watersheds on May 18 were comparable to or even higher than those recorded on subsequent sampling dates. This pattern demonstrates the tolerance of these fungi to biochemical change. It seems likely that decreases in fungal occurrence and numbers of conidia during June and July may be related to the low streamflow and resultant elevated temperatures.

The possible effects of Dimilin on fungal occurrence can be assessed in two ways. The first way is by examining the direct utilization of residual Dimilin in litter and soil (Wimmer 1994). In an earlier study (Dubey 1992), five species of aquatic hyphomycetes (*Clavariopsis aquatica*, *Heliscus lugdunensis*, *Lemonniera aquatica*, *Lunulospora curvula* and *Tetracladium marchalianum*) showed increased growth rates with increased Dimilin concentrations. However, direct effects of insecticides, such as Dimilin, on aquatic microorganisms probably are modified by a number of factors, including the extent to which the insecticide is water soluble, the contact time between the insecticide and the fungal mycelium, the nutritional status of the environment in which the fungus interacts with the insecticide, the amount of fungal cell material present, and the initial insecticide concentration applied.

The second way to examine the effects of Dimilin involves monitoring changes that may occur in the biochemical environment of treated watersheds as a result of reduced defoliation as gypsy moth larvae are killed after the application of the insecticide. For example, reduced defoliation may result in increases in the watershed's buffering capacity, pH, and Ca and Mg status, and decreases in streamflow and NO_3 and NH_4 compared to conditions of greater defoliation (Downey and others 1994). Low streamflow rates also favor the production of allochthonous coarse particulate organic matter (CPOM) and fine particulate organic matter (FPOM), which are basically produced by the enzymatic leaf processing action of fresh water hyphomycetes. CPOM and FPOM serve as major food sources for many aquatic macroinvertebrates. Downey and others (1994) recorded a relatively high density of aquatic macroinvertebrates from mountain streams in Virginia where an abrupt crash in gypsy moth populations due to disease prevented the occurrence of a significant defoliation during the 1992-93 growing seasons. This finding illustrates the relationship between aquatic hyphomycetes and Dimilin -- Dimilin kills gypsy moth larvae, thereby minimizing defoliation, permitting CPOM and FPOM production, and contributing to increased macroinvertebrate activity and success.

CONCLUSIONS

In the present study, Dimilin application was not shown to exhibit any clear evidence of a direct influence on conidial production in treated watersheds two days after treatment. Fungal colonization data for northern red oak and sugar maple leaves suggest that fungal growth and decomposition activities in the treated watersheds were similar to or slightly greater than those occurring in the control watersheds. If aquatic hyphomycetes are affected by Dimilin, these effects are manifested in an indirect rather than a direct manner.

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THE EFFECT OF ACORN INSECTS ON THE ESTABLISHMENT AND VIGOR OF NORTHERN RED OAK SEEDLINGS IN NORTH-CENTRAL WEST VIRGINIA

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Abstract: During a 2-year investigation into the effect of small mammals on northern red oak (*Quercus rubra*) acorn survival and germination, widespread germination failure and lack of seedling vigor was apparent in control quadrats on one of two watersheds under study. Insects were present in and on the failed acorns but it was unknown whether they were primary invaders or merely scavengers. The purpose of the present study was to determine: 1) the proportion of acorn failure that could have been attributed to insect infestation, and 2) the effect of cotyledon damage due to insects on the vigor of northern red oak seedlings. Northern red oak acorns were collected from good and excellent sites on the two watersheds in October 1993. All acorns located under the crowns of 40 study trees were collected and float-tested for viability. Samples of 18 apparently sound acorns were placed in mammal exclusion cages under each of the study trees; nine acorns were buried and nine were placed on the soil surface. In late spring of 1994, any failed acorns and seedlings with cotyledons attached were dissected. Insect presence or damage, percent cotyledon damage, and overall vigor were recorded. Anaylses of variance (ANOVAs) were used to compare: 1) mean seedling vigor by watershed, year, and treatment, 2) insect infestation rates on the two sites and between treatments in 1994, and 3) the effect of cotyledon damage on seedling vigor in 1994. Important results include the identification of three insect pests in germinating northern red oak acorns in north-central West Virginia and the finding that insect infestation may decrease vigor but does not necessarily preclude germination or seedling establishment.

INTRODUCTION

During the course of a 2-year study to determine the effects of small mammals on the survival of northern red oak acorns (*Quercus rubra*), widespread germination failure and lack of seedling vigor were noted on control plots that were protected from rodent damage with screening (Gribko and Hix 1993). Surface-sown acorns fared poorly in both years on one of two watersheds under study. Insects were present in and on the failed acorns but no detailed investigation of the cause of failure was made. Since insect damage was suspected to play a role in the lack of seedling success, a study was initiated in the fall of 1993 to investigate the impact of insects on germinating northern red oak acorns.

In most studies of acorn insects, *Curculio* weevils (Coleoptera: Curculionidae) are found responsible for much of the damage to acorn crops (Brezner 1960, Tryon and Carvell 1962a and 1962b, Marquis *et al.* 1976, Gibson 1982, Weckerly *et al.* 1989, Oak 1992). Infestations of an acorn moth, *Melissopus latiferreanus* Walsingham (Lepidoptera: Oleuthreutidae), and gall-forming wasps of the genus *Callirhytis* (Hymenoptera: Cynipidae) may also be severe in certain years (Gibson 1982, Oak 1992). All of these insects have been established as primary pests of northern red oak acorns (Gibson 1982). As such, they are capable of breeding in otherwise sound acorns as they develop on the tree. In the small mammal study initiated in 1990, an intense effort was made to eliminate acorns that were infested with primary pests. Therefore, if insects did contribute to the observed seedling failure, it is highly probable that species other than these were responsible.

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Other insects, although present in collections of northern red oak acorns, have often been disregarded due to their low numbers or to the perception that they act primarily as scavengers of the frass and detritus left in acorns vacated by primary pests. Unlike primary invaders, these insects cannot breach the acorn shell and are limited to damaged, previously infested, or germinating acorns for oviposition sites. The most important insects in this group are: 1) weevils of the genus *Conotrachelus* (Coleoptera: Curculionidae) 2) an acorn moth, *Valentinia glandulella* Riley (Lepidoptera: Blastobasidae), and 3) a nitidulid sap beetle, *Stelidota octomaculata* Say (Coleoptera: Nitidulidae). Three species of *Conotrachelus* weevils have been observed breeding in acorns in the United States: *C. posticatus* Boheman, *C. naso* Leconte, and *C. carinifer* Casey. All three are capable of breeding in captivity in northern red oak acorns. (Gibson 1964). However, *C. carinifer* is primarily a coastal species more commonly found infesting bottomland oaks. It has appeared in collections of northern red, black (*Quercus velutina)*, and scarlet oak (*Quercus coccinea*) from Georgia (Gibson 1964), but Brooks (1910) makes no mention of this species in West Virginia and it will not be discussed further here. Of the remaining two species, *C. posticatus* appears to be the most serious pest of northern red oak (Winston 1956, Gibson 1964, Galford *et al.* 1988).

Gibson (1964) reports that adults of *C. posticatus* appear from June to August and begin mating and ovipositing within days of appearing. Rather than ovipositing in acorns as they mature on the tree, *Conotrachelus* weevils wait until they fall to the ground and then deposit eggs through cracks or other openings in the shell. The eggs hatch within days of being laid and the larvae pass through 5 instars before emerging from the acorn in 2-4 weeks. The larvae then burrow down into the soil and construct pupation cells by twisting their bodies until a sealed chamber has formed. It has been suggested that under natural conditions *C. posticatus* will pass the first winter in the larval stage and will not emerge as adults until late spring or early summer of the following year (Gibson 1964). The weevils will then pass their second winter in the adult form. However, both Brezner (1960) and Gibson (1964) report that under laboratory conditions *C. posticatus* will pupate immediately and overwinter as adults.

Conotrachelus weevils were historically considered to be pests of oaks in only the white oak group. However, this conclusion was reached based only on observations made in autumn when the weevils were found to infest germinating white and chestnut oak acorns (Gibson 1964, Gibson 1971, Gibson 1972). Most authors fail to mention the presence of *Conotrachelus* weevils in northern red oak or indicate that they are so rare as to be incidental (Brooks 1910, Brezner 1960, Dorsey *et al.* 1962). However, very meticulous examination of acorn crops has revealed that small numbers of *Conotrachelus* weevils can be found in damaged northern red oak acorns in the fall (Gibson 1964, Gibson 1982, Galford *et al.* 1988). They followed infestation by other insects or attacked acorns with cracked or mammal-damaged shells. Research conducted in the spring on germinating northern red oak acorns has indicated that *Conotrachelus* weevils, particularly *C. posticatus*, can be serious pests (Galford *et al.* 1988, Galford *et al.* 1991a). In addition to their habit of breeding in the cotyledons of acorns, these weevils cause considerable damage to the shoots and radicles of germinating acorns.

The acorn moth, *Valentinia glandulella*, has been reported by many authors to be a scavenger of acorns vacated by primary pests such as *Curculio* weevils (Winston 1956, Brezner 1960, Gibson 1971, Gibson 1972). It was originally assumed that the larvae of this species fed only on the frass and detritus left behind in acorns by other insects. However, Gibson (1972) suggested that *Valentinia* larvae could cause additional damage to the acorn if during their foraging they consumed the remainder of the cotyledons. Subsequently, this species has variously been described as a secondary invader of acorns (Gibson 1982), a primary pest of germinating acorns (Galford 1986), and a primary invader of sound immature acorns (Galford *et al.* 1991a). The life cycle of this species has not been widely reported; however, some basic information is available. In the fall, the adult moth seeks out damaged acorns that have fallen to the ground and deposits eggs on or in cracks and other openings in the acorn shell (Williams 1989). When the larvae hatch, they enter the acorn, spin a web over the opening, and then feed on the remainder of the embryo, the frass of the previous occupant, and other materials, such as fungi, that may be present (Winston 1956, Williams 1989). It has been suggested that the larvae overwinter as early instars (Galford *et al.* 1991a). Winston (1956) reports that maturation may take up to a year but indicates that this may be partially controlled by the availability of food. Williams (1989) and Gibson (1972) both report that *Valentinia glandulella* pupates in the nut but no indication of the duration of the pupal period is given.

Valentinia glandulella has not been found to be a particularly important pest of acorns in the fall; however, because this species has until recently been considered primarily a scavenger, some researchers may have neglected to report their findings of it. Other authors have lumped *Valentinia* and *Melissopus* together in reports of infestations by lepidopterous larvae (Myers 1978, Gibson 1982). In one of the few studies in which lepidopterous larvae were separated by species, *Valentinia glandulella* was found in 38 of 283 collections of upland oak acorns made in West Virginia and was found to infest 0.5-11% of each collection (Dorsey *et al.* 1962).

Recently, Galford (1986) found *Valentinia glandulella* to be a serious pest of sound chestnut, white, and northern red oak acorns as they germinated. The larvae consumed emerging radicle tips as the acorns germinated or gained entrance to acorns as the seed coats split and fed on the outer surfaces of the cotyledons (Galford 1986, Galford *et al.* 1988). Since the larvae did not destroy the hypocotyl, which links the developing radicle with the cotyledon, it was suggested that some of the acorns may have retained their viability. In fact, many apparently healthy seedlings were produced in this study from *Valentinia*-infested acorns. The authors suggested that the only significant impact of this moth on northern red oak regeneration might be the attraction of more serious pests such as nitidulid beetles and *Conotrachelus* weevils.

Of the three species of sap beetles in the genus *Stelidota* found in the United States, only *Stelidota octomaculata* is considered a serious pest of northern red oak acorns (Galford *et al.* 1991b). Adults of this species become active in early spring when northern red oak acorns begin to germinate. They feed extensively on the emerging radicles and then breed in the cotyledons of the acorns as the shells split (Galford *et al.* 1988). This beetle can completely destroy an acorn and, in Ohio, was found to be one of the most serious pests of germinating northern red oak acorns. Krajicek (1960) reports that sap beetles (presumably *S. octomaculata*) were found in Iowa associated with northern red oak acorns that began germination but did not produce seedlings

Only limited information is available on the effects of these insects on northern red oak regeneration. Their most serious impacts can be expected during germination; however, most investigations of acorn insects have been conducted in the fall before red oak acorns begin to germinate. Recently, some work has been completed by Galford *et al.* (1991a) in Pennsylvania on germinating acorns. They found that 92% of surface-sown and 8% of buried northern red oak acorns that were protected from mammal predation were damaged by this group of insects. Buried acorns were destroyed by weevils and sap beetles that burrowed down through loose soil. In a study conducted the following year, insects damaged or destroyed 64% of northern red oak seedlings and 63% of germinating acorns (Galford *et al.* 1991a). Of the 1800 acorns used in that study, only 13% produced healthy seedlings.

The purpose of the present study was to determine if the same degree of damage could be expected on highly productive sites in West Virginia and to further determine if insect infestation was the cause of diminished seedling vigor on the less successful site. The effect of acorn burial on insect infestation was also examined.

METHODS

Study Site

This study was conducted on the West Virginia University Forest located in north-central West Virginia along the westernmost range of the Allegheny Mountains. This 7600-acre experimental forest is part of the Coopers Rock State Forest which straddles Interstate 68 in Monongalia and Preston Counties.

Two study sites were selected. The first site was located in the Lick Run watershed of the Forest where cove hardwood stands were selected on a northeast-facing slope. This study area was characterized by very high site indices for northern red oak (81 to 97), an abundance of mature yellow-poplar and northern red oak, and a moderate ground cover of herbaceous and woody vegetation. The SAF cover type was yellow-poplar--white oak--northern red oak (Eyre 1980). This site was located on a mid-slope position with an average slope of 12% (McNeel 1993). The soils are Dekalb stony sandy loams (Baur 1959). This study area will henceforth be referred to as the Lick Run site.

The second site was located in the Glade Run watershed of the Forest. The stands selected in this area were located on a drier northwest-facing slope and were characterized by lower site indices for northern red oak (68 to 73), a relative absence of yellow-poplar, a significant component of mature black cherry, and sparse ground cover. The SAF cover type on this site was also yellow-poplar--white oak--northern red oak (Eyre 1980). This site was located on a higher mid-slope position with an average slope of 17% (McNeel 1993). Soils were Dekalb stony sandy loams; however, the A horizons were thinner and contained more stone than those on the Lick Run site. This study area will henceforth be referred to as the Glade Run site.

Plot Establishment

Paired square plots of 0.5 acre were established on each site in May and June of 1990. The plots were isolated by a buffer strip on each side. Due to constraints imposed by a concurrent study, three pairs of plots were located on the Lick Run site and only two pairs were located on the Glade Run site. Each plot was divided into quarters and a mature (> 12 inches dbh), mast-producing, dominant or codominant northern red oak was located within each quarter. Therefore, a total of 40 trees (4 on each plot) were selected for study.

A cluster of three 1-foot square quadrats was randomly located within the area under the crown of each study tree. One of the quadrats in each cluster was fully enclosed with 0.5-inch mesh hardware cloth to exclude all potential mammalian and avian predators. These exclosures were constructed with mesh bottoms to prevent predators from entering from below and served as controls in the small mammal study. The tops of the exclosures were hinged so that they could be opened for observation. The remaining two quadrats were fully or partially accessible to small rodents and other mammalian predators and were not used in the present study.

Acorn Collection and Preparation

In 1990 and 1991, northern red oak acorns were collected off- site from a variety of locations in West Virginia and western Maryland from mid-September to late October of each year. The acorns were thoroughly mixed and then tested for viability at least 3 times over a period of 2 weeks using the float method (Korstian 1927, Schopmeyer 1974). Acorns that floated in water, had caps attached (indicating premature absiccsion), were damaged or discolored, or had insect exit holes or ovipositor scars were discarded. All acorns were stored in an unheated root cellar until use.

In the final year of study, acorns were collected on the study area. In mid-October 1993, all acorns, regardless of apparent condition, were manually collected from the ground under the crown of each of the 40 study trees. Acorns collected under the 4 study trees on each plot were then combined to provide a representative sample of acorns produced on each plot. These acorns were floated at least 3 times during a 2-week period and rejected acorns were set aside for use in another portion of the study.

Field Survival and Germination

In early November of 1990, 1991, and 1993, 9 apparently sound, undamaged acorns were placed on each quadrat in a square grid pattern. Nine acorns per quadrat was determined to be a reasonable approximation of that naturally occurring on a 1-foot square area (Gysel 1957). The acorns were pressed slightly into the humus to prevent them from rolling but were not buried. To assess the effect of burial on acorn survival, additional acorns were planted one inch deep in mineral soil on each quadrat. In 1990, only 3 acorns were buried; however, in 1991 and 1993, 9 acorns were buried. Therefore, there were a total of 12 acorns sown on each quadrat in 1990, 9 surface-sown and 3 buried, for a total of 60 acorns on each plot. In 1991 and 1993, a total of 18 acorns were sown on each quadrat, half on the surface and half buried, for a total of 72 acorns per plot. Leaf litter was placed over the acorns and the exclosures were wired shut and left undisturbed until the following spring. Around May 31 of each year, the exclosures were opened and the vigor of each seedling was rated 0 to 4 (Table 1).

Table 1. Seedling vigor rating descriptions

Rating	Description
0	Did not germinate
1	Germinated but weak root system, root or shoot dieback; not likely to survive
2	Strong root system, shoot small or just forming, generally earlier in development than seedlings with a rating of 3 or 4
3	Strong root system, no true leaves but strong healthy shoot
4	Same as a rating 3 seedling but at least one set of true leaves present

In 1994, any failed acorns and the seedlings with attached cotyledons were dissected with anvil shears. Insect damage or presence, disease, and apparent desiccation were recorded. In addition, the cotyledons were quartered and percent damage was estimated. All larvae present were collected and preserved in 80% ethanol for later identification.

RESULTS

Seedling Vigor in All Three Years of Study

Mean seedling vigor on each quadrat was calculated by year and treatment. Overall means by watershed are shown in Table 2. Analysis of variance revealed that mean vigor was significantly higher on the Lick Run site in all 3 years of study ($F = 22.60$ $Pr > F = 0.0001$),. In addition, year ($F = 21.16$, $Pr > F = 0.0001$) and treatment ($F = 29.21$, $Pr > F = 0.0001$) were found by the main effects model to significantly affect seedling vigor; however, there was also a significant year by treatment interaction ($F=14.18$, $Pr > F = 0.0001$). Examination of the interaction using additional ANOVA's and t-tests indicated that treatment was only significant in 1992 ($T = 6.16$, $Pr > |T| = 0.0001$). In that year, seedlings produced by buried acorns on both sites were more vigorous than those produced by surface-sown acorns. Among just the buried acorns, there was no significant difference between seedling vigor in 1992 and 1994, although vigor in both of these years was significantly higher than that observed in 1991 ($F = 15.04$, $Pr > F = 0.0001$). Among just surface-sown acorns, there was significantly higher vigor in 1994 than in either 1991 or 1992 ($F=16.77$, $Pr > F = 0.0001$). This was apparent on both sites but was more important on the Glade Run watershed. Average vigor in 1991 and 1992 on this site was 1.3 and 1.7, respectively, indicating that very few acorns were able to produce viable seedlings in either year. Seedling vigor rose to 2.6 in 1994, suggesting that the average seedling was healthy, well-developed, and capable of surviving. This was quite apparent in the field, as quadrats and entire plots that did not produce a single seedling in the previous years of study were found to be highly successful in 1994. On the Lick Run site, average vigor in 1991 was 2.3, in 1992 was 2.0, and in 1994 was 3.0. Healthy, viable seedlings were produced in all 3 years on this site; those produced in 1994 were exceptionally vigorous.

Table 2. Mean seedling vigor by year, watershed, and treatment.

Year	Site	Treatment	No. quadrats	Mean Vigor	Standard Error
1991	Lick Run	Surface	24	2.3	0.18
		Buried	24	2.3	0.17
	Glade Run	Surface	16	1.3	0.12
		Buried	16	2.0	0.24
1992	Lick Run	Surface	24	2.0	0.18
		Buried	24	3.3	0.15
	Glade Run	Surface	16	1.7	0.24
		Buried	16	2.8	0.25
1994	Lick Run	Surface	24	3.0	0.18
		Buried	24	3.0	0.11
	Glade Run	Surface	16	2.6	0.11
		Buried	16	2.7	0.15

Overall Insect-Infestation Rates on the Two Sites in 1994

In 1994, 56.9% of the 216 surface-sown acorns on the Lick Run site were sound. Twenty-seven percent had been at least partially damaged by insects, 5.6% were diseased, and the remainder exhibited damage due to root or shoot dieback (3.4%), desiccation (0.4%), surface mold (0.4%), or unknown causes (0.4%) (Figure 1). Most of the insect damage was caused by *Conotrachelus* weevils, although *Valentinia* moth larvae, and very small numbers of nitidulid sap beetles and fly maggots were identified (Figure 1). In contrast, 49.1% of the surface-sown acorns on the Glade Run site were sound, 24.8% were insect damaged, 10.3% were affected by root and shoot dieback, 8.5% were diseased and 1.8% were desiccated. Again, *Conotrachelus* weevil larvae were responsible for most of the insect damage (Figure 1). In general, buried acorns fared much better. On both sites, approximately 76% of the buried acorns were undamaged and approximately 10% were insect damaged. Root and shoot dieback affected 1.7% of the germinating acorns on the Lick Run site and 2.1% on the Glade Run site. Just under 9% of the acorns on the Glade Run site and 5.3% of those on the Lick Run site appeared to be diseased; however, the isolation of pathogens was not attempted (Figure 1).

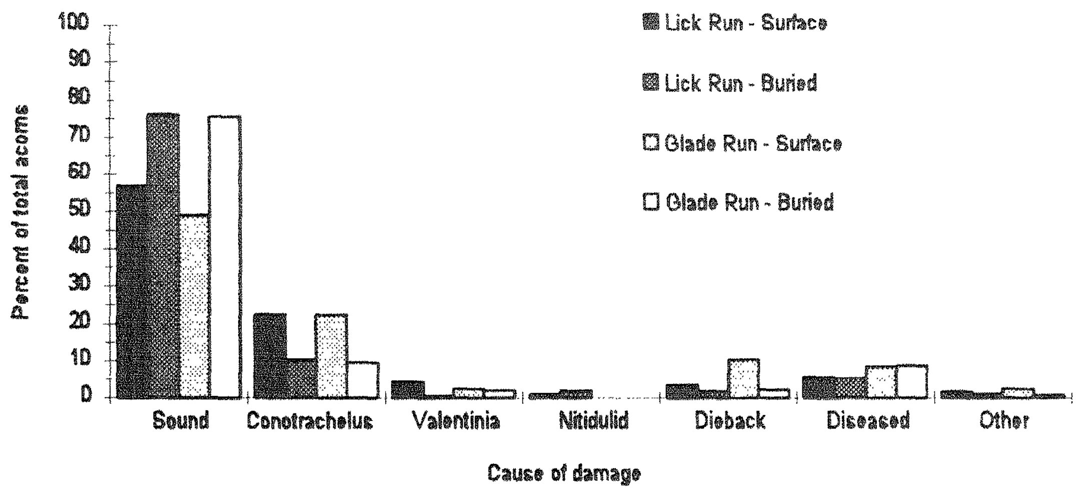

Figure 1. Total percentages of sound and damaged acorns by site, treatment, and damaging agent. Note: these are pooled percentages and are not based on the quadrat-level means used in the analysis of variance.

Comparison of Insect Infestation Between Sites in 1994

To allow comparison of insect infestation between the sites, percent infestation by any insect or combination of insects was calculated by treatment on each quadrat. Acorns infested by more than one insect were counted only once in this analysis and those infested by fly maggots were excluded as they appeared to have succumbed to disease before infestation. Analysis of variance on these data revealed that insect infestation did not vary by site ($F = 0.31$, $Pr > F = 0.5824$); however, there was a significant treatment effect ($F = 4.69$, $Pr > F = 0.0335$) with no site by treatment interaction. On average, surface-sown acorns were about twice as likely to be infested regardless of site (Table 3). Infestation rates on individual quadrats within the sites were quite variable.

Table 3. Mean percent of acorns infested by insects on each plot in 1994 by site and treatment.

Site	Teatment	No. plots	Mean infestation rate (%)	Range on individual quadrats (%)	Standard error, (%)
Lick Run	Buried	6	11.6	0-44	1.2
	Surface-sown	6	24.1	0-100	7.4
Glade Run	Buried	4	10.4	0-44	2.3
	Surface-sown	4	19.4	0-89	7.4

Cotyledon Damage and Seedling Vigor in 1994

Each acorn was classified as sound, insect-infested, or damaged by other agents. Mean vigor and mean percent cotyledon damage were then calculated by group and treatment on each quadrat. Analysis of variance indicated that there were significant differences in vigor among the groups (F = 139.58, Pr > F = 0.0001). Seedlings from sound acorns were found by Fisher's LSD comparisons to be significantly more vigorous than those produced by damaged acorns, regardless of damaging agent, site, or treatment. In addition, acorns damaged by insects produced significantly more vigorous seedlings than those damaged by other agents such as desiccation and disease. Differences in seedling vigor are obvious in the pooled data (Figure 2).

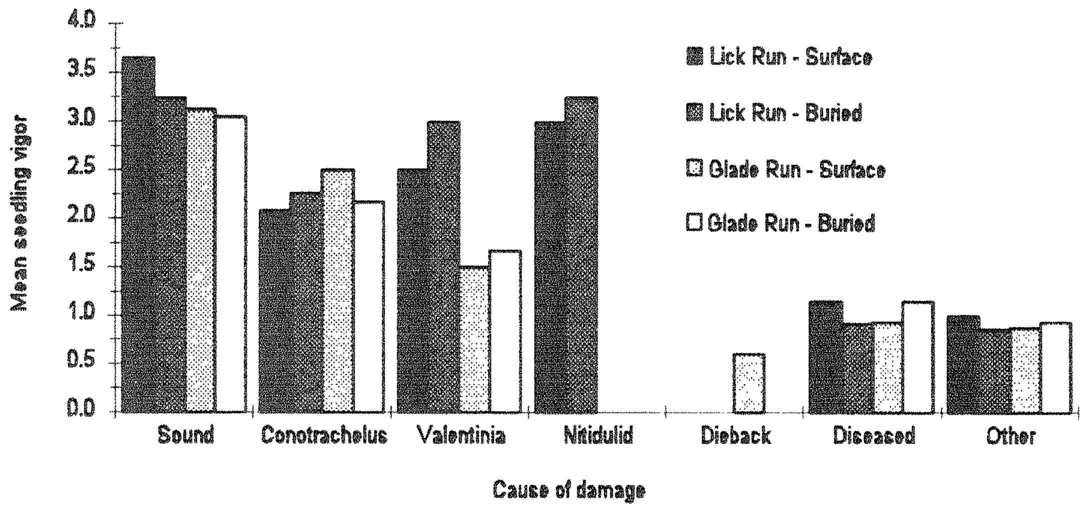

Figure 2. Average vigor of sound and damaged acorns by site, treatment, and damaging agent. Note: these means are calculated using all of the data pooled by site and treatment and are not based on the quadrat-level means used in the analysis of variance.

An additional ANOVA was conducted to determine if desiccation and disease resulted in more extensive cotyledon damage than did insects. This analysis, which excluded sound acorns, revealed that percent cotyledon damage was significantly higher in acorns damaged by agents other than insects (F = 19.24, Pr > F = 0.0001). Cotyledon damage due to insects averaged 14.8% (SE=2.5%) while that caused by other agents averaged 38.9% (SE=5.0%). Site and treatment had no significant impact on the degree of cotyledon damage observed in either group of acorns.

These results suggested that percent cotyledon damage could be used to improve the original analysis of variance on vigor. Therefore, percent cotyledon damage by all agents was used as a covariate with site and treatment in an analysis of covariance. This analysis demonstrated that percent cotyledon damage was significantly related to seedling vigor (F = 8.06, Pr > F = 0.0060) and that it explained some of the variation within site (Figure 3). There was no significant treatment effect.

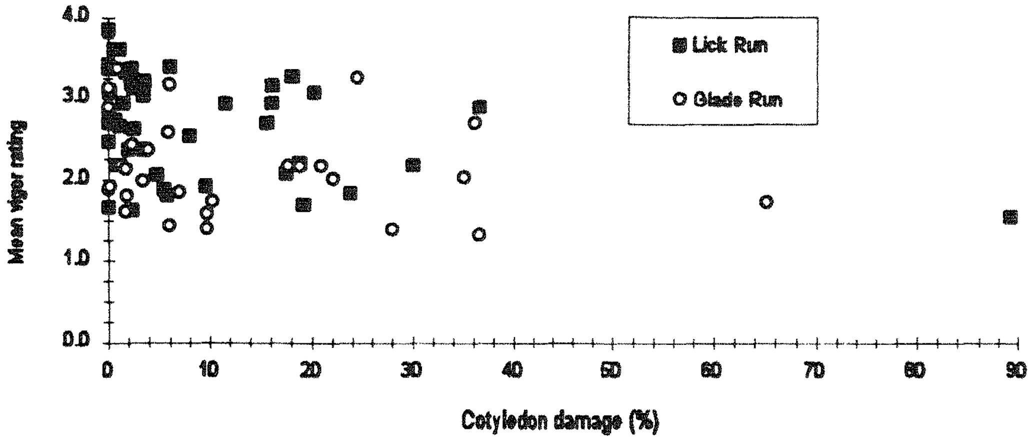

Figure 3. Mean seedling vigor versus mean cotyledon damage by site. Each observation is based on a single quadrat.

DISCUSSION

Seedling vigor was consistently better on the Lick Run site regardless of the year of study, indicating that the additional data pertaining to acorn condition and damage collected in 1994 could be expected to have at least some relevance to the results from the previous two years. However, vigor was found to be significantly higher among surface-sown acorns on both sites in 1994, indicating that growing conditions were not consistent across the 3 years. This annual variation, likely weather related, cannot be accounted for with a single year of study. Therefore, it is unlikely that the cause of the widespread failure observed on the Glade Run site in 1991 and 1992 can be determined here. However, initial data on the incidence of insects in germinating northern red oak acorns can be reported for north-central West Virginia. In addition, the effects of these insects on seedling vigor in a year of high reproductive success can be examined.

The results of the 1994 study indicate that all three of the insects noted to be serious pests of germinating northern red oak acorns in Ohio (Galford *et al.* 1988) and Pennsylvania (Galford *et al.* 1991a) were also present in north-central West Virginia. In concurrence with the results of both of these studies, *Conotrachelus* weevils were the most serious pest of germinating acorns. The *Valentinia* moth was much less prevalent. In addition, the incidence of moth larvae was not uniform across the study area. This species appeared sporadically in individual quadrats and usually infested several acorns in each affected quadrat. *Valentinia* moth larvae have not been previously reported to infest buried acorns; however, in this study, small numbers were found feeding in buried acorns on both sites (Figure 1).

The nitidulid sap beetle was almost absent from the study area. Cotyledon damage due to the feeding and breeding activities of adult sap beetles was extremely minor in the few acorns infested on the Lick Run site. As suggested by Galford et al. (1991a), sap beetles may not have been active by late May when the acorns and seedlings were collected from the field. Their possible impact later in the growing season deserves more study, as sap beetles were found capable of widespread seedling damage in Ohio (Galford *et al.* 1988).

Overall, the incidence of acorn pests in germinating northern red oak acorns was much lower than that reported in the Ohio and Pennsylvania studies. However, weather conditions were quite unusual in West Virginia during the winter of 1993-94. A relatively wet fall was followed by an extremely cold winter with much greater than normal snowfall. A hard crusty snowpack remained on the study area almost constantly throughout the winter. Spring came late and hard frosts were still occurring in mid- to late May. However, by May 30-31, when the exclosures were opened, daytime temperatures had exceeded 70°F for several days and the ground was beginning to warm. In contrast, the winters of 1991 and 1992 were very mild with sporadic snowfall and only patchy accumulations of snow on the study area. In both of these years there was unseasonably warm weather in late February when temperatures ranged from 60°F to 70°F for a week to 10 days.

In 1991 and 1992, acorns in the study area began germinating by late February; however, in 1994, germination did not begin until mid-April. Galford *et al.* (1991a) found larval acorn moths in Pennsylvania to become active in germinating acorns by mid-February, weevil larvae to commence feeding by mid-March, and sap beetles to begin activity in late May. The hard winter and late spring in West Virginia in 1994 may have delayed emergence of the insects and it is possible that insects had not begun to emerge until shortly before the exclosures were opened. In addition, the late germination of the acorn crop may have resulted in a lack of suitable habitat for insects that did emerge early. In the case of the sap beetle, it appears that breeding was delayed. The few acorns that were infested by nitidulids showed only minimal oviposition damage and no larvae were present. Had the study been continued into the summer, sap beetles, and perhaps late-emerging weevils and acorn moths, may have had more of an impact.

In addition, Galford *et al.* (1991a) indicate that most acorns infested by insects in central Pennsylvania were completely destroyed and were incapable of producing viable seedlings. This was not the case in the present study. Although insect infestation and resultant cotyledon damage did reduce seedling vigor, they were not severe enough in most cases to cause lack of seedling success. The fact that insect infestation on average resulted in only 14.8% cotyledon damage and that larvae were still present in most infested cotyledons indicates that the adult insects may have emerged too late to have more than a minimal impact on the rapidly growing seedlings.

Of even more significance is the lack of difference in percent insect infestation between the sites, even though the seedlings on the Glade Run site were again found to be less vigorous. It was initially hypothesized that the lack of seedling success and vigor on the Glade Run site was due in part to insect infestation; however, at least in 1994, this was not the case. As mentioned previously, the widespread reproductive failure observed on the Glade Run site in 1991 and 1992 was absent in 1994. Glade Run acorns produced healthy seedlings in 1994, although they were in general smaller and less well-developed than those produced on the Lick Run site. This appeared to be a microsite effect, perhaps caused by the warmer, drier northwest aspect or more exposed slope position of the Glade Run site.

Several corollaries can now be put forth to explain the acorn failure on the Glade Run site. First, if insect infestation and effect is assumed to have been similar on both sites in the previous two years of study, then some other factor must have been responsible for the lack of seedling production. This factor may have been desiccation as the Glade Run site is drier and more exposed than the Lick Run site. Or the acorns may have become diseased. Winston (1956) and Dorsey *et al.*(1962) identified several bacterial and fungal agents that may affect acorn viability even in the absence of insect infestation. Overall, desiccation and disease were found to be slightly more prevalent on the Glade Run site (Figure 1), although there were not sufficient numbers of desiccated or diseased acorns to allow statistical analysis. Both were found in this study to cause almost complete cotyledon destruction and loss of acorn viability. No seedlings were produced by desiccated acorns and the seedlings produced by diseased acorns exhibited a notable lack of vigor (Figure 2). Since the winters of 1991 and 1992 were relatively dry with a lack of snowpack, widespread desiccation on the Glade Run site is a particularly good possibility.

Conversely, the relatively minimal effects of insects in 1994 may have been an anomaly. Populations may usually be higher on one or both sites. If this was the case in 1991 and 1992, feeding in the cotyledons may have been more extensive and in itself may have caused more notable lack of vigor or may have predisposed acorns to failure due to drying or disease. Several more years of study on a greater number of sites would provide additional insight.

SUMMARY

It has been established that *Conotrachelus* weevils, the acorn moth, *Valentinia glandulella*, and the nitidulid sap beetle, *Stelidota octomaculata*, infest germinating northern red oak acorns in north-central West Virginia. The data from a single year of study indicate that these insects were much less prevalent and much less damaging on this study site than they were on sites in Ohio and Pennsylvania. However, the severity of the winter of 1994 and the late spring frosts may have resulted in delayed emergence.

It is suspected that agents other than insects were responsible for the acorn failure and lack of vigor noted in 1991 and 1992. Disease and desiccation, when they did occur, almost invariably caused acorn failure in 1994. These factors may have had more widespread effects in the previous years of study and warrant additional study in future years.

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LOGGING SAFETY IN FOREST MANAGEMENT EDUCATION

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Abstract: Forest management degree programs prepare students for careers in forestry by teaching a combination of biological sciences (e.g., silvics and genetics) and business management (e.g., forest policy and timber valuation). During a 4-year degree program, students learn the impact of interest rates, equipment costs, and environmental policies on forest management and silvicultural decisions. However, little consideration is given to worker safety and health and its impact on forest management. This paper illustrates the ethical and economic importance of logging safety to forest managers and advocates incorporating safety issues into existing forestry courses. An appendix provides examples of safety and health information that can be integrated into forest policy and forest economics courses.

INTRODUCTION

Four-year forest management programs are designed to prepare students for professional careers in management of natural resources, including the business aspects of finance and personnel management. Students are exposed to a diverse curricula, ranging from the biological sciences to accounting principles. This broad program emphasis is encouraged through the *Society of American Foresters (SAF) Accreditation Standard for Forestry Program Mission, Goals and Objectives* (Society of American Foresters 1994a), in which the interdisciplinary nature and service orientation of the forestry profession are emphasized. The SAF places importance on management training -- two of the four areas of study that must be adequately represented in the forestry curriculum are Management of Forest Resources (including forest engineering, harvesting and utilization) and Forest Resource Policy and Administration (including policy development, administration, and personnel management). Forestry curricula must "provide students with an understanding of the social, cultural, political, legal, economic, institutional, and historical influences on forestry" (Society of American Foresters 1994a).

Forestry programs traditionally meet this goal of providing students with an understanding of socioeconomic influences on forestry through policy and management courses. External influences on forestry typically addressed in these courses include organizations, cultural resources, environmental concerns, pollution control, military policy, taxation, and international trade policy (see tables 1 and 2). One important topic, occupational safety and health, is not typically addressed in these courses.

WHY TEACH SAFETY AND HEALTH IN FORESTRY PROGRAMS?

Worker safety concepts should be integrated into forestry education for several reasons. First, logging is the primary tool for accomplishing forest management objectives on the ground. Logging has long been considered a dangerous industry, and death certificate data indicate that the rate of work-related fatalities in the logging industry is extremely high (Myers and Fosbroke 1994), with regional rates ranging from a low of 87.0 deaths per 100,000 workers in the southeast to 394.3 deaths per 100,000 in the central hardwood region. For comparison, the fatality rate across all industries is 7.0 per 100,000 workers, and the rate in the manufacturing sector (of which logging is a part) is 4.4 per 100,000 (Jenkins et al. 1993). The logging industry has also been identified as having a high rate of nonfatal injuries with a lost workday case rate of 10.7 per 100 full-time workers in 1990 compared to a private industry average of

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Table 1. Examples of Forest Management Influencing Legislation Taught in Forest Policy Courses[1].

Legislation	Date	Notes
Magna Carta	1215	King's ownership of wildlife in trust for all people
King's Broad Arrow	1691	Reserved mast trees for the British navy
Lacey Act	1900	Prohibited interstate trade of wildlife illegally taken
Antiquities Act	1906	Preservation of cultural artifacts
Week's Law	1911	Watershed protection; Fire protection
Forest Cons. and Taxation	1949	Tax incentives for certain forest management practices
Land and Water Cons. Fund	1964	Public purchase of private land for recreational use
Wilderness Act	1964	Established the Wilderness Area system
Nat'l Historic Preservation Act	1966	Assessment of activity impact on historic sites
Clean Air Act and Amendment	1970, 1973	Designation of air quality classes, scenic visibility
Fed. Water Pollution Control Act	1972	Stop discharges, attain fishable/swimmable waters
Endangered Species Act	1973	Protection of endangered plants/animals, critical habitat
Eastern Wilderness Act	1974	Extended 1964 act to eastern U.S.; added 16 new areas

[1] Sources: Cubbage, O'Laughlin, and Bullock (1993); Dana and Fairfax (1980)

Table 2. Examples of Organizations and Events that Have Influenced Forest Policy[1].

American Assoc. for the Advancement of Science	Monongahela National Forest Controversy
American Forestry Association	National Academy of Sciences
Bitterroot National Forest Controversy	National Trail System
Civilian Conservation Corps	Native Alaskan Lands Settlement
Council on Environmental Quality	Office of Management and Budget
Environmental Protection Agency	Sand County Almanac publication
Farm Abandonment & Westward Expansion	Sierra Club
Hetch Hetchy	Soil Conservation Service
Friends of the Earth	Society to Protect New Hampshire Forests
Izzak Walton League	Tellico Dam

[1] Sources: Cubbage, O'Laughlin, and Bullock (1993); Dana and Fairfax (1980)

3.9 and a manufacturing industry rate of 5.3 per 100 full-time workers (U.S. Department of Labor 1992). Though there have been tremendous advances in harvesting technology over the past 30 years, the logging industry has seen little improvement in injury statistics (McCormack 1963, Myers and Fosbroke 1994).

The second reason for teaching forestry students about worker safety is that forest management decisions directly affect logging safety. There are many examples. The decision to leave den trees may raise logger's risk of being hit by a falling snag. The selection of a residual stand density influences the probability of a logger being injured in the hit-tree reaction type of incident described by Peters (1991). Decisions about the length of a cutting contract may influence the amount of time loggers have to complete the job safely. Even forestry graduates that do not make harvesting decisions may be employed by industry in supervisory positions where they are responsible for other employees. Under the provisions of the 1970 Occupational Safety and Health (OSH) Act (Public Law 91-596), employers are responsible for assuring safe and healthful working conditions for all employees (see Appendix).

Graduating forestry students need to be aware of their responsibility for understanding and following regulations that apply to their jobs.

Finally, teaching safety to forestry students is an ethical obligation of any forestry program. The "Code of Ethics" set forth by the Society of American Foresters (Society of American Foresters 1992), states in its preamble that compliance with the SAF canons "ensures just and honorable professional and human relationships, mutual confidence and respect, and competent service to society." Professional foresters are morally and ethically bound to ensure that their decisions and actions do not jeopardize the safety of others. Graduating forestry students need to be aware of how their future management decisions can affect the safety and health of other workers.

CURRENT STATUS OF SAFETY IN FORESTRY PROGRAMS

Programs that train students to become professional foresters often devote less program time to safety than do programs that train forestry technicians. This is partially exhibited by differences in SAF requirements for accreditation of professional programs and recognition of technical programs. Though current *Guidelines for Accreditation of Educational Programs in Professional Forestry* (Society of American Foresters 1994a) do require coverage of personnel management and do require that facilities provide an environment that is safe, healthful, and conducive to learning, the guidelines make no other mention of safety. In contrast, the *Standards and Procedures for Recognizing Educational Programs in Forest Technology* (Society of American Foresters 1994b) have a specific curriculum requirement for "Woods Safety," which is to include basic first aid, identification of hazards, hand and power tool safety, and pesticide safety.

In May of 1993, the authors sent a request to the 45 professional degree programs accredited by the Society of American Foresters. Each program was asked to provide a college catalog describing their program, course syllabi of management and policy related courses, and a copy of the most recent self-evaluation report. These materials were reviewed to determine how prominent a role safety topics played in the way courses and programs are described to prospective students. Thirty-one forestry programs provided materials (26 schools sent catalogs, 22 sent course syllabi, and 18 sent self-evaluation reports). Only seventeen programs referenced any safety concept within the reviewed material and these references were generally limited to the harvesting course. Based on this review, most professional forestry degree programs do not currently emphasize safety issues in their descriptions of course content.

Though the numbers above suggest that safety is not an emphasis area in forest management programs, most programs do have some safety components. Frequently, the strongest safety component of 4-year programs is in the summer forestry camps. Here, a few days are spent teaching the technical aspects of harvesting, road construction and chain saw use. Most 4-year programs also touch briefly on safety issues in a variety of courses. For example, logging hazards are discussed in harvesting classes, though the impact of these hazards in terms of lives lost and lost work time injuries is typically not. Pesticide labelling is covered in planting, silviculture, and entomology courses. Ecology and wildlife management courses also discuss pesticide safety, though usually from the environmental contamination standpoint. Each year, a few students gain practical experience in safe woods operations from forest managers while working for the school at the university woodlot or forest. Other attempts are made to instill a consciousness of safety among forestry students, including the requirement that all students wear hard hats and sturdy boots during field labs and industry tours.

What is Missing?

Professional foresters need to make rational decisions based on an understanding of safety principles and an awareness of safety issues that affect forest (and any other management) operations. Forestry programs should prepare students for challenges they will face by at least making them aware of: the safety record of the logging, sawmilling, and paper manufacturing industries; the existence of safety regulations, standards, and policies; the identification and control of hazards; the management of safety; the methods of preventing injuries; the impact of safety programs on insurance premiums; the concepts of insurance and shared risk; the impact of injuries on operating costs and employee morale; the responsibility and liability of decision makers and managers; and the influence of management decisions on worker safety.

When the National Research Council (NRC) surveyed academic and nonacademic forestry groups to identify needs in forestry education (National Research Council 1990), respondents suggested a need to "move from technician-type courses to more analytical, decision-making, conflict resolution types of courses." Expansion beyond technical safety topics (e.g., first aid and tool safety) toward the legal, economic, and moral aspects of safety and health fits well with this NRC recommendation. This expanded coverage of safety and health issues will provide future foresters with the analytical tools they will need to evaluate management decisions.

INTEGRATING SAFETY CONCEPTS INTO EXISTING COURSES

Integration of safety and health concepts into forestry education **will not** require a new course, "Safety in Forest Operations." Forestry curricula already contain a full complement of course requirements; any new course would require elimination of an existing course. The ultimate goal should be to teach future foresters to consider the safety implication of all decisions. To do this, safety thinking needs to be incorporated into many courses, wherever a safety issue is relevant. This need not be difficult because most safety issues relate in some way to concepts that are taught in existing courses.

For example, forest policy courses traditionally include tax laws, environmental regulations, recreational development programs, and resource funding programs because of the influence of these regulations and programs on forest management decisions. The inclusion of safety and health regulations, the regulatory process, and safety research organizations fits into the concept of teaching policies and programs which influence forestry (see tables 3 and 4 for selected examples). Additional topics that could be incorporated into forest policy courses include the regulatory process (including the OSH Act's provision for public comment during standards development), owner liability, third party tort, and specific Occupational Safety and Health Administration (OSHA) and national consensus standards related to forestry operations.

In addition to the above forest policy examples, other topics can be integrated into the existing curricula. Introductory forestry courses should cover sources of injury and illness information, injury statistics specific to forest industries and occupations, and the importance of safety. Timber harvesting courses should describe specific hazards associated with logging and recommended ways of minimizing hazards, especially machine guarding, rollover protection, and the identification and safe felling of hazardous trees. Forest Management courses should emphasize the role of managers in ensuring safe and healthful working conditions. Other safety topics for forest management include safety language in logging contracts, hazard communication, recordkeeping, accident investigation, and safety management programs. Silviculture courses should explain the effect of cutting method, leave tree selection, and cutting cycle on logging safety.

Specific information on the Occupational Safety and Health Act, the history of workers' compensation, and the incorporation of workers' compensation costs in machine cost calculations are provided in the appendix. This material provides details of the type of information that could be integrated into forest policy and forest economics courses. Other examples of incorporating safety issues into an existing curriculum are described by Taylor et al. (1994).

Table 3. Examples of Safety Legislation, Standards, and Policy Impacting Forest Management[1].

Legislation	Date	Notes
Federal Workers' Compensation	1908	Federal law providing compensation for federal workers injured on the job
State Workers' Compensation	1911	Wisconsin and Maryland pass laws similar to federal workers' compensation law
Walsh-Healy Act	1938	Specified working conditions for employees working for private companies under contract to the U.S. government
Fair Labor Standards Act	1938	Prohibited children under 18 years old from working in hazardous occupations (including logging)
Occupational Safety and Health Act	1970	Created regulatory and research agencies and a process for development and enforcement of OSH standards
Safety Requirements for Pulpwood Log.	1971	ANSI national consensus standard
OSHA Pulpwood Log. Standard 1910.266	1971	OSHA adopted ANSI consensus standard
NIOSH criteria document on logging	1976	Recommendation for an occupational standard on logging from felling to first haul
Safety Requirements in Logging	1978	ANSI consensus standard extending prior pulpwood requirements to all logging
ANSI withdraws Safety Req. in Logging	1984	ANSI committee fails to renew standard
OSHA Logging Standard	1994	Proposed in 1989, OSHA promulgated a single standard for the logging industry on October 12, 1994.

[1]Sources: DeReamer 1980; Hammer 1989; Kavianian and Wentz (1990); Public Law 91-596 (1970); Readers' Digest (1975); U.S. Department of Labor (1989, 1994)

Table 4. Organizations Influential in the Establishment of Safety Policy Affecting Forest Management[1].

Organization	Notes
American National Standards Institute	Develops national consensus standards
American Pulpwood Association	Produces logging safety materials; facilitates safety
American Society of Agricultural Engineers	Forest Operations Safety Committee provides a forum for harvesting safety research
American Society of Safety Engineers	Established an independent board to certify safety professionals
International Labor Organization	Established as part of League of Nations to improve working conditions around the world; major contributor to woods worker training and international recommendations
National Fire Protection Association	Develops national consensus fire protection standards
Nat'l Institute for Occupational Safety and Health	Conducts occupational safety and health research, trains safety and health professionals
National Safety Council	Private, non-profit organization working in traffic, home, recreational, and occupational safety
Occupational Safety and Health Administration	Administers the OSH Act, promulgates regulations, and provides state training grants

[1]Sources: DeReamer 1980; Hammer 1989; Kavianian and Wentz (1990); Readers' Digest (1975)

SUMMARY

Logging is well known as a hazardous industry, both in terms of fatal and nonfatal outcomes. Recent statistics, when compared to statistics from 30 years ago, indicate that the industry's injury record is not improving (Myers and Fosbroke 1994). These facts led OSHA to promulgate a new standard for logging operations (U.S. Department of Labor 1994). The new mandatory standard has direct implications on the way logging is conducted. Since logging is the primary tool for accomplishing natural resource management objectives, this standard also impacts forest management decisions. Therefore, graduate foresters increasingly will need to be aware of occupational safety and health concepts. Professional forestry degree programs have traditionally provided students with a wide range of background; however, worker safety and health typically is not a major focus of class instruction. Integrating important occupational safety and health issues into existing curricula can be done, but will take a concerted effort on the part of faculty to expand existing courses into new subject areas. This paper demonstrates a few examples of how safety topics can be covered in forestry courses. The appendix contains additional examples. It is hoped that faculty will consider these examples, look at their existing courses, and ask, "Are there important safety issues that I should incorporate into my courses?"

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APPENDIX

SELECTED SAFETY TOPICS FOR FOREST POLICY AND FOREST ECONOMICS COURSES

The Occupational Safety and Health Act

The most sweeping U.S. law regarding worker safety and health was passed by Congress on December 17, 1970. The preamble to the Occupational Safety and Health (OSH) Act (Public Law 91-596) includes a promise to "assure safe and healthful working conditions for working men and women." Section 5 of the Act defines (in broad terms) the duties of employers and employees with respect to occupational safety and health. An employer has the duty under Section 5(a)(1) "to furnish to each of his employees employment and a place of employment which are free from recognized hazards that are causing, or are likely to cause death or serious physical harm to his employees." An employer also has the duty to "comply with occupational safety and health standards promulgated under this Act." This section of the OSH Act **clearly** places on forest managers the responsibility of knowing what standards are applicable to forestry operations. An employee also has a duty under Section 5(b) to "comply with occupational and safety and health standards and all rules, regulations, and orders pursuant to this Act which are applicable to his own actions and conduct."

Within 2 years of the effective date of the Act, the Secretary of Labor was to "promulgate as an occupational safety and health standard any national consensus standard, and any Federal standard, unless he felt that the promulgation of such a standard would not result in improved safety and health for specifically designated employees." Several existing Occupational Safety and Health Administration (OSHA) standards resulted from adoption of national consensus standards developed by organizations such as the National Fire Protection Association and the American National Standards Institute (ANSI) (Kavianian and Wentz 1990). The original pulpwood standard (U.S. Department of Labor 1993a) is an example of a national consensus standard that was developed by ANSI and promulgated by OSHA into the new OSHA standards in 1971 (U.S. Department of Labor 1989). OSHA continues to review consensus standards during regulatory review and development.

OSHA has promulgated general industry standards and industry-specific standards. General industry standards apply to all industries. Examples include electrical, machinery and machine guarding, hazardous materials communication, fire protection (Kavianian and Wentz 1990), and lockout/tagout standards (U.S. Department of Labor 1993b), and recordkeeping regulations (U.S. Department of Labor 1986). Other standards apply to a specific industry. The logging standard that OSHA recently promulgated[2] (U.S. Department of Labor 1994a) is an example of an industry-specific standard.

Several aspects of the Occupational Safety and Health Act and the standards and regulations promulgated under the Act influence forestry operations[3]. The new logging standard, and the pulpwood standard that it replaced, obviously apply to the harvesting of trees. However, these are not the only factors of which forest managers need to be aware. The Act clearly was intended to hold employers responsible for the safety of their employees. OSHA has used the

2 For a discussion of the new OSHA logging standard and what it means for forest management, see Myers and Fosbroke (1995). For a copy of the text of the new standard, contact: U.S Department of Labor, Occupational Safety and Health Administration, Office of Publications, Room N-3101, 200 Constitution Avenue, NW., Washington, D.C. 20210.

3 Examples of OSHA requirements are included to apprise the reader of the range of regulatory issues affecting forestry and logging employers. This is not a complete list, and a full description of the specifics of these requirements is beyond the scope of this paper. The reader should also be aware that OSHA is continually revising its standards and regulations; therefore, affected readers should remain cognizant of the status of applicable OSHA regulations by contacting their Regional OSHA Area Office.

provisions of the General Duty Clause [Section 5(a)(1)] to cite employers that allowed a recognized hazard to persist at a site of employment, even when no specific OSHA standard or regulation had been violated. Additionally, there are many general industry standards that forestry employers are also responsible for meeting, even though logging and forestry are not specifically mentioned in these standards. For example, a sawmill owner may be held responsible for failing to maintain protective guarding on machinery.

Any company employing 11 or more employees is required to maintain an annual log of employees' occupational injuries and illnesses. These logs must be posted annually for public disclosure and provided to OSHA upon request (U.S. Department of Labor 1986). OSHA must also be notified of any fatality or incident resulting in the hospitalization of 3 or more employees within 8 hours of the incident, or when the employer became aware of the incident (U.S. Department of Labor 1994b).

Workers' Compensation

The development of the Workers' Compensation System in the United States is another topic relevant to courses in forest policy. Workers' compensation costs are a significant portion of overall labor costs (DeReamer 1980). Additionally, discussion of workers' compensation provides the opportunity to introduce students to the concepts of shared risk, of occupational injury and illness costs, and of risk management.

Workers' compensation is a system of insurance, initiated in the early 1900's, that is funded by employers to compensate workers who receive an injury or illness while working. Employer premiums are based on an experience-rating mechanism, such that employers with fewer occupational injuries and illnesses pay lower rates than employers with poor safety records (U.S. Chamber of Commerce 1984). Currently, all 50 states and the District of Columbia have workers' compensation laws. Each state administers its own law and these laws vary in terms of the employers covered, the definition of a compensable injury or illness, and the type of system (U.S. Chamber of Commerce 1984).

Several premises underlie the workers' compensation system (U.S. Chamber of Commerce 1984). First, industrial employers should assume costs of occupational disabilities without regard to any fault involved. Second, economic losses resulting from occupational disability are considered costs of production. Third, employers are relieved from lawsuits under common law involving negligence. The goal is that adherence to these principles promotes honest study of injury and illness causes rather than concealment of fault. As a result, future incidents and human suffering can be prevented. The experience-rating mechanism is intended to encourage employers' interest in safety and rehabilitation as a means of reducing costs.

Adding Workers' Compensation Cost to Machine Cost Calculation. Calculating the hourly machine cost of harvesting equipment entails a combination of time study and financial analysis, accounting for a projected production rate (e.g., cords/day), fixed costs (e.g., investment and tax costs), and variable costs (e.g., fuel and maintenance costs). Inclusion of workers' compensation premiums as a cost factor in machine cost calculations provides an appreciation for the effect of workers' compensation insurance on total operating expense. Because workers' compensation insurance in the logging industry is expensive and increasing rapidly (Lansky 1990, Longwell and Lynch 1990, Williams 1991, and Stevens and Giannetti 1992), premium costs should be considered in the financial analysis methods taught in forest economics classes.

An example of how to calculate the impact of workers' compensation on operating costs is provided on the next page. In this example, the hourly machine cost for a medium-sized cable-skidder is determined using a workers' compensation rate of $35.62 per $100.00 of payroll. Most of the calculations are based on the methodology laid out in a U.S. Department of Agriculture Forest Service pamphlet entitled, "How to Calculate Costs of Operating Logging Equipment" (Miyata date unk.). The exception is that a workers' compensation premium was added to the labor costs. All cost items have been updated to approximate realistic costs in 1994.

Example of Machine-cost Calculation for a Cable Skidder Using the Methodology of Miyata		
BASIC ASSUMPTIONS		
Purchase Cost	$90,000	
Less: Tire	-9,500	
Initial Investment (P):	$80,500	
Salvage Value (S): 20% of P	$16,100	
Economic Life (N):	3yrs	
Schedule operating hours (SH):	2,000 hrs/yr	
Utilization	65 percent	
Productive Hours (PH):	1,340 hrs/yr	
FIXED COSTS		
Depreciation (D): (P-S)/N		$21,466/hr
Interest, Insurance Taxes (ITT): ITT=16%((P - S) (3+1)/(2)(3))=9445.33		9,445/yr
Yearly Fixed Cost (YFC):D+ITT		$30,911/yr
Hourly Fixed Cost (HFC):YFC/PH		$23.07/hr
OPERATING COSTS		
Maintenance and Repair (MR): 0.5(D)/PH		$8.01/hr
Fuel (F): 4 gal./hr at $1.00/gal.		$4.00/hr
Lubricants (L): L=(((12 gal.)($4/hgal.)+138)/100 hurs) + ((50#)($1.03/#)/1340 hrs)=1.86+.04=$1.90/hr		$1.90/hr
Tire (T): T=(1+0.15)($9,500)/3,000 hrs= $3.64/hr.		$3.64/hr
Hourly Operating Cost (HOC):		$17.55/hr
Hourly Machine Cost (HMC):HFC+HOC		$40.62/hr
LABOR COSTS		
Hourly Wage		$7.00/hr
Social Security @7.57%		$ .53/hr
Workers' Compensation 35.62%		$2.49/hr
Total Labor Cost (TLC):		$10.02/hr
Hourly Machine Cost (HMCL):HMC+TLC		$50.64/hr

A comparison of the proportion of the hourly machine cost for three different levels of workers' compensation premiums are shown in Table 5. The premiums are the low, mean, and high rates for the calendar year 1989 from a survey of state workers' compensation systems (American Pulpwood Association 1990). The cost a company pays for insuring a single logger against work-related injury or illness accounted for as little as 2.4 to as much as 10.1 percent of the hourly owning and operating cost of a cable skidder. Even at the mean compensation premium rate of $35.62 per $100.00 of payroll, workers' compensation is an important cost factor.

Table 5. The Effect of Different Workers' Compensation Premiums on the Hourly Machine Cost of a Cable-Skidder.

Premium Rate ($/$100 payroll)	Hourly Machine Cost ($/hr)	Percent (%)
17.08	49.35	2.4
35.62	50.64	4.9
76.90	53.53	10.1

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FOREST MANAGEMENT PRACTICES AND THE OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION LOGGING STANDARD

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Abstract: The Occupational Safety and Health Administration (OSHA) has established safety and health regulations for the logging industry. These new regulations move beyond the prior OSHA pulpwood harvesting standard by including sawtimber harvesting operations. Because logging is a major tool used by forest managers to meet silvicultural goals, managers must be aware of what the OSHA standard would mean to them. Many aspects of the new standard pertain to the training of logging employees, safe equipment operation, and safe harvesting techniques, but there are sections of the OSHA standard that impact forest management practices, especially for hardwood forests, in much the same way as environmental regulations. There is the potential for forest management practices to influence the safety of logging operations by considering how the stand will be harvested when selecting silvicultural treatments for a stand. Forest managers will also be responsible for balancing conflicts between environmental issues and OSHA regulations, such as the removal of hazardous trees from a stand, the placement of skid trails, or where logging is initiated in a stand. These and other issues are discussed to give forest managers a better appreciation of their role in making logging a safer industry.

INTRODUCTION

Logging is one of the most flexible tools available to the forest manager to meet the silvicultural, biological diversification, economic, and recreational goals developed for a forest stand. In reviewing such classical forestry texts as "The Practice of Silviculture" (Smith 1962) and "Regional Silviculture of the United States" (Barrett 1980), the majority of the topics directly, or indirectly involve harvesting methods that can be applied to a forest stand and the expected future results that these harvesting methods will produce in the forest stand. The use of silvicultural systems and logging to promote wildlife habitats is also a common practice (Yoakum and Dasmann 1969), as well as the use of specific silvicultural treatments and logging to enhance recreational uses of forest stands (Knudson 1980). Thus, natural resource management, especially silviculture, is highly dependent on logging.

Given this close relationship between forest management and logging, forest managers must be aware of what regulations impact the logging industry. Environmental regulations and public concerns on environmental issues related to logging are now commonly included in the decisions a forest manager makes in practicing silviculture in any forest stand (Cubbage et al. 1993). A new issue, which until recently has not been a concern for forest managers in the central hardwood region, is worker safety in the logging industry. This will assume more significance with the final promulgation of the Occupational Safety and Health Administration's (OSHA) Logging Operations Standard (U.S. Department of Labor 1989).

As with any new set of regulations, forest managers will need to know and understand the OSHA logging standards and how these regulations impact upon their management decisions. Equally important, forest managers should consider and assess how their management decisions impact upon logging safety.

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THE OSHA LOGGING OPERATIONS STANDARD

Background

Logging is one of the most hazardous industries in the United States from both a fatal and nonfatal injury perspective (U.S. Department of Labor 1984, Paulozzi 1987, Leigh 1988, Myers and Fosbroke 1994). In 1989, the logging industry had a work-related fatality rate of 193 deaths per 100,000 workers (U.S. Department of Health and Human Services 1994), a rate more than 34 times higher than the total private sector fatality rate of 5.6 deaths per 100,000 workers (Jenkins et al. 1993). The greatest risk for fatal injuries in the logging industry were in those regions that were associated predominantly with hardwood sawtimber harvesting (e.g., Central Hardwood and Eastern Mixed-Hardwood regions), with fatality rates of over 300 deaths per 100,000 workers (Myers and Fosbroke 1994). In 1989, the logging industry had an estimated injury rate of 19.2 work-related injuries per 100 full-time workers compared to a general private sector rate of 8.2 work-related injuries per 100 full-time workers (U.S. Department of Labor 1991). Data suggest that these fatal and nonfatal injury rates have remained well above the national average for more than 30 years (McCormack 1963, Myers and Fosbroke 1994).

Based on these types of injury statistics, OSHA acted in 1989 to address the major occupational hazards associated with logging through a new proposed standard specific to the logging industry. Prior to this proposed rule, OSHA maintained a standard which was only applicable to pulpwood logging (U.S. Department of Labor 1988a). The 1989 proposed rule, which replaces the pulpwood standard, covers the entire logging industry, including sawtimber operations. The final OSHA logging standard was signed on October 4, 1994, with an effective date of January, 1995.

Impact On The Logging Industry

Unlike the prior pulpwood standard, the OSHA logging standard covers both pulpwood and sawtimber harvesting operations. As such, the standard impacts mostly those parts of the country which do not harvest large quantities of pulpwood and do not have existing state-specific regulations on worker safety and health for sawtimber logging operations. In general, logging operators in the eastern hardwoods, central hardwoods, and mountain regions of the United States are for the first time required to plan for and meet worker safety and health standards set by OSHA. Logging operators in the South and Lake States that harvest primarily pulpwood will see less of an impact on their operations because of their compliance with the prior OSHA pulpwood standard, while those engaged with sawtimber harvesting will be affected. Logging operators in the Pacific Northwest will see little impact because of existing state regulations that cover sawtimber harvesting. The main focus here is on the probable impacts the OSHA standard has on hardwood sawtimber operations that primarily use manual felling with log skidders as the timber harvesting method.

The OSHA logging standard contains four areas: Training; general requirements; equipment protective devices; and tree harvesting. The intent of these sections is to provide, as much as possible, performance requirements for employers to reduce the risk of work injuries. A performance requirement is one that states the objective of a rule, but allows employers broad latitude in how they meet the objective (U.S. Department of Labor 1989). Specification requirements, a rule which sets forth a specific requirement that employers must adhere to, also exist in the standard.

The new OSHA standard requires employers to be more responsive to the training of their employees for the specific tasks they are to perform, including providing them with sufficient knowledge to identify and avoid hazardous conditions on the logging site. The new standard requires employers to maintain the proper maintenance of tools and equipment used on the logging site, and requires a greater use of safety devices on such equipment as skidders and yarders to protect the operator and other workers. The standard also requires the employer to be more conscious of work assignments and work activities to prevent bystanders from being exposed to hazards related to felling trees or rolling logs on the logging site.

These general changes may require hardwood sawtimber logging operations to be modified, not only in how employers prepare their employees and equipment to do the logging job, but also in how the logging operation is laid out and conducted. Such methods as having the bucking crew and skidder crew located within the same area where trees are actively being felled is not be permitted under the OSHA standard. The location of skid trails and landings may have to be modified in such a way as to reduce the exposure of skidder operators or workers in the landing area from hazards caused by tree felling.

Impact On Forest Management

While the OSHA logging standards are the primary responsibility of the employer, forest managers need to understand these standards to reduce, as much as possible, conflicts between management objectives and logging safety requirements. The impact of the new OSHA regulations could result in changing the requirements of a hardwood logging job to the extent that forest management decisions may need to be modified to facilitate the logging of a stand in accordance with safety regulations. Being aware of the OSHA requirements before finalizing the marking and layout of a logging operation can avoid such potential conflicts.

Some aspects of the OSHA regulations that forest managers should consider are:

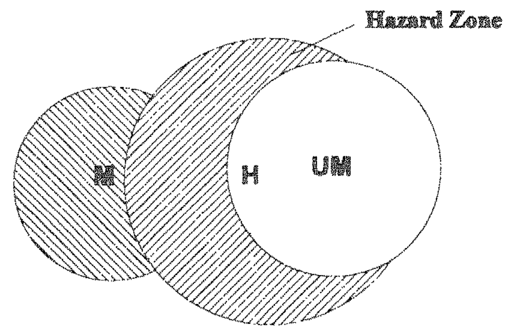
Snags. One specific provision of the standard for hazard abatement requires the identification and removal of hazardous dead, broken, or rotted trees or limbs from the area before felling marked trees. If the hazardous tree, or limb, is not removed, then it must be avoided. No work can occur in the hazard area around the hazardous tree or limb except to make the area safe. In the case of hazardous trees, since the concern by OSHA is that the tree may fall unexpectedly into a work area, the hazard zone defined by the hazardous tree would be expected to be the same as that for a tree which is being manually felled--two tree-lengths around the hazardous tree (Figure 1). Table 1 provides some examples of the acreage associated with the hazard zone from hazardous trees left in the stand.

Table 1. Acreage* for a hazard zone associated with hazardous trees in a stand of timber.

Height of Hazardous Tree (feet)	Acreage of Hazard Zone
50	0.72
60	1.04
70	1.41
80	1.85
90	2.34
100	2.88

* Acreage=$[\ \pi\ \{2\ (\text{Height of Tree in Feet})\}^2\ ]/\ 43{,}560$

Forest managers who intend to leave snags, or other poor quality trees, for the purpose of wildlife habitat should determine if the tree will pose a hazard to a feller. If so, the manager should adjust the marking of timber to ensure that the hazardous tree will not be within two tree-lengths of any marked tree, or mark the hazardous tree for removal and select an alternative, nonhazardous tree for wildlife purposes. The manager should also consider the placement of skid trails, landings, or other similar work areas to ensure they are all two tree-lengths away from the hazardous trees. Managers may also consider flagging the area around hazardous trees to ensure that loggers working in the stand are aware of the hazard.



H-Location of Hazardous Tree
M-Location of Markable Tree
UM-Location of Unmarkable Tree

Figure 1. Diagram of the OSHA "Two Tree-Length" Rule and its impact on marking trees.

Skid Trails and Roads. The requirements for road construction are not included in the OSHA logging standard because they are covered under the OSHA Construction Standard (U.S. Department of Labor 1988b). The placement of skid trails, however, are affected by the standard. The placement and construction of trails are not permitted to exceed the stability limitations of the machine.

The standards would require the forest manager to give more consideration to the placement of skid trails such that they do not involve crossing steep grades, which are common in hardwood stands. Where such grades are unavoidable, other options may need to be considered for the moving of logs, such as cutting roads to reduce the grade. At the same time, the manager would need to make decisions during the layout of the trails on whether to remove hazardous trees (which if left standing, might meet management goals for wildlife habitat) to allow for the placement of skid trails on acceptable grades, or whether to relocate skid trails in less acceptable areas to retain specific hazardous trees.

Locating trails to meet safety considerations also has the potential to conflict with trail locations that would meet environmental considerations, especially with respect to the crossing of streams, or other sensitive areas in the stand. The running of skid trails perpendicular up steep slopes, which may be feasible without exceeding the stability limitations of a skidder, is a limited option due to current environmental regulations that, in many instances, restrict or ban such trail locations because of the environmental concerns. Thus, the objective of reducing as much as possible the running of skidders on steep slopes is a recommended practice from both a safety and environmental standpoint. However, the use of the most level terrain for the placement of skid trails from a safety perspective, may conflict with buffer zone locations, or require the crossing of streams that would be unacceptable from an environmental perspective.

Location of Landings or Yards. One provision of the OSHA standard is the requirement that work ongoing in a stand be spaced such that fellers actively felling trees be at least two tree-lengths away from other logging activities such as bucking, limbing, skidding, yarding, or landing activities. This requirement, while not necessarily impacting the placement of landings and yards, would require the recognition of where the landings and yards are located with respect to ongoing felling activities. The forest manager must decide during the marking of the stand on whether to refrain from marking any tree within two tree-lengths of the proposed landing or yard, or whether to mark timber in this area knowing that no landing or yarding activities would be permitted while those trees are felled. The location of hazardous trees within two tree-lengths of the landing or yarding area must also be resolved, as stated previously.

Sequence of Harvesting. The OSHA standard requires that harvesting of the stand be conducted such that the manual felling be conducted up-slope of, or on the same level as, previously felled trees (Figure 2). The standard would, from a practical standpoint, encourage the logging operation to proceed from the bottom of the slope to the top of the slope. In many instances, skid trails would need to be constructed prior to initiating logging, especially if the landing areas and access roads for the logging job are located at the top of the slope. If the access roads are located at the bottom of the slope, skid trails would require constant maintenance to remove slash because the skid trails would go through previously timbered areas. Concerns for soil erosion and run-off from the logging site also need to be considered. This may require planning for the placement and maintenance of water bars, or other soil stabilization techniques, during the logging operation rather than at the end of the operation to reduce erosion. Initiating logging at the top of the slope and using the lower slope as a buffer zone during the logging operation is still feasible, but would require logging to be conducted laterally, and would not allow for felling trees up-slope into previously logged areas.

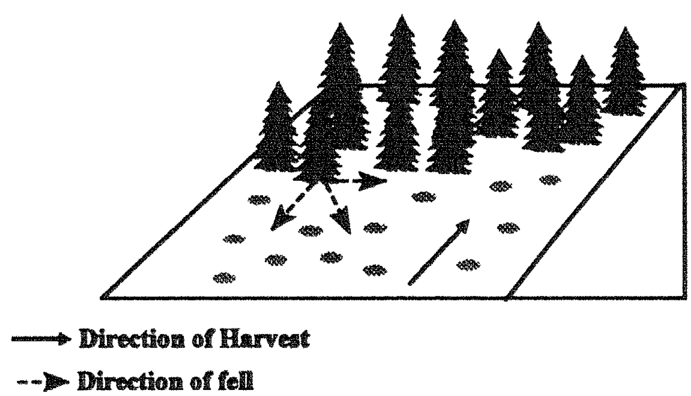


Figure 2. OSHA requirement for felling trees on sloped terrain.

The issues presented here are not all-inclusive of the potential impact the OSHA logging standard may have on a forest manager. They reflect the more obvious issues forest managers dealing with hardwood stands will need to consider when planning a harvest.

The forest manager should also consider that more time may need to be allotted to complete some logging jobs. Time requirements will be affected by such factors as: The type of harvest proposed for the stand; the temporary suspension of work due to felling occurring within two tree-lengths of other activities; the requirement that fellers not be located within two tree-lengths of each other while felling trees; the required suspension of logging operations due to hazardous weather; the suspension of work in an area until a hazardous tree, or other hazardous condition has been removed; the requirement that hung-up trees be removed by the use of skidders, or other similar mechanical system that isolates the worker from the hung-up tree; and the requirement that trees felled on slopes be blocked prior to limbing or bucking if they cannot be limbed and bucked from the up-hill side of the tree. Failure by the forest manager to consider these new work requirements for the logging crew when determining the amount of time needed to safely log a stand of timber could result in poor time estimates. Taking such factors into account will prevent unnecessary conflicts with the logging operator over how quickly the logging job is being conducted.

The new OSHA standard may also create a new level of responsibility for the forest manager. With the adoption of the logging standard by OSHA, the standard has become a common industry practice and establishes a standard of care for third party, non-direct employers (Smith 1991). The forest manager may not cause a logging operator to knowingly violate the OSHA standard, which could be a consequence of the manner in which the forest manager marks the timber and lays out skid trails, landings, and other aspects of the harvest. If a forest manager knowingly sets forth requirements in violation of the OSHA standard, the forest manager may be found to be a liable party under third-party tort law for any injury, fatality, or property loss that is incurred by the logging operator, or worker, because of that requirement. Furthermore, OSHA is considering a requirement in construction that would place responsibility upon primary contractors for maintaining injury and illness records for all employees working on a work site, including subcontractors (Newell 1994). This precedent of making primary contractors accountable for injuries of subcontract employees could extend to other industries, including logging. Thus, while not directly responsible for ensuring that a logging operation is conducted in compliance with the OSHA logging standard, forest managers are indirectly responsible because they are the individuals planning and stating the conditions under which the logging operations will be conducted.

FOREST MANAGER'S IMPACT ON LOGGING SAFETY

Compliance with the OSHA logging standard will be the primary responsibility of the logging operator. However, this does not mean that forest managers do not have a professional or moral obligation to consider the safety of workers performing logging in a stand for which the forest manager is responsible. The Society of American Foresters' code of ethics makes it clear that forest managers are to perform their work with the utmost honesty, integrity, and professionalism (Society of American Foresters 1992). Forest managers have traditionally applied these professional standards to the land owner, or other employer of their services. Clearly, the forest manager has a professional obligation to the land owner, or other employer, to ensure that all logging operations performed on their land meet existing regional, state, or federal laws, including those related to safety. Furthermore, forest managers should apply these same professional standards to all constituencies they interact with. Logging operators are clearly a constituent of the forest manager--one that forest managers need if they are to meet most, if not all the goals outlined to them by a land owner, or other employer. Therefore, the forest manager has a clear professional obligation to assist the logging operator in making any logging operation as safe as possible whether one views this from the professional obligation to the owner of the timber, or from the professional obligation to society in general.

There are several ways that the forest manager can become involved in promoting the safety of workers logging a stand under the forest manager's care. The single most effective means would be through the contract for the logging job. It is common practice to include conditions in logging contracts for environmental requirements in the logging operation (e.g., placement of water bars, culverts, seeding skid trails). The incorporation of safety into the contract can be simply done by including a provision that the operator will perform the logging operation in compliance with the OSHA logging standard. Provisions for fines, or halting work on the site for violations of this provision, would be handled in the same manner as with environmental requirements. The forest manager will need to have a sound working knowledge of the OSHA standard, but this is no different than the need of the forest manager to have similar working knowledge of environmental or other regulations that are part of conducting a timber harvest.

The forest manager can also influence the safety of the logging operation beyond the provisions of the OSHA standard. Decisions on what types of silvicultural treatment will be used in a particular stand can greatly influence the types of hazards the logging workers will face when harvesting the timber. Many of the hazards faced by loggers are associated with felled trees striking other standing timber, which can result in the felled tree becoming hung up, breaking a top, or changing its direction while falling (Peters, 1991). The use of silvicultural treatments that will minimize the likelihood of felled trees striking standing trees would reduce worker risk.

Where the use of potentially lower-risk silvicultural treatments is not possible, the forest manger can still reduce the risk to the logging worker through the layout of the logging operation and through the marking of the timber to be harvested. The issues of the placement of landings, skid trails, and roads has been previously mentioned. The marking of timber around hazardous trees has also been noted, but there is more the forest manager can do, especially in marking the stand.

The felling of a tree is the greatest hazard in logging (Peters 1991, Myers and Fosbroke 1994). The forest manager should be aware of this and attempt to visualize how each marked tree will be felled by a logger, noting possible hazards the logger will face in the process (e.g., high likelihood of the marked tree becoming hung up in an adjacent tree, limited options for the placement of an escape path for the feller). A system for assessing the likelihood of hanging a felled tree into a standing tree, and other related hazards, has been proposed by Peters et al. (1993), and may be adaptable for use by forest managers for field use. If the hazard can be reduced by removing another tree in the felling area, the forest manager may consider marking that tree along with the original tree marked for removal. If there is no obvious way to reduce the hazard to the logger, the forest manager should consider marking an alternative tree which poses less risk.

The forest manager should also consider leaving den trees that are sound and pose little or no hazard to the logger. As many hazardous trees as possible should be removed in the stand, leaving only those that are needed to meet specific management goals. While this may require leaving merchantable trees for wildlife purposes, it does give the forest manger more flexibility in marking the stand by not losing large areas of the stand due to the OSHA hazard zone requirement for hazardous trees.

The use of directional felling when logging the stand is another requirement the forest manager may consider. This will encourage the proper use of undercuts and backcuts when felling a tree, improve the likelihood that hazards identified by the forest manager when marking the stand are noted by the feller when dropping the tree, and allow for safer limbing, bucking, and skidding of the felled timber because trees would be felled in a logical, rather than a random direction. The use of directional felling also has the benefit of reducing the damage to the residual standing timber, improving the long-term timber value of the stand (Simmons 1979).

While forest managers cannot ensure that all aspects of a logging operation are conducted in a safe manner, the more emphasis they place on worker safety in those aspects of the logging operation where they are involved, the more likely the logging operator is to log the stand in a safe manner. Taking such a position on logging safety is no different than the forest manager's role in actively enforcing environmental requirements, or placing penalties on a logger who harvests non-marked trees. By setting the goal of having all logging operations they oversee being done safely, forest managers can have an impact, an impact which they should actively pursue as part of their professional work ethic.

THE FUTURE

With the establishment of the OSHA logging standard, logging safety is an area that many forest managers managing hardwood forests will be asked to incorporate into their management decisions for the first time. This will require forest managers to not only understand what parts of the OSHA standard will affect their management decisions for a stand of timber, but also place an ethical obligation on them to see that they do all in their power to ensure that a logging operation is conducted in a safe manner. This will require forest managers to view their decisions in a new light, similar to their taking new views on management decisions based on environmental regulations and constraints. To do this job well, forest managers must have a better understanding of the basic concepts of logging safety and how to apply these concepts in a stand of timber. Education on safety concepts will be a part of this, not only for forest managers presently working in the field, but as part of the formal educational system for the forest managers of the future. The more forest managers understand safety issues, the better they will be able to incorporate these issues into their everyday work.

The need to balance safety issues with other factors such as environmental regulations, economic goals, bio-diversity goals, or the many other constraints a forest manager must consider, is unavoidable. Forest managers cannot ignore the OSHA standard any more than they can ignore environmental regulations. This will necessitate compromise and ingenuity on the part of the forest manager. Still, in most instances, solutions do exist and it will be the forest manager who will need to find these solutions.

In many instances, the concepts of forest management and forest harvesting have not worked closely together. The forest manager makes the decisions on what is to be harvested with little concern on how the harvesting is done. New harvesting methods are only viewed as an improvement to an existing silvicultural tool. This "removed" attitude toward harvesting systems ignores how important a tool harvesting is to forest management. As with any tool, the forest manager can only use it effectively if he completely understands it. Forest managers need to know how harvesting systems work, how economical harvesting will be in any given stand of timber, and not remove themselves from the role of making harvesting systems better. Forest managers also need to become more involved in the development of safer harvesting systems (National Research Council 1990). By tying together the goals of forest management with the goals of developing safer harvesting systems, the forest manager gains additional flexibility in balancing logging safety with all the other issues that must be considered in managing a forest. Research into the development of management-harvesting models could provide many solutions, not only for logging safety issues, but for environmental and other concerns as well (National Research Council 1990). Without this interaction between forest management and forest harvesting, the forest manager will always be asked to adapt to, rather than influence, harvesting technology--asked to adapt to a tool, rather than shape the tool for the intended purpose.

SUMMARY

The new OSHA logging standard will have an impact on the forest manager managing hardwood stands. Areas for which the forest manager will see the greatest impacts are the marking of stands, the placement of roads and skid trails, the location and development of landings or yards, and possibly the sequence in which the stand is logged. The forest manager can also play a major role in decreasing the hazards in logging timber through taking a professional interest in logging safety. Of the many influences that the forest manger can effect, the greatest safety influences can be effected in the logging contract, and in how the stand is marked for harvesting. Finally, the forest manager should take a more active role in the development of new harvesting technology, especially since it is the forest manager who is a major end user of these new harvesting techniques.

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HARDWOOD SILVICULTURE AND SKYLINE YARDING ON STEEP SLOPES:

ECONOMIC AND ENVIRONMENTAL IMPACTS

John E. Baumgras[1] and Chris B. LeDoux[2]

Abstract: Ameliorating the visual and environmental impact associated with harvesting hardwoods on steep slopes will require the efficient use of skyline yarding along with silvicultural alternatives to clearcutting. In evaluating the effects of these alternatives on harvesting revenue, results of field studies and computer simulations were used to estimate costs and revenue for skyline yarding operations. The methods evaluated include group selection and three treatments each for conventional shelterwood, thinning, diameter limit, and irregular shelterwood to initiate two-age management. Harvesting costs ranged from \$15.97 to \$42.22/100 ft^3, gross revenue from \$59 to \$131/100 ft^3, and net revenue from \$58 to \$2,809/acre. Environmental impacts observed at field sites and those reported in the literature indicate that relatively low levels of soil disturbance and residual stand damage can be achieved with skyline yarding.

INTRODUCTION

Public concern about the clearcutting of eastern hardwoods, combined with contemporary forest management issues such as ecosystem management have encouraged forest-land managers to consider alternative silvicultural practices and harvesting systems. Alternatives for even-age management include shelterwood and group selection, while irregular shelterwood (deferment) cuts can be used to initiate two-age management. In sawtimber stands, thinning can yield the volumes of sawlogs required for commercial operations. While often criticized, diameter-limit cuts are perhaps the most popular option on private forestland.

The adverse visual impact of large clearcuts has been a major source of public concern. Forested landscapes are affected by the size of clearcut units and the percentage of the viewing area that has been harvested (Palmer and others 1993). Interior views of harvested stands were evaluated for six silvicultural methods ranging from clearcutting to single-tree selection. Scenic beauty increased with residual basal area and years elapsed since harvesting, and decreased with amounts of logging slash (Pings and Hollenhorst 1993). Modifying the size and spatial relationships of harvest units and/or using silvicultural practices other than clearcutting can ease public concerns about timber harvesting.

The growing emphasis on maintaining the productivity and sustainability of forested ecosystems makes protection of soil and water resources an increasingly important issue. Efforts to reduce environmental impacts are primarly responsible for the reintroduction of cable yarding to the eastern hardwood region (Patrick 1980). Using a skyline yarder versus rubber-tired skidders can greatly reduce the need for truck roads and skid trails. (Kochenderfer and Wendel 1978) and significantly reduce the amount of bare or compacted soil within harvest units (Swanston and Dyrness 1973).

Until recently, commercial application of skyline yarding in the Appalachian hardwood region was confined largely to relatively large clearcut units. However, case studies in Pennsylvania (Fairweather 1991) and West Virginia (Wendel and Kochenderfer 1978) indicate that light to moderate residual stand damage is possible with cable yarding in partial cuts of hardwood stands on steep slopes.

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To reduce the environmental and visual impacts of harvesting timber on steep slopes in the Appalachian hardwood region, unconventional applications of cable yarding technology will be required to implement the silvicultural practices that the public now demands. Although harvesting revenue is not the sole consideration in forest management decisions, commercial timber sales are needed to meet goals related to ecosystems management objectives on public lands. And because cash flows remain critical to harvesting decisions on private lands, harvesting economics is an important consideration in selecting harvesting systems and silvicultural practices for steep-slope hardwood sites.

METHODS

Computer simulation was used in a sensitivity analysis of harvesting costs and revenues for 13 silvicultural treatments. Simulation allowed standardized production assumptions to be applied to all treatments and provided estimates of cost and revenue for hypothetical treatments.

The information required to simulate specific harvesting operations was obtained through field studies of skyline yarding operations. A conventional shelterwood harvest, an irregular shelterwood harvest (deferment cut), and a thinning were monitored at a study site on the Nantahala National Forest near Franklin, North Carolina. The three 6- to 8-acre units were located in a yellow-poplar, red oak, and white oak stand, with a site index of 80 (50-year basis for northern red oak) on slopes of 30 to 50 percent. All units were yarded with an inexpensive shop-built yarder rigged with a 30-foot tower and a gravity outhaul carriage. Also studied was the use of a commercial skyline yarder in four group-selection units at a site on the Pisgah National Forest near Asheville, North Carolina (LeDoux and others 1991). Loggers at both study sites harvested pulpwood and sawlogs from trees 8 inches and larger in dbh. Cycle-time equations were developed and additional data obtained on yarding delay times and causes and times to rig skylines and change landings. We also developed stand tables for both the initial and cut stands.

Because of important differences between study sites and among harvesting units at each site with respect to equipment, unit dimensions, crew size, and delay times unrelated to silvicultural treatments, observed production rates and costs were not directly comparable. As a result, comparison of yarding production and costs for silvicultural alternatives was standardized using simulation models calibrated on observed production rates (using cycle-time equations) and delay times obtained from field data.

Silvicultural Treatments

The 13 treatments evaluated include the three treatments observed at the Franklin site: conventional shelterwood (stand 1), irregular shelterwood (stand 2), and thinning (stand 3). The initial attributes of these stands were similar (Table 1). The scope of the sensitivity analysis was broadened to include treatments that were not observed at the Franklin site but could be implemented to satisfy alternative ownership or ecosystem management objectives. These hypothetical treatments were developed using initial stand tables from the Franklin site and modifying the cut-stand tables from the observed treatments.

The conventional shelterwood harvest observed at the Franklin site removed approximately 70 percent of the initial basal area of trees 7.5 inches and larger in dbh. Alternatives that removed approximately 30 and 50 percent of initial basal area from the smaller diameter classes represent treatments required to obtain oak regeneration on medium to good sites (Schlesinger and others 1993). For the three conventional shelterwood treatments, the mean dbh of harvested trees ranged from 11.9 to 17.1 inches (Table 2).

The irregular shelterwood or deferment cut was applied to initiate two-age management. The observed harvest of stand 2 (Table 1) removed all but 20 ft^2/acre of basal area, leaving mostly trees that were 8 to 18 inches in dbh. Two variations of the observed treatment were developed by modifying the diameter distribution of the residual basal area, leaving trees 12 to 22 and 20 to 30 inches in dbh, respectively (Table 2). For these three treatments, the mean dbh of trees harvested ranged from 15.3 to 17.1 inches. The different treatments could affect the visual quality of the residual stand, or reflect the scheduled harvest of residual trees. If the residual stand were to remain until the next crop matures, residual trees would be smaller than trees left to be harvested in the next 20 to 40 years.

Table 1.--Initial attributes of timber stands at the Franklin study site

Stand	No. trees/ per acre[a]	Basal area[a]	Mean dbh	Merchantable volume[b]
		ft^2/acre	inches	ft^3/acre
1	76	117	16.8	3,669
2	77	111	16.3	3,378
3	73	119	17.2	3,773

[a]Trees ≥ 7.5 inches in dbh.
[b]Volume of wood and bark to merchantable top ≥ 4.0 inches diameter (inside bark).

Equal amounts of basal area also were removed in all three thinnings. The observed thinning (essentially a thinning from above) removed 47 ft^2/acre of basal area in trees with an average dbh of 17.8 inches (Table 2). Modifying the diameter distribution of trees removed from stand 3 (Table 1) produced thinnings with cut trees averaging 13.7 and 15.1 inches in dbh (Table 2). These two alternatives would concentrate growth on the largest trees and help create an "old growth" or park-like appearance. Thinning trees with a mean dbh of 13.7 inches also produced a cut stand similar to that resulting from thinning in younger sawtimber stands.

Two types of silvicultural treatments not observed at the Franklin site--group-selection and diameter-limit harvests--also were evaluated using the initial stand tables for stands 1, 2, and 3. Because results were similar, only those from stand 1 are presented. The diameter-limit cuts were evaluated with dbh limits of 12, 15, and 18 inches. The group selection harvested all trees 7.5 inches and larger in dbh. Management alternatives for applying group selection include the size of openings created and the spatial relationships between units. For this analysis, openings of 0.23, 0.92, and 2.75 acres were evaluated; the 0.23- and 0.92-acre openings were located at varying distances from the yarder landing.

Economic Analysis

Production rates for cable yarding were estimated with THIN, a computer simulation model (LeDoux and Butler 1981). The simulations applied the yarder cycle-time equation developed for the shop-built yarder observed at the Franklin site, as well as delay times that included a standardized component for all silvicultural treatments and a delay component unique to each treatment. The yarding corridor was standardized at 150 ft by 800 feet (2.75 acres). In addition, group-selection cuts also were simulated for openings of 100 by 100 feet and 200 by 200 feet. These openings were located 100 to 700 feet from the yarder landing. The times to move the yarder to a landing and to change corridors at each landing were standardized using the average of times recorded on all units at the Franklin site. The log populations required for each THIN simulation were obtained from cut-stand tables unique to each treatment; it was assumed that stems were bucked to a maximum log length of 32 feet as observed at the Franklin site.

Felling and limbing production rates, log populations for the THIN simulations, and yields of roundwood products were estimated with GB-SIM, a harvesting simulation model developed for ground-based harvesting systems (Baumgras and others 1993). Because felling and limbing generally are completed before yarding begins, felling and yarding production can be simulated independently. Inputs to these simulations include the cut-stand tables specified for each silvicultural treatment. GB-SIM uses tree-taper equations developed for Appalachian hardwoods to estimate log lengths and volumes. Equations for estimating percentages of trees by tree grades, and sawlog volumes by log grade also are used by GB-SIM to estimate sawlog yields by species and grade.

Table 2.--Attributes of cut stands resulting from conventional shelterwood, group selection, and diameter limit applied to stand 1, irregular shelterwood applied to stand 2, and thinnings applied to stand 3.

Treatment	No. trees per acre	Basal area	Mean dbh	Volume per acre	Average volume per tree
		ft^2/ac.	inches	---------ft^3----------	
Conventional Shelterwood[a]					
Cut 70%	50	80	17.1	2,519	50.4
Cut 50%	44	53	14.9	1,614	36.7
Cut 30%	36	28	11.9	817	22.7
Irregular Shelterwood[b]					
Lv. trees 8-18 inches	58	91	17.1	2,852	49.2
Lv. trees 12-22 inches	63	91	16.3	2,728	44.0
Lv. trees 20-30 inches	71	91	15.3	2,711	39.3
Thinning[c]					
17.8 inches $\bar{X}$ dbh	27	47	17.8	1,556	57.6
15.1 inches $\bar{X}$ dbh	38	47	15.1	1,493	41.5
13.7 inches $\bar{X}$ dbh	46	47	13.7	1,327	32.3
Group Selection[d]	76	117	16.8	3,669	48.3
Diameter Limit[e]					
12 inches dbh	52	99	18.6	3,311	63.7
15 inches dbh	38	86	20.2	2,911	76.6
18 inches dbh	25	67	22.2	2,299	91.9

[a]Percentage of initial basal area.
[b]Dbh of residual trees.
[c]Mean dbh of cut trees.
[d]Volume/acre from groups harvested, not entire stand.
[e]Minimum tree dbh harvested.

Production rates for log bucking and loading estimated from results of production studies (Baumgras and LeDoux 1989) indicate that these rates would greatly exceed simulated yarder production for all treatments. Since bucking and loading production would be constrained by yarding production, fixed costs and wages for yarding, bucking, and loading were allocated to production at the rate estimated for yarding. Felling and limbing costs were based on production rates simulated for these functions. Rates for wages and equipment costs were obtained from USDA Forest Service appraisal guides and published rates for chain saws, loaders, and trucking. All rates were inflated to 1994 levels using the Producer Price Index for all commodities.

Estimated logging costs represent the sum of felling, limbing, yarding, bucking, and loading costs. Net revenue represents the gross value of roundwood products delivered to the mill minus logging and hauling costs. Delivered prices for sawlogs and pulpwood represent median prices obtained from published price reports (Pa. State Univ. 1990-93; Tenn. Div. For. 1990-93) (Table 3). The estimates of haul cost assume a 40-mile haul distance.

Table 3.--Roundwood product prices applied to economic analysis

	Sawlogs[a]			
Species	Grade 1	Grade 2	Grade 3	Pulpwood[b]
		Dollars/mbf		Dollars/100 ft^3
White oak	325	185	100	45
Red oak	485	285	125	45
Yellow-poplar	175	125	85	45
Other hardwoods	190	140	85	45

[a]Factory grade sawlogs, USDA Forest Service grades 3 or better, scaling diameter ≥ 10 inches.
[b]Roundwood with diameter inside bark ≥ 4 inches, not meeting the quality or dimension requirements for sawlogs.

Environmental Impacts

Environmental impacts were monitored on the shelterwood and thinning units harvested at the Franklin site. Soil disturbance was surveyed by sampling disturbance classes (Dyrness 1965) at 5-foot intervals along 50-foot random azimuth transects. Residual stand damage was sampled by recording damage to trees located on 1/10-acre plots after felling, and again after yarding. To assess visual quality before and after harvesting, oblique aerial photographs were taken of each harvest unit.

RESULTS

Stand Attributes

Because the three initial stands in Table 1 are similar and 7 of the 13 treatments evaluated were applied to stand 1, differences between stands harvested were largely a function of the silvicultural treatments. For the diverse array of treatments estimates of volume harvested ranged from 817 ft^3/acre for the 30-percent shelterwood harvest to 3,669 ft^3/acre for the group selection (Table 2). Average volume per tree harvested ranged from 22.7 ft^3 for the 30 percent shelterwood to 91.9 ft^3 for the 18-inch diameter-limit cut.

Differences among the three treatment levels evaluated for each of four silvicultural methods were most pronounced for the conventional shelterwood cuts: volume harvested ranged from 817 to 2,519 ft^3/acre, and average volume per tree ranged from 22.7 to 50.4 ft^3 (Table 2). The three diameter-limits also had a large impact on attributes of the cut stand. Increasing the diameter limit from 12 to 18 inches dbh reduced the volume harvested by 30 percent, but increased average tree volume by 44 percent. The three irregular shelterwood cuts showed the least amount of variation. With only 20 ft^2/acre of basal area, the diameter distribution of the residual trees had minimal impact on volume harvested (2,711 to 2,852 ft^3/acre) and average volume per tree (39.3 to 49.2 ft^3).

Cost and Revenue

The results in Table 2 show how the selection and application of silvicultural methods can affect critical attributes of the harvested stand component. These attributes, especially volume per acre and volume per tree, are closely correlated with harvesting system production and costs, and with product yields and revenue.

The sensitivity of cost and revenue to silvicultural treatments is most evident from estimates of net revenue that range from \$58 to \$2,809/acre (Table 4). The 12-inch diameter-limit, group-selection, and 15-inch diameter-limit cuts produced the largest estimates of net revenue, \$2,809/acre, \$2,789/acre, and \$2,712/acre, respectively. The two lowest estimates resulted from the 30-percent removal shelterwood (\$58/acre), and the thinning of trees averaging 13.7 inches dbh (\$382/acre).

The heavy stocking of large trees and the substantial component of high-value oaks contributed to relatively low harvesting costs and high revenue per unit of volume. Given the assumptions of the analysis, estimated revenue generally exceeded costs by such a wide margin that the economic feasibility of 11 of 13 options tested was not a critical issue. Four of the 5 silvicultural methods and 7 of the 13 specific treatments yielded more than \$2,000/acre.

The key attributes of logging-machine production cycles form the link between harvesting conditions and harvesting-system production. Although machine cycle times generally increase with average tree volume and/or numbers of trees per cycle, the relative gains in volume exceed the increases in cycle times. Consequently, production rates generally increase with trees/acre, volume/acre, and volume/tree. These relationships are modeled by the THIN and GB-SIM programs.

The lowest harvesting costs are associated with the highest volumes per acre. In the case of the three conventional shelterwood cuts, reducing volume per acre from 2,519 to 817 ft^3 and average volume per tree from 50.4 ft^3 to 22.7 ft^3 (Table 2) more than doubled harvesting costs (Table 4). When only the diameter distribution of basal area removed in thinning was altered, the changes in volume/acre and volume/tree caused logging cost to increase by 46 percent, from \$21.50 to \$31.45/100 ft^3.

Another important element in the net revenue equation is the value per unit of production, represented by gross revenue in Table 4. Because larger diameter trees generally yield higher proportions of merchantable volume in grade 1 or 2 sawlogs, gross revenue is highly correlated with the mean dbh or average volume of trees harvested. Although the tree and log-grade estimates incorporated in this analysis are not completely site specific, they represent observed stand attributes and well-documented relationships among tree species, dbh, and sawlog quality. Estimated gross revenue ranged from \$59 to \$131/100 ft^3 (Table 4), reflecting the estimated grade distribution of sawlogs and the proportions of sawlog and pulpwood volume. The percentage of sawlog volume in grade 1 logs ranged from 10 to 38. The percentage of merchantable volume in pulpwood ranged from 13 to 59.

Estimates of cost and revenue for the group-selection cut (Table 4) represent a 150- by 800-foot (2.75-acre) opening adjacent to the landing. Because the cost of changing landings or rigging the skyline to yard each unit is largely independent of unit area, smaller units result in higher costs per unit volume for moving the yarder and changing corridors. Depending on the location of the unit (100 to 700 feet from the landing), yarding a 100- by 100-foot (0.23-acre) unit increased costs by \$14 to \$22/100 ft^3 over those for the 2.75-acre unit. In this comparison, net

Table 4.--Simulated yarding production, estimated logging costs, gross revenue, and net revenue

Treatment	Yarder production[a]	Logging cost[b]	Gross revenue[c]	Net revenue[d]
	ft^3/hr.	Dollars/100 ft^3		Dollars/acre
Conventional Shelterwood				
Cut 70%	416	20.55	113	2,069
Cut 50%	336	25.48	98	1,004
Cut 30%	193	42.22	59	58
Irregular Shelterwood				
Lv. trees 8-18 inches	465	19.01	116	2,481
Lv. trees 12-22 inches	400	21.14	114	2,245
Lv. trees 20-30 inches	347	23.37	99	1,788
Thinning				
17.8 inches $\bar{X}$ dbh	426	21.50	124	1,441
15.1 inches $\bar{X}$ dbh	332	25.72	98	927
13.7 inches $\bar{X}$ dbh	257	31.45	70	382
Group Selection	454	18.77	105	2,789
Diameter Limit				
12 inches dbh	504	16.84	111	2,809
15 inches dbh	555	16.41	120	2,712
18 inches dbh	608	15.97	131	2,407

[a]Delay-free production rate.
[b]Total cost to fell, limb, yard, buck, and load.
[c]Average value of sawlogs and pulpwood delivered to mill.
[d]Gross revenue - logging cost - haul cost x volume/acre.

revenue is reduced by $513 to $789/acre. Compared to the 2.75-acre unit, a 200- by 200-foot (0.92-acre) unit located 300 to 600 feet from the landing increased costs by $5 to $8/100 ft^3 and reduced estimated net revenue by $163 to $174/acre. These comparisons do not include the additional cost of locating harvest units, planning yarding corridors, or locating the landings required to harvest numerous small units scattered throughout a larger harvest area. Also, the estimates of net revenue reported for group-selection cuts represent dollars from each acre actually harvested. Because the entire stand would not be harvested with each entry, net revenue per acre for the entire stand would be much lower than net revenue per acre harvested. For example, given a 20-year cutting cycle and a 100-year rotation such that 20 percent of the stand is cut each entry, net revenue per entry for the entire stand would be 20 percent of that estimated for each acre actually harvested.

The values in Table 4 for the group-selection cut represent harvesting the entire 2.75 acre-corridor. With respect to estimated costs and revenue per acre harvested, this is equivalent to a conventional clearcut. Expressing net revenue as a percentage of that estimated for this group selection cut illustrates the relative impacts of silvicultural alternatives to large-opening group selections or clearcuts (Fig. 1). Five of the 12 alternatives evaluated yield more than 80 percent of the revenue available from clearcutting. However, four alternatives yield less than half of the net revenue available from clearcutting, two less than 15 percent, and one only 2 percent.

Environmental Impacts

Analysis of data on soil disturbance at the Franklin site revealed no difference between the observed shelterwood and thinning treatments with respect to percentage of area in each soil-disturbance class. Deep soil disturbance and deep disturbance combined with visible soil compaction was found on 10 percent of the area. Most of this occurred within the yarding corridors, the extraction path between the tailhold and the yarder. Seventy-one percent of the area showed no disturbance.

The results of the stand damage surveys indicate that logging damage was significantly greater on the two shelterwood units than on the thinning unit. Sixteen percent of the residual trees were destroyed on the conventional and irregular shelterwood units compared to only 5 percent on the thinning unit. On the two shelterwood units, 13 percent of the trees received bark wounds larger than 100 square inches, versus only 1 percent on the thinning unit. Other damage, small bark wounds and abrasions and broken limbs, affected 51 percent of trees on the shelterwood units versus 36 percent on the thinning units.

Trees destroyed were uprooted or broken off, generally during felling operations. Most of the large bark wounds occurred during yarding operations, with frequency increasing with proximity to yarding corridors. Much of the difference between damage on the shelterwood and thinning units can be attributed to the heavier removals on the shelterwood units (Table 2). It is important to note that trees on the thinning unit were felled by an experienced crew while the felling crew on the two shelterwood units included relatively inexperienced chain-saw operators.

From the oblique aerial photos of the three harvested units at the Franklin site it is difficult to distinguish the thinning unit from the adjacent uncut area. The observed conventional shelterwood cut and the irregular shelterwood cut were visible on the photos, though there was much less contrast between the cut and adjacent uncut areas than would be apparent with a clearcut.

DISCUSSION

Each of the 13 silvicultural treatments evaluated represent different forest management objectives or desired future conditions. Consequently, the estimated cash flows are not intended for ranking or selecting treatments. Nonetheless, efficient management requires an understanding of the relationships between silvicultural prescriptions and harvesting revenue. Whether timber sales represent an important source of revenue or a means of managing vegetation, costs and revenue from harvesting operations play an important role in forest operations.

Results of the cash-flow analysis demonstrate the sensitivity of cost and revenue to silvicultural treatments: logging costs ranged from \$15.97 to \$42.22/100 ft^3, gross revenues from \$59 to \$131/100 ft^3, and net revenues from \$58 to \$2,809/acre. Due to the composition of the initial stands, the group-selection, diameter-limit, and heavy shelterwood cuts all yielded large cash flows. However, treatments requiring significant reductions in harvested volume per acre and/or volume per tree resulted in large reductions in estimated net revenue--as much as \$2,011/acre for the conventional shelterwood cuts and \$1,059/acre for thinnings. There also were significant variations in net revenue resulting from location and dimensions of the group-selection units. The estimates of harvesting cost and net revenue reflect the relatively low cost of a shop-built yarder, which is commonly used in southern Appalachia.

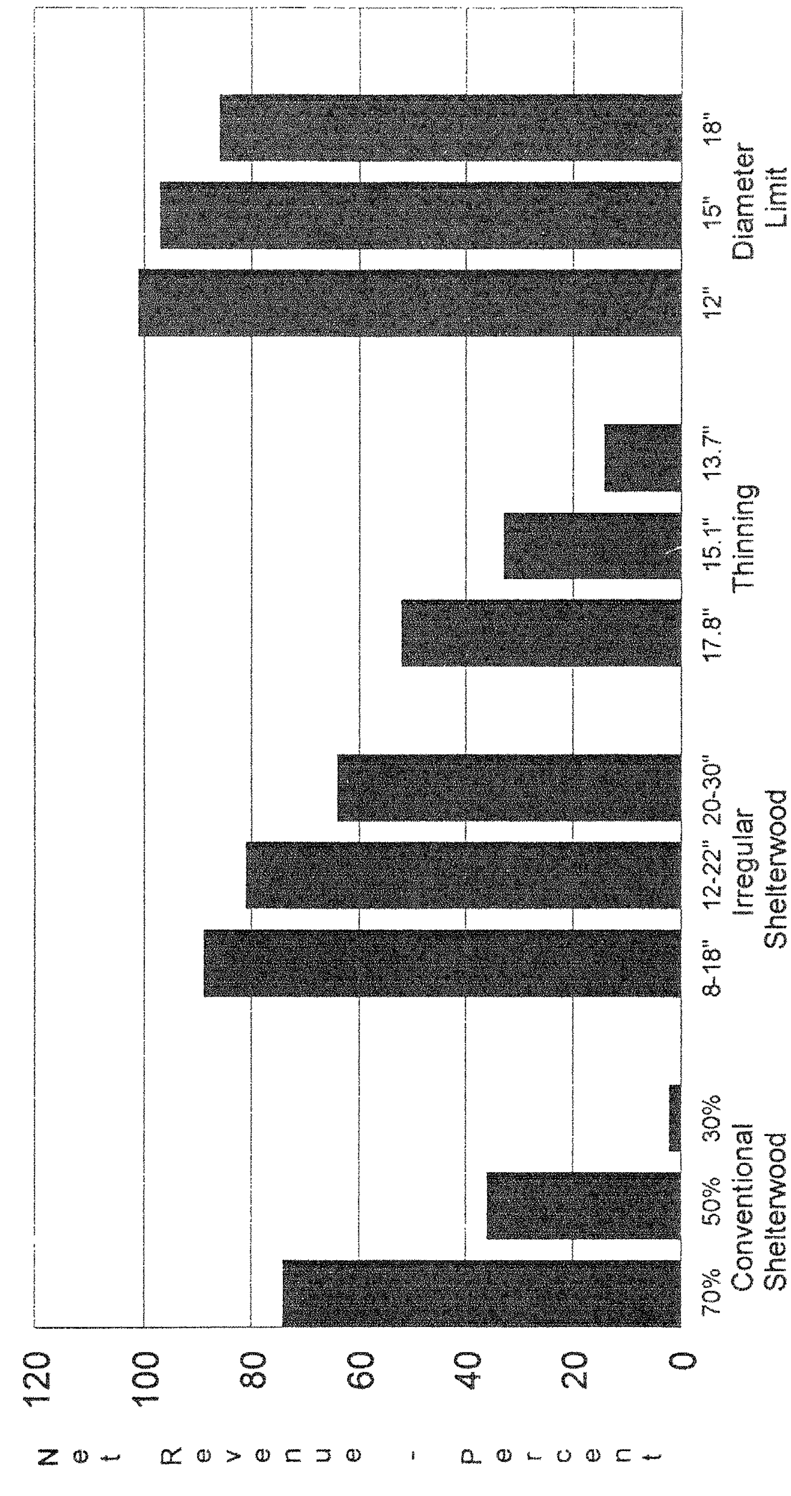

Figure 1. Percentage of net revenue available from the 2.75-acre group-selection cut; for conventional shelterwood removing 30, 50, and 70 percent of basal area; irreguar shelterwood leaving trees 8 to 18, 12 to 22, and 20 to 30 inches dbh; thinning removing trees averaging 17.8, 15.1, and 13.7 inches dbh; and diameter-limit cuts to 12, 15, and 18 inches dbh..

Compared to conventional ground-based harvesting systems operating in large clearcut units, the harvesting system and silvicultural treatments evaluated in this study provide an opportunity for significant reductions in environmental impacts associated with harvesting timber on steep slopes. Levels of soil disturbance and compaction sampled on observed shelterwood and thinning units were similar to those reported for western skyline operations (Swanston and Dryness 1973), less than those reported for ground-based systems (Hatchell and others 1970), and considerably less than those reported for mechanized whole-tree harvesting systems (Martin 1988). Observations at the Franklin site also indicated that soil disturbance on specific yarding corridors could have been reduced further by rigging the skyline for more lift and bucking large stems to lighten payloads. Effective application of cable yarding requires expert sale layout skills to locate yarder landings and yarding corridors that provide the skyline deflection required to allow the yarder to operate and to minimize soil disturbance.

Harvesting damage to residual trees can affect the health and value of future stands. The light damage on the observed thinning unit was similar to that reported for partial cuts in hardwoods harvested with rubber-tired skidders (Nyland and Gabriel 1971) and skyline yarders (Fairweather 1991). The heavier damage on both observed shelterwood units was comparable to that reported for conventional ground-based systems used in heavy shelterwood cuts in hardwoods (Nichols and others 1993).

Cable yarding in a variety of silvicultural treatments in Appalachian hardwoods (Wendel and Kochenderfer 1978) resulted in less stand damage than was observed for the thinning or shelterwood units at the Franklin site. These low levels of damage resulted from wide yarding corridors being felled before yarding, and directional felling to minimize felling damage and facilitate yarding stems through standing timber. Yarding damage also can be moderated by logging during the dormant season, or allowing for damage when marking the cut trees and then harvesting heavily damaged trees before moving the yarder to the next corridor. Radio-controlled carriages can be positioned to select the best extraction path to laterally yard logs to the skyline corridor. Forest managers also need to recognize the potential for stand damage when prescribing silvicultural treatments, especially where large-diameter trees or trees with large tops are harvested. Although residual stand damage is unavoidable, attaining acceptable levels of damage requires only that the condition of the residual stand satisfies silvicultural objectives.

Visual quality is one of the more important reasons why many forest managers are seeking alternatives to clearcutting. Compared to clearcut units, aerial photos of the Franklin site indicate an enhanced visual quality of harvested units, especially the thinning unit. Although interior views were not evaluated at the Franklin site, results reported by Pings and Hollenhorst (1993) contrast scenic values of interior views for similar silvicultural treatments. On a scale of 1 to 10, uncut areas rated 7.17 versus 5.12 for clearcuts. Ratings for other silvicultural treatments were 6.28 for thinnings, 6.22 for shelterwood, and 5.55 for irregular shelterwood. Cable yarding also improves the visual quality of harvest sites by eliminating the highly visible network of skid trails on steep hillsides.

As increasingly stringent constraints are imposed on harvesting practices, the more important it will be to recognize the implications of these constraints with respect to the economic feasibility of specific treatments and the tradeoffs among management alternatives. Skillful planning of timber sales and effective control of harvesting operations will allow forest managers to meet both environmental and silvicultural objectives.

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FOREX - AN EXPERT SYSTEM FOR MANAGING EVEN-AGED UPLAND OAK FORESTS ON STEEP TERRAIN

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Abstract: An expert system, FOREX, was developed to access the data from the database management provided by MANAGE. For a specific site index, the user of FOREX can obtain information on present net worth, optimal thinning entry timing, optimal stand rotation age, diameter at breast height, volume by grade and value of the trees harvested, and based on the cable yarder used, the average slope yarding distance, truck class, road class, log-bucking methods, and the number of thinnings desired. This paper describes FOREX, which is valuable to forest managers, planners, loggers, and landowners, planning to harvest even-aged upland oak stands located on steep terrain.

INTRODUCTION

Commercial forest management involves making decisions regarding various activities that range from regeneration efforts to commercial logging operations. A rigorous financial evaluation must be performed. Decisionmakers must know which variables affect cost and profitability and understand how these variables interact for a particular harvesting operation. They must be able to determine the total volume, species, and individual size of hardwood logs that can be removed without incurring a loss. To evaluate the long-term costs and benefits of the harvesting and silvicultural treatments that form the chain of activities and yields in the life of a stand, a computer systems simulation model called MANAGE was developed (LeDoux 1986). MANAGE, a computer program written in FORTRAN V, is a combination of discrete and stochastic subroutines. The model allows the manager to evaluate how alternative harvesting technology, silvicultural treatments, market price, and economic combinations affect costs and benefits over the life of the stand.

The model input is a detailed individual user-specified tree list, and the output simulates stand growth based on some user-specified silvicultural treatment, harvest of desired volume or stems with the logging system specified, sale cost of the wood, and economic analysis for the respective treatment and entry. The process is repeated for user-specified alternative mixes of entry timing, logging equipment, silvicultural treatments, and economic conditions for the life of the stand in question. The results are stored by entry and life of the stand. Users can specify numerous management scenarios during the life of the stand and evaluate the outcomes.

MANAGE, although valuable, takes substantial computing time for each execution when run on personal computers. The calculation of present net worth (PNW) of an activity is based on a number of variables such as slope yarding distance, buck type, and road class. The user has to specify the values of these variables each time the program is run. It is impractical to run MANAGE for so many combinations. Moreover, it is very difficult for a novice to understand the output of MANAGE and interpret the results. An expert system is best suited for this type of challenge. Here we detail an expert system called FOREX designed for managing even-aged upland oak forests on steep terrain.

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DOMAIN OF FOREX

The stand tables used to initiate the simulations were those published by Schnur (1937) for even-aged upland oak/hickory forests. Five sites with indices 40, 50, 60, 70, and 80 which are rated worst, bad, average, good, and excellent, respectively, are considered in this expert system. These site indices cover the majority of the range of tree growth characteristics of the development and yield potential available in the northeastern area of the United States. The management plan is to reduce each 2-inch diameter class of trees by 30 to 50 percent to simulate thinning the stand and 100 percent to simulate final harvest. This is a common approach for thinning stands. Thinning could be performed a number of times during the life of the stand before final harvest. Thinning is used as a variable; the user has the choice of performing from one to three thinnings before final harvest. Although we only highlight the results of the oak hickory database with the above mentioned treatments, the user could run MANAGE for the scenario of interest and thus expand the database.

The average slope yarding distance specified is 200 and 400 feet. In reality, any yarding distance may be used on the terrain in which the harvesting is being performed, but the forest manager could easily control the yarding distance to conform to the above mentioned values.

The grading of logs is controlled by a parameter called buck type. A value of 1 for buck type allows logs to be graded based on the length and diameter at each end regardless of where in the tree the log came from. A value of 2 for buck type, although essentially the same as buck type 1, allows only the butt logs to be graded as a grade 1 log. In this demonstration, the buck type was a user-specified variable.

The species mix is held constant throughout the simulations. The species mix included white oak, red maple, red oak, and hickory based on Schnur's (1937) tables and species commonly found in the oak/hickory upland oak range of the northeastern area of the United States. The species remained the same for each site index. Again, the user can manipulate species composition and related analysis for any scenario of choice and add to the database.

The yarders used for harvesting were Bitterroot for stands 7 to 9 inches in dbh, Koller K-300 for stands 9.1 to 16 inches in dbh, and Ecologger I for stands greater than 16 inches in diameter. The one-way mileage from the landing to the mill was assumed to be 25. The delay cost per cubic foot, the move cost per cubic foot, and the PNW discount rate were assumed to be 0.03, 0.03, and 0.03, respectively. Mill prices (in 1,000 board feet) for the logs by grade and by species were:

	Grade			Cordwood
Species	1	2	3	Cord volume
Red Maple	200	125	50	40
White Oaks	450	250	100	40
Red Oak	450	250	100	40
Hickory	210	160	100	40

The road class ranges from 2 through 6, with decreasing speed characteristics as class increases. The trucks that haul the logs are classified based on their capacity. The truck class ranges from 1 through 5, with decreasing capacities as class increases.

The scenarios within the domain of FOREX were limited to outcomes that breakeven or result in profitable ventures. Outcomes that did not breakeven were not included in the database.

The choice of the variables influencing the harvesting of the forest stand has been made by USDA Forest Service experts at the Northeastern Forest Experiment Station based on those that would provide the most applicability in the forest management domain (LeDoux 1986, LeDoux et al. 1994).

RESULTS FROM MANAGE

For each site index, given type, and for different combinations of the variables, MANAGE was executed approximately 1,000 times. Figure 1 shows the various combinations for which the runs were performed. The objective was to execute MANAGE for a specific set of conditions and change the age at which the harvesting activities are done so that breakeven is achieved.

Figure 2 shows a sample MANAGE simulation run. The results from MANAGE show age of the stand when the activity was performed, the number of trees that were present, average dbh, the volume of wood harvested, the sale cost of the wood, the cost of logging, and the PNW.

In this manner, until financial breakeven was achieved in each run, MANAGE was executed for different site indices, thus bringing the total number of runs to approximately 4,500. The data generated from such numerous executions of MANAGE were analyzed, organized and captured in DBASE III[4], a database management system.

DATABASE DESIGN

A database file was created for each site index, in DBASE III. The fields used for each record were: the site index; yarding distance; the road class; the truck class; the percentage of thinning; the activity age; the PNW of the activity; the optimal rotation age; the PNW corresponding to the optimal rotation age; the total PNW; the volume of timber by grade 1, grade 2, grade 3, and cordwood; dbh; total volume of timber for all grades; volume of timber for each grade at the optimal rotation age; number of trees cut at the activity age; and average dbh of the trees harvested at the optimal rotation age.

EXECUTION OF FOREX

The flow chart shown in figure 3 illustrates the execution of FOREX. At the start, the user is presented with two options: to obtain information on the PNW, dbh, and the volume for a specific set of management activity parameters (option 1), or to know what type of management activity to perform to attain the desired minimum PNW, dbh, and/or the volume (option 2).

Option 1

When the user chooses option 1, FOREX presents the user with a choice of site indices to specify. After specifying the appropriate site index, the user is then required to specify the values for the constant parameters in the forest management domain, such as the yarding distance, the buck type, the road class, the truck class, and the percentage and the number of thinnings desired. An important and convenient feature of FOREX is that the user can specify the value of any parameter as "unknown" and FOREX will accept it. If all parameters are known, then there will be a unique solution or result. If one or more parameters are unknown, then FOREX will present as many alternate solutions or results as applicable.

The results can be sent to a printer, a text file, or the computer screen, as desired by the user. The output may consist of hundreds of options or a few options depending upon the values of the parameters. The user may be interested in curtailing the number of alternate solutions by specifying a lower bound on the PNW, dbh, and/or the volume of wood obtained from the management activities. Another important feature of FOREX is that it remembers the values of the constant forest stand parameters used in the previous run when the user begins a fresh consultation. This feature enables the establishment of a link between successive executions of FOREX.

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[4]DBASE III, Registered Trademark of Ashton Tate; 1986.

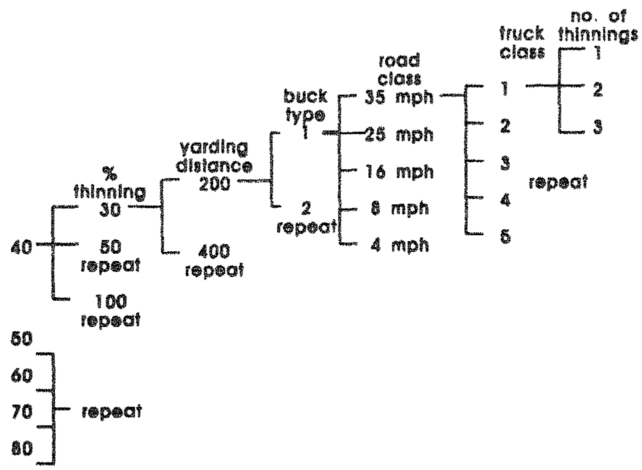

Figure 1. Various combinations of parameters.

MANAGE pc

** COMPLETED ** <↑↓> to scroll summary <ESC> main menu

** data is per acre ** <space bar> acre/tract toggle

Summary of Current Run

Age	Live Trees	AvgDBH (inches)	MerchVolume (ft3)	MillPrice ($)	LoggingCost ($)	PNW ($)
90	226	10.17	3,317.35	2,824.91	1,617.53 v	1,207.38
90	120	12.87	2,906.66	2,686.47	1,332.43 v	1,354.04
90	106	5.73	410.70	138.44	512.40dv	-373.97
100	106	7.32	691.58	233.12	470.09 v	-160.09
110	103	8.82	1,030.64	347.41	560.57 v	-97.28
120	99	10.23	1,398.14	471.28	706.48 v	-72.51
130	98	11.61	1,815.57	606.90	870.60 v	-54.93
140	97	12.92	2,287.71	1,018.37	1,055.28 v	-5.19
150	95	14.11	2,725.18	1,975.58	1,222.04 v	71.63
160	94	15.31	3,249.17	3,029.88	1,422.36 v	103.23
170	89	16.34	3,598.45	4,201.04	1,548.25 v	115.09
180	86	17.27	3,972.84	5,540.42	1,685.14 v	112.99
190	80	18.41	4,313.53	7,014.73	1,802.11 v	103.21
200	76	19.37	4,647.73	8,390.10	1,919.06Dv	86.56

***** end of projections *****

Manage Activities: 1 PNW of Activity(s):$ 1354.04

Optimal Rotation Age: 170 PNW of Optimal Rotation:$ 115.09

Range of measures ages: 90 to 200 years Sum :$ 1469.13

Figure 2. Sample MANAGE run.

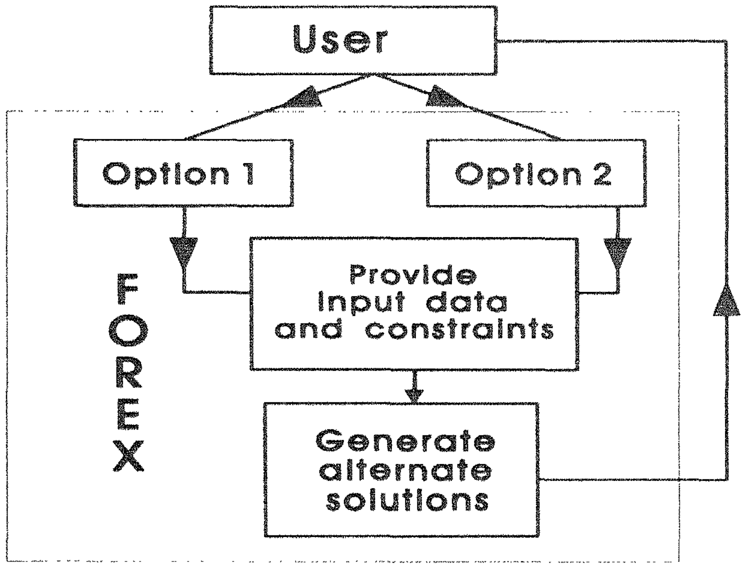

Figure 3. Execution of FOREX.

Option 2

In choosing option 2, the user elects to specify lower bounds on the PNW, dbh, and the volume at the very beginning, even before specifying any values for the forest stand parameters. This option is usually chosen by users who are not aware of the forest stand parameter values but do have a clear understanding of the objectives they want to achieve. They may be interested in obtaining a minimum PNW, and/or a minimum dbh, and/or a minimum volume of wood, and they do not care which management activity is used to attain them.

Thus, after choosing option 2, the user is asked to specify the lower bounds on the PNW, dbh, and/or the volume. The dbh and the volume constraints can be set for the last activity, whereas the PNW constraint can be set as a sum for all activities performed. This is followed by the specification of the forest stand parameters--again it is acceptable for many of these parameters to be "unknown." The second option presents a set of management activities that will meet or exceed the user-specified lower bounds.

If the user is presented with a large number of alternative solutions, the user may be interested in curtailing the number of solutions, as described for the first option. Although the program will cease to execute after providing the solutions for the second option, an important feature of FOREX is that it remembers the lower bound values used for the objectives in the previous execution of the FOREX second option. As for the first option, the results of the second option can be sent to a printer, a text file, or the computer screen. In both options, when the number of alternate solutions is less than five, the results will only print to the screen.

SYSTEM DESIGN FEATURES

As stated previously, the system is able to handle user-specified values of "unknown" to any variable. This situation is a characteristic of an expert system. If any variable is labelled as "unknown," the system reacts by finding the solution space that accommodates all possible values of the variable, if the user is pursuing the first option. On the other hand, if the user is pursuing the second option, wherein constraints are placed on the PNW, wood volume, and tree diameter, the system finds the solution space accommodating only those values of the "unknown" variable that lead to the values of PNW, wood volume, and dbh satifsying the constraints.

If the user would like to execute FOREX using the values of variables specified in the previous run, the system is designed to "remember" the values of the previous run. The system asks if the user wants to use those values. This aspect of system design facilitates sensitivity analysis.

OUTPUT OF FOREX

A typical output from FOREX is shown in figure 4. The user has chosen option 1 with a site index of 40, yarding distance of 200 feet, road class 4, (16-mph road), truck class 2, and buck type 1. The next question presented to the user is the level of thinning desired. The user states the answer as "unknown". The system then determines the number of alternate solutions as 7. This means that there are seven ways (options) to harvest the stand and realize benefits. Option 1 refers to full harvest. The optimal rotation age and the PNW are reported along with wood volume and the number of trees cut. Similar information is provided for option 2, which specifies 30 percent thinning once. Output includes average dbh of the trees, number of trees, the total volume of timber in cubic feet, along with the volumes of each grade (grades 1 through 3) in board feet and for grade 4 in cubic feet, PNW. The output can be sent to the computer screen, a text file, or to the printer. The useful aspect regarding the system is that the user can specify the name of the ASCII file and the system will not only create it, but also successfully append all results of all consultations with FOREX in that file, if the user so desires. Thus, the FOREX system design facilitates iterative use and hence generates a number of alternatives from which the user can select the best.

CONCLUSIONS

FOREX is an expert database integrated system that uses the data from simulation runs. It provides the user with the ability to perform sensitivity analysis and eliminates the need to sort through simulation runs. FOREX is an intelligent computer software that uses the principles of artificial intelligence and interfaces effectively with a database management system to bring a powerful tool into the hands of the forest manager.

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```
************************************************************************
Option 1   Site:40     Yarding Distance:200    BuckType:1
               Road Class:4  Truck Class:2     Origin: 1932

                The activity chosen is full harvest.

Optimal Rotation Age (ORA) is 160 years.
                                  PNW at ora is $88
The Average DBH is 14.12 inches.

Total Volume   = 4383 cu.ft
Grade 1 = 4971 board ft.
Grade 2 = 774 board ft.
Grade 3 = 159 board ft.
Grade 4 = 3104 cu.ft.
# of trees = 150

************************************************************************
press any key to continue!!!
```

```
************************************************************************
Option 2   Site:40     Yarding Distance:200    BuckType:1
               Road Class:4  Truck Class:2     Origin: 1932

Suggested activity is 30 % thinning 1 time.

Thinning       First     Full Harvest

Age (years)         130        160
# of Trees           62        120
DBH (inches)      12.02      14.50
Volume(cu.ft)      1262       3732
G1 (bd.ft)          486       4859
G2 (bd.ft)            0        175
G3 (bd.ft)          339       1058
G4 (cu.ft)         1046       2313
PNW ($)               7         78

************************************************************************
press any key to continue!!!
```

Figure 4. Sample output from FOREX.

EFFECT OF THE HARDWOOD RESOURCE ON THE SAWMILL INDUSTRY IN THE CENTRAL AND APPALACHIAN REGIONS

William Luppold [1]

Abstract: The Central and Appalachian hardwood regions contain a diverse and valuable timber resource. The regions are important to the hardwood industry because they contain 68 percent of the eastern hardwood sawtimber. Furthermore, more than 70 percent of the hardwood lumber produced in the United States is manufactured at mills located in 16 of the states in the regions. This paper examines the hardwood sawmill industry and its relationship to the hardwood resource in the Central and Appalachian Regions. The major conclusion is that there is considerable regional variation in the size and concentration of the sawmill industry. This variation is affected by the differences in the volume and density of the hardwood resource in different states in the regions.

INTRODUCTION

The hardwood forests within the 16 Central and Appalachian states (Figure 1) are a valuable natural resource. These forests contain 68 percent of the hardwood sawtimber volume in the United States (Powell and others 1993). A high proportion of this sawtimber is in the more desired species such as the select red and white oaks (Luppold and Dempsey 1994). Furthermore, virtually the entire United State's supply of black cherry, black walnut, and sugar maple exists in these states (Powell and others 1993). The large volume and high value of this timber base allow these regions to be a major source of hardwood lumber.

The large variety of climates and growing conditions in the Central and Appalachian states has caused the hardwood resource in these states to be extremely diverse. The four principal hardwood forest types existing in the regions are: aspen-birch, maple-beech-birch, oak-hickory, and oak-pine. There also is considerable local and regional variation in species mix between hardwood stands of similar forest types.

The hardwood industry adapts to local conditions such as volume, quality and type of resource, and transportation costs. Analysis by Luppold (in press) found regional differences in the average size and market concentration within the hardwood sawmill industry. This finding suggests that regional characteristics of the resource may be the cause. The objectives of this paper are to examine the hardwood industry in the Central and Appalachian Regions and to determine how differences in the resource base contribute to long term regional differences in the industry.

THE HARDWOOD LUMBER INDUSTRY

Information concerning the hardwood lumber industry has been incomplete or in error. For instance, U.S. Department of Commerce estimates of hardwood lumber production underestimates the size of the industry by more than 40 percent (Luppold and Dempsey 1994). However, detailed information about the industry is available from primary wood processing directories published by individual states. In this study, the data on the number of mills and average size of mills were primarily developed from these directories and USDA Forest Service records. The specific procedures used to develop the sawmill information presented in this study are outlined in Luppold (in press).

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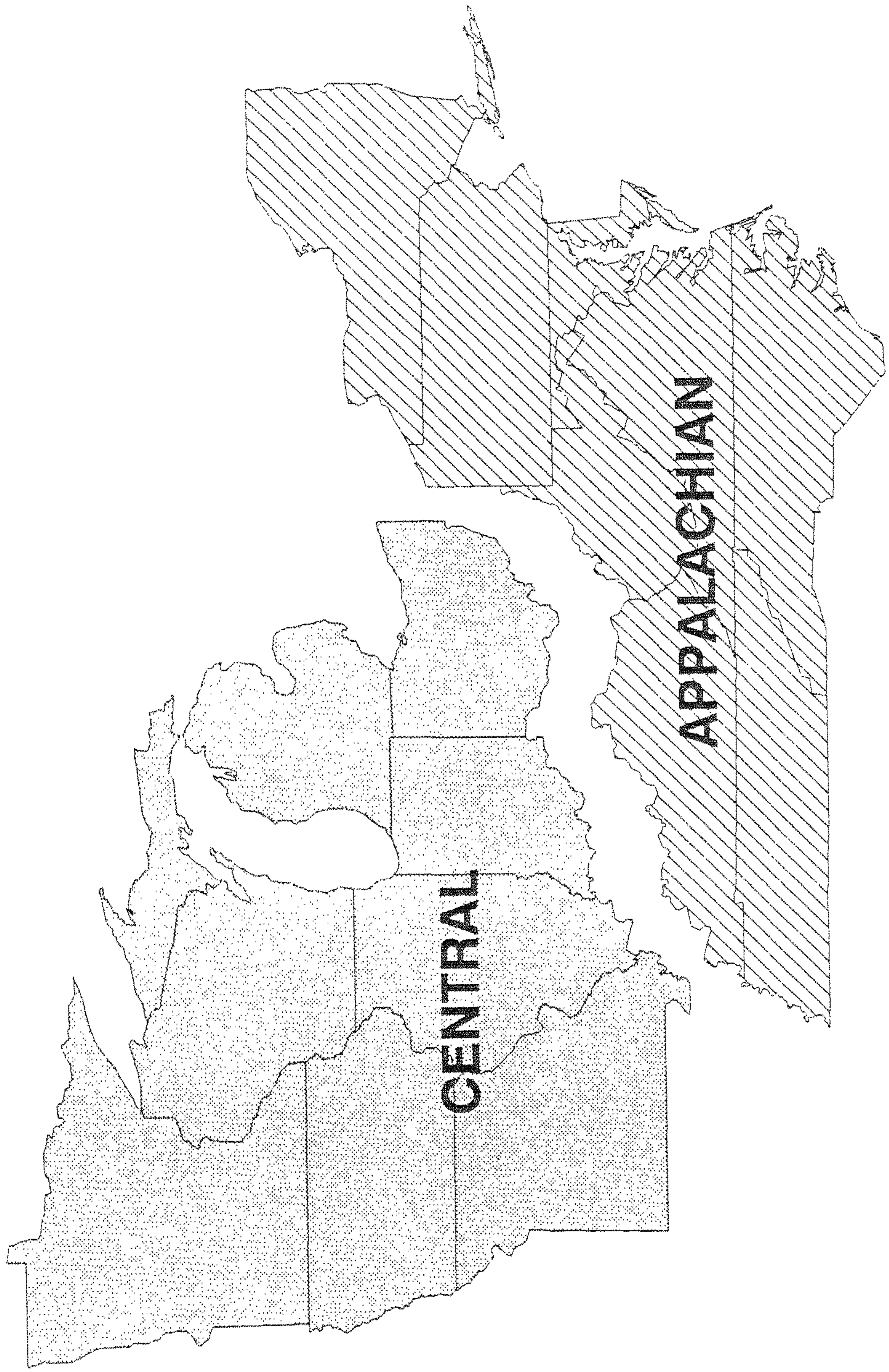

Figure 1. Central and Appalachian hardwood production regions.

Estimates of the hardwood lumber production capacity and average size of sawmills in the 16 Central and Appalachian states are summarized in Table 1.

Table 1. Estimated hardwood sawmill capacity, number of sawmills, and average capacity of sawmills in states in the Central and Appalachian Regions.

Region	State	Year	Estimated capacity of mills (mmbf)	Number	Average production (mmbf)
Central	Wisconsin	92	528	201	2.63
	Ohio	92	524	207	2.53
	Michigan	91	559	247	2.26
	Indiana	93	393	191	2.06
	Iowa	90	70	38	1.97
	Missouri	92	636	375	1.70
	Illinois	93	117	70	1.67
	Minnesota	90	244	240	1.02
	Total region		3,071	1,569	1.96
Appalachian	Maryland	94	179	46	3.90
	Virginia	92	717	239	2.98
	N Carolina	92	616	208	2.96
	W Virginia	92	581	226	2.57
	Tennessee	89	890	353	2.60
	Kentucky	90	936	395	2.37
	New York	91	511	221	2.31
	Pennsylvania	91	1,028	578	1.81
	Total region		5,458	2,266	2.41

In 1991, the sawmills in the states listed in Table 1 produced nearly 8.4 billion board feet of hardwood lumber (Luppold and Dempsey 1994). This volume represents 70 percent of the total United States production in 1991. The state with the largest sawmill capacity is Pennsylvania. Other states with considerable capacity include North Carolina, Virginia, Tennessee, and Kentucky. Relatively little lumber was produced in Iowa, Illinois, and Minnesota.

The 16 states listed in Table 1 contain over 3,800 hardwood sawmills that produce at least 100,000 board feet of hardwood lumber per year. In addition to these mills, there are at least 1,000 mills that produce less than 100,000 board feet per year in the states listed in Table 1. In Minnesota alone there are more than 425 small sawmills that had a combined total production of 11.4 million board feet in 1993. However, the total output of these smaller mills seems to be less than 5 percent of total production in the 16 state area.

The average size of hardwood sawmills varies considerably by state. However, there are some geographic similarities. Virginia and North Carolina have similar hardwood lumber industries when considering the level of production, the number of mills, and the average size of the mill. Average capacities of sawmills in Tennessee, West Virginia, Ohio, and Kentucky are similar. For the most part, sawmill size decreases the farther north and west a state is located in the 16 state area.

The small size of the average sawmills in Pennsylvania masked the fact that some of the largest mills in the 16 state area are in this state. Pennsylvania also has the largest number of hardwood sawmills producing more than 5 million board feet annually. One reason for the low statewide average sawmill size is the large number of Amish sawmills. Another reason is the large number of mills that specialize in railroad crosstie production. Both Amish-owned sawmills and sawmills that produce rail ties tend to produce between 100,000 and 1 million board feet of lumber annually. In 1991, 470 sawmills in Pennsylvania fell in this range of production.

LUMBER PRODUCTION RELATIVE TO THE HARDWOOD RESOURCE

Variation in the size, density, and quality of the hardwood resource between states may help explain regional differences in the hardwood sawmill industry. To understand the relationship between the hardwood sawmill industry and the resource, a comparison of the resource in the 16 states is presented in Table 2.

Table 2. Hardwood sawtimber inventories, timber density, and percent of resource in select species in states in the Central and Appalachian Regions.

Region	State	Sawtimber inventory (mmbf)	Timber density [a] (Million bdf/acre)
Central	Wisconsin	30,394	2.91
	Ohio	28,926	4.00
	Michigan	39,451	3.38
	Indiana	18,946	4.56
	Iowa	5,767	2.98
	Missouri	23,064	1.93
	Illinois	17,782	4.50
	Minnesota	22,693	2.36
Appalachian	Maryland	11,384	5.65
	Virginia	58,295	5.09
	N Carolina	62,541	5.70
	W Virginia	53,886	4.84
	Tennessee	42,963	4.04
	Kentucky	43,996	3.70
	New York	37,991	3.23
	Pennsylvania	59,421	4.20

a/ Since inventory statistics do not separate hardwood timberland from softwood timberland, the timber ratios are based on both hardwood and softwood inventories.

As would be expected, the volume of hardwood lumber produced is correlated with the size of the resource in a specific state. The states within the Appalachian Region have large volumes of hardwood sawtimber and the greatest sawmilling capacities. The states of Iowa, Illinois, and Minnesota have small inventories of hardwood timber and produce small quantities of hardwood lumber. Indiana and Missouri have relatively small inventories of hardwood sawtimber but produce high volumes of hardwood lumber. However, both these states were net importers of hardwood sawtimber during the early 1990's (Hackett and Mayer 1993; Hackett and others 1993). Another state that is a net importer of hardwood sawtimber is Ohio (Widmann and Long 1992).

To measure the relationship between standing timber volume and lumber production capacity, the following equation was estimated using ordinary least squares:

$$\mathrm{Ln(Capacity)}_i = b_0 + b1\ \mathrm{Ln(Inventory)}_i + b_2\ \mathrm{Importer} \qquad (1)$$

Where: $\mathrm{Ln(Capacity)}_i$ = the natural log of sawmilling capacity for state i,
$\mathrm{Ln(Inventory)}_i$ = the natural log of sawtimber inventory for state i,
Importer = a zero one variable that shifts the slope for the states of Missouri, Indiana, and Ohio (equals 1 if net importer)

The double log or multiplicative functional form was used for this equation because it provided a better statistical fit than a linear or other log linear forms. The ordinary least square results presented in Table 3 indicate that a 1 percent increase in sawtimber inventory will, on average, result in a 1.08 percent increase in sawmilling capacity. Because equation 1 was estimated using cross sectional data, the estimated results indicate a long run adjustment by the hardwood lumber industry in a particular state to the resource of that state. Short term increase in capacity due to incremental increases in inventory could be considerably lower than estimated.

Table 3. Ordinary least squares estimates of the relationship between hardwood sawmill capacity and the volume of the hardwood resource and average sawmill capacity and timber density for states in the Central and Appalachian Regions.

Equation[a]	Explanatory variable	Regression coefficient	Student's "t"[b]
(1) Capacity of sawmilling industry:			
Capacity	Intercept	-5.17	3.89
	Inventory	1.08	8.45
	Importer	0.51	2.45
R^2 = .848			
(2) Average capacity of sawmilling industry:			
Avercap	Intercept	0.07	.37
	Density	0.62	4.66
	INIL	-0.45	4.45
R^2 = .772			

a Equations described in text.
b Critical "t" value for P level of 0.05, 1.782.

The significance and sign of the importer slope shifter indicate that the estimated relationship between sawmill capacity and inventory is slightly higher for importing states. The relatively high R^2 and significance of all independent variables indicate that the relationship between sawmill capacity and sawtimber inventory is quite significant.

The size of a sawmill may be affected by the density of the forests on timberlands. This relationship exists because procurement costs increase with distance or as greater quantities of timber are demanded from a finite resource. In states where the resource is spread out over a large area, one would expect to find large numbers of small and intermediate sized mills. In regions where large volumes of timber exist in relatively small areas, one would expect to find large sawmills. As indicated in Tables 1 and 2, the average size of hardwood sawmills is correlated with timber density.

The major exceptions to the correlation between average mill size and timber density are Illinois, Indiana, and Pennsylvania. Both Illinois and Indiana have large agricultural industries that use much of the land base in these states. The timber resource in these states is often located in small patches of land that are unsuitable for farming. Although the densities of these stands are high, the spatial separation of these patches increases procurement costs. As previously mentioned, the small average size of sawmills in Pennsylvania is, in part, the result of Amish ownership and the rail tie industry.

To measure the relationship between average capacity of sawmills in a state and timber density, the following equation was estimated using ordinary least squares:

$$Ln(Avercap)_i = b_0 + b_1 Ln(Density)_i + b_2 INIL \qquad (2)$$

Where: $Ln(Avercap)_i$ = the natural log of average capacity of sawmills in state i,
$Ln(Density)_i$ = the natural log of density of the sawtimber inventory for state i,
INIL = a zero one variable that shifts the slope for the states of Indiana and Illinois (equals 1 for IN and IL)

The double log or multiplicative functional form also was used in this equation. The ordinary least square results presented in Table 3 indicate that a 1 percent increase in sawtimber density will, on average, result in a 0.62 percent increase in average sawmilling capacity over the long run. The significance and sign of the INIL slope shifter indicate that average sawmilling capacity in Illinois and Indiana seems to be lower because of the scattered but highly dense hardwood resource in these states. The relatively high R^2 and significance of all independent variables indicate that the relationship between timber density and average sawmill capacity is significant.

SUMMARY AND CONCLUSIONS

The hardwood sawmill industry in the Central and Appalachian Regions is a diffuse group of manufacturers who are dependent on and affected by the diverse forest resource in these regions. Analysis presented in this paper found that the hardwood sawmill industry varies considerably from state to state. Most of the differences in the size of a sawmill industry between states are related to the volume of sawtimber that exists in the state. Furthermore, the size of the average sawmill is dependent on the density of the timber resource in the state.

The relationship between the hardwood resource and the hardwood sawmill industry aids in understanding how the constantly changing hardwood resource will affect future lumber production. In areas of an expanding resource, one can expect greater lumber production. If the resource is allowed to mature to a high density, one can expect larger and possibly more efficient sawmills. However, changes in demand for this timber resource by the pulp and engineered building products industries may change the relationship estimated in this paper. If these alternative users start consuming large volumes of hardwood sawtimber, there is a potential for a structural change within the hardwood industry.

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VARIATION IN PIN KNOT FREQUENCY IN BLACK WALNUT LUMBER CUT FROM A SMALL PROVENANCE/PROGENY TEST

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Abstract: This small study examined the frequency of knots (> 1 growth ring), pin knots (latent or suppressed buds), and pin knot clusters in 4/4 black walnut (*Juglans nigra* L.) lumber from 42 logs, 18 to 21 cm dbh, cut from a 14-year-old provenance/progeny test. Two boards from opposite sides of each log were analyzed for number of knots, pin knots, and pin knot clusters. The boards averaged 1.4 knots per linear meter across all sources with no differences among logs within a source or between the apical and basal halves. From 50 to 56% of the pin knots occurred as 2, 3, or 4 pin knots clustered within 3 cm of each other. Boards from Missouri "super" seedlings had fewer pin knot clusters than boards from nursery bedrun seedlings. On an average, the boards from all sources had 8.1 pin knots or pin knot clusters per linear meter with no differences between the apical and basal halves. In most cases, highly significant differences in pin knot numbers existed among the logs originating from the same seed or seedling sources. Selecting parent trees for desirable nut or timber characteristics did not affect the number of knots, pin knots, or pin knot clusters in their progeny. These results suggest that retention of suppressed buds is controlled by environmental and not genetic factors.

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