Proceedings:

Guidelines for Managing Immature Appalachian Hardwood Stands



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West Virginia University
College of Agriculture and Forestry,
Division of Forestry
Cooperative Extension Service,
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Workshop Proceedings

GUIDELINES FOR MANAGING IMMATURE APPALACHIAN HARDWOOD STANDS

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Edited By

H. Clay Smith and Maxine C. Eye

USDA Forest Service
Northeastern Forest Experiment Station
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Planning Committee

West Virginia University, Division of Forestry
Co-chairmen: William E. Kidd, Jr.
Jack E. Coster
Kenneth L. Carvell

USDA Forest Service
Northeastern Forest Experiment Station
Co-chairmen: H. Clay Smith
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George W. Wendel
David A. Marquis
Gary W. Miller
Neil I. Lamson
Southeastern Forest Experiment Station
Donald E. Beck
Northeastern Area State and Private Forestry
Arlyn W. Perkey

Program Moderators

Robert E. Phares, Former Assistant Director
USDA Forest Service
Northeastern Forest Experiment Station
Morgantown, WV

Jack E. Coster, Director
West Virginia University
Division of Forestry
Morgantown, WV

David G. Lilly, District Forester
WV Department of Agriculture, Forestry Division
French Creek, WV

David E. Denham, CFM Manager
Westvaco Corporation
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FOREWORD

How to do it, that is what this workshop is all about. This proceedings will provide field foresters and landowners with an update of current available information for managing immature Appalachian hardwood stands. We all have dozens of questions and concerns and though several of these will be answered, some will not. Basically, guidelines are "guides" and we asked the authors to make recommendations based on the current literature, their knowledge, and experience. We wanted a "state-of-the-art" proceedings for managing immature Appalachian hardwood stands. Though many of these papers do provide current information and ideas, landowners and foresters will still have to decide what is best for their situations. From the practical sense, use what information you can and modify what you cannot.

ACKNOWLEDGEMENTS

We appreciate the efforts of all the authors in writing their papers before the workshop. Through their cooperation, it was possible to have the proceedings available for the workshop. A special thanks to all those reviewing and typing the papers and to the publications staff at West Virginia University for their assistance in printing the proceedings. Finally, thanks to Robert E. Phares for promoting this workshop before his retirement.

To avoid repetition of scientific names of trees and other plants, only common names are used in the proceedings. Both common and scientific names are listed in the Appendix.

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EFFECT OF PAST HISTORY ON PRESENT STAND COMPOSITION AND CONDITION

Kenneth L. Carvell

Professor of Silviculture and Forest Ecology
Division of Forestry
West Virginia University
Morgantown, WV 26506

ABSTRACT

The original forests of the Appalachians differed in many respects from present hardwood stands. The strong preference for harvesting certain species has resulted in such commercially important trees as black walnut, butternut and white oak being less common in present stands. The heavy cuttings and wildfires at the turn of the century destroyed the habitat for red spruce and decreased the area dominated by hemlock. Smaller areas of abandoned farm land often seeded-in with Virginia, shortleaf, or white pines. Where large fields were abandoned, bird-disseminated species such as hawthorn, sassafras, black locust, crab apple, and eastern redcedar now dominate. The impact of the chestnut blight (*Endothia parasitica*) was particularly serious, since American chestnut was economically the most productive species on average and poorer sites. Thus, Appalachian stands, today, differ markedly in both composition and structure from the original forests.

The mountains, plateaus, and valleys of the Appalachians originally supported magnificent hardwood stands composed of a vast number of species. These hardwood forests could be grouped into northern hardwood mixtures at the higher elevations, cove and oak-chestnut types at intermediate elevations, and small areas of bottomland hardwoods along streams. Coniferous types were interspersed throughout this hardwood matrix. Locally, spruce-fir or spruce-hemlock mixtures capped the ridges and tablelands, and white pine or white pine-hardwood stands were diffused throughout the better sites. Hemlock, which behaves more like a hardwood than a conifer, was an associate of many coniferous and hardwood types, and occasionally formed pure stands. Yellow pines, pitch, table mountain, and shortleaf, occurred locally in pure stands after fire, and in mixtures with oaks on the drier sites. In spite of these coniferous inclusions, however, the Appalachians were predominantly hardwood country.

When the first trappers and traders penetrated the southern Appalachian wilderness, they discovered scattered treeless areas. These forest openings were of several kinds; some natural, some

man-caused. In certain localities these made up a considerable acreage. Treeless areas could be grouped into five categories: sphagnum bogs, resembling the muskeg of the north country; grassy glades, dominated by tall grasses; upland meadows, of debatable origin, but perhaps the result of Indian burning; "old fields," areas formerly cleared by the Indians for agriculture and now starting to grow-up; and finally the high elevation balds, dominated by shrubs and stunted tree cover, but not a true tree line. Although obscured by the dense forest, these openings were discovered readily, since the first trappers and traders followed animal trails and these often led from one glady area to the next. These openings, particularly the grassy glades and old fields, were sought out at an early date by the homesteaders and settled first, since they were spared the difficult task of clearing the dense forest cover to provide crop and grazing land.

In spite of these scattered openings, more than 90% of the land was forested, and in the southern Appalachians 90% of the forest was hardwood.

Land Clearing

During the first century of settlement, much suitable land was cleared for agriculture or pasture. In the southern Appalachians, former agricultural use is not as evident today as in the North, since cellars, wells and stonewalls were uncommon. Hence, after mountain farms were abandoned, all traces of this former land use disappeared quickly. Mountain farm land was often cleared by girdling or peeling the trees, then farmed for several years. When crop yields declined, these patches were abandoned and adjacent areas cleared. This pattern of agriculture was taken for granted. Such small clearings usually seeded-in quickly with desirable species and returned to productive forest.

During the mid- and late-nineteenth century many mountain farms were abandoned. This trend began just prior to the Civil War. It is interesting that many of our best old-growth stands of pine and hardwood date back to the 1860's. Still other old farms were abandoned as coal mines, oil wells and manufacturing developed, attracting young people from the farms. In addition, many Appalachian families moved West to Missouri, Kansas, or California, to find more level land, or dig for gold or silver.

When mountain farms were abandoned, the composition, stocking and condition of the new stands depended on the size of the clearing, seed source, and available soil moisture. Many stands of yellow-poplar, white pine and yellow pines, today, owe their presence to land abandonment. The pattern in which the least productive fields were abandoned is reflected in the ages of the respective stands today, and many mountain slopes have older stands above and progressively younger stands below.

Where abandoned fields were too large to be covered adequately by wind-borne seed, bird-disseminated species gradually invaded. These pioneers vary from one section of the Appalachians to another, but include hawthorn, crab apple, black locust, cherries, sassafras, persimmon, gray birch, and on limestone soils, eastern redcedar. This temporary cover dominates until other hardwoods seed-in beneath, work their way through the canopy, and shade out the pioneers.

Era of Light Selective Cutting

The first timber cuttings in the Appalachians were light and selective. In these, only the best white pine, red spruce or choice hardwoods, black walnut, butternut, black cherry, yellow-poplar, cucumbertree, white oak, American chestnut or white ash, were removed. Such light cuttings often had little impact on the stands, since many smaller trees of each species were left. Diameter-limits were often 22 to 26 inches.

One species that I want to mention, in particular, is white oak. Cooperage was the cardboard box or metal drum of the nineteenth century, and the construction of both slack and tight cooperage was a highly-developed skill in the settlements of the Appalachians. Coopers were essential artisans. Slack cooperage used primarily slippery and American elm; for tight cooperage, white oak of the highest quality was essential. With the thriving local distilling industry, allowing mountain folks to convert their surplus grain to a more portable, high-priced product, the demand for tight cooperage was insatiable. Appalachian whiskies, such as Old Monongahela Rye, were sold throughout the world. Thus, the first oak cuttings were for white oak, and at that time the red oaks were considered unmerchantable species. White oak was completely cut-out of many mountain areas, and is just returning, today, to mixed oak stands in its original proportions.

Era of Heavy Cuttings

The first large sawmills and pulpmills in the Appalachians were built by men attracted by the white pine and red spruce. By 1860 there were large white pine mills in northern Pennsylvania, and by the mid-1870's there were white pine mills in West Virginia.

White pine was their game, and they cut giant pines from choice hardwood stands leaving the hardwoods for later loggers. When the white pine was gone, other mills moved into these localities to cut the hardwoods; thus, many areas were logged twice.

By the mid-1880's mills were springing up at the higher elevations to cut the red spruce. They were attracted by the spruce for pulp, but used the larger trees for construction lumber, much of which was used to build the fast-growing tenement districts of the cities along the Eastern seaboard. Between 1890 and 1920 many Appalachian mountain towns had their own paper mill. The last virgin spruce stands had been cut by the late twenties.

By 1900 the ever-expanding demand for lumber had resulted in markets for nearly all hardwood species. With the introduction of steam skidders and high-lead systems, the impacts of logging were devastating. Cable yarding systems damaged or knocked down all smaller trees. As the deep blankets of slash dried out, it was inevitable that these "slashings" burned, and wildfire became commonplace, even expected. In many areas, after repeated burns, the seed source was eliminated, the organic top-layer of soil destroyed, and pioneer vegetation, wild grasses, dense colonies of ferns, and such hardwoods as fire cherry and aspen became the dominant cover. The only fire prevention activities were to protect the towns, logging camps, and equipment from fire, and these often failed.

There was little public concern over conserving the forest resources from wildfire until the disastrous fire years of 1908 and 1909. Between 1900 and 1910 many eastern states established their forest service organizations, enacted conservation legislation, and made preliminary surveys of existing forest reserves. Effective fire suppression and detection activities, however, were slow in coming.

Impacts of Cuttings on Composition

From the beginning, many hardwood stands have been sorted over repeatedly for the most valuable species and highest quality trees. In each cut, the best was taken and the poorest left. This resulted in leaving a seed source of the wrong species, and eliminating the desirable species except for trees with undesirable genetic characteristics.

Black walnut, butternut, white oak, and black cherry were far more abundant than would be surmised from present stand composition. These were sought out repeatedly by the colonists, and have been removed regularly from stands. As these species became scarcer, they were cut to lower and lower diameter limits, thus the seed source was also removed. Hickory was cut heavily in some localities for wagon and carriage construction, and beech was cut in some areas due to its great value for charcoal.

During cutting operations such species as red maple, sycamore, scarlet oak, blackgum, and sweet birch were usually left. This not only left these trees to encumber growing space, but they towered above second-growth stands for decades during their years of greatest seed production. Today these species are more abundant than they were in the original forests.

Hemlock was removed in many logging operations, or at least felled and debarked for tanning material. When hemlock was left, however, it usually died from exposure, sun scald, or wildfire. After heavy cuttings and fire, hemlock often survived only in ribbons along streams, or on rocky points where fire did not burn. It is interesting to observe hemlock, today, re-invading its original sites, seeding-in as an understory species on lower- and middle-third slopes,

and working its way up into the main canopy due to less frequent wildfire and lighter cuttings.

Such hard pine types as Virginia and shortleaf are now occupying increasingly large areas due to continued land abandonment during the twentieth century. Many of these sites were formerly in hardwoods, and without intervention by foresters will return to hardwood types.

Impacts of Cuttings for Small Wood Products

Locally throughout the Appalachians the demand for small wood products for firewood, chemical wood and charcoal has been a major factor in shaping the composition and condition of present-day stands. The firewood market was greatest near large centers of population. The chemical wood industry was located in northern Pennsylvania and southern New York State, and the charcoal makers had their greatest impacts in the immediate area of iron furnaces, since this fuel was made within a few miles of the furnace sites.

Hardwood stands in the vicinity of industrial centers were cut-over repeatedly for small wood products. New stands of sprout origin sprang up after these cuttings, and today these stands exhibit the typical problems of repeated coppicing: degradation of stand composition to species which sprout the best, particularly red maple; a high incidence of butt rot; and clumpwise arrangement of stems, resulting in poor bole form and poor natural pruning. These problems are not serious as long as sprout stands continue to be managed on short rotations, but become increasingly severe when sprout stands are left to grow into sawtimber; this is a problem that we are now experiencing in many Appalachian hardwood stands.

Virgin Stands

Today we are finding that there are more small tracts of virgin timber than once thought, and each of these tracts has an interesting story as to why it was spared when most stands were being cut. These natural areas are important as they give insight into the natural composition and structure of the original forests.

The reasons why particular stands were spared varied, but such stands were usually spared for economic considerations or chance rather than sentiment. Some stands were left due to surveying errors, disputed ownership, or inconvenient location; other for recreation or such use as oil wells. Occasionally a sawmill family would keep a tract uncut, in reserve, as insurance against hard times.

Loss of the American Chestnut

When the chestnut blight entered the Appalachians, during the late teens, there was great concern in all mountain communities, since this tree was not only a valuable lumber source for houses, farm buildings and fences, and for telephone poles, but the annual nut crops provided many rural Appalachian farms with a vital supplemental income each fall.

American chestnut was abundant both in cove hardwood types and mixed oak-chestnut stands, but its loss was most tragic on the average and poorer sites, those now dominated by mixed oaks, since here chestnut was invariably the best species, growing rapidly and forming a straight, clear bole. In mountain coves and on other good sites there were many other choice species to replace the chestnut when it left; on average and poorer sites, however, equivalent replacements were lacking. Many poor hardwood sites could be managed profitably when they had a strong chestnut component but cannot be profitably managed today.

Predominant Form of Today's Stands

The great era of heavy cuttings and wildfire has resulted in most of our present-day stands being even-aged, or at the most, two-storied, with scattered cull wolf trees remaining from the last rotation. It is little wonder that even-age management systems have become the rule in Appalachian hardwood management, since so many stands were inherited in relatively even-age condition.

This predominantly even-age condition has presented a difficult problem to hardwood silviculturists interested in uneven-age management, since so few uneven-aged stands, suitable for research, are available. Thus most current studies in uneven-age management, or selection cutting, are done in even-aged stands, giving only one side to the applicability of uneven-age management.

Summary

The original Appalachian forests were dominated by hardwood stands, although locally intrusions of spruce, pines and hemlock occurred. More than 90% of the forest land was dominated by hardwoods.

The clearings made by the first settlers were of small size, and quickly restocked with desirable species when fields were abandoned. The size and number of abandoned fields increased rapdily after 1850, and has continued to the present. This has resulted in many areas seeding-in and with Virginia, shortleaf and white pines or yellow-poplar. Where very large acreages were abandoned, however, they have failed to receive an adequate amount of wind-borne seed, and bird-disseminated species have occupied the site, giving a temporary cover of low-value hardwoods.

The initial cuttings in Appalachian stands were light and selective, and made to supply local needs. These resulted in little change in stand composition or quality. As the demand for lumber increased on a national scale, however, most species became merchantable, and by 1900 nearly all species were being cut. These large-scale cuttings were invariably followed by wildfire, causing great changes in site conditions. Fire cherry, aspen, sassafras and red maple, interspersed with wild grasses and ferns, became common. Red spruce, pines and hardwoods re-invaded slowly after these drastic changes in site conditions.

Strong species preference in early cuttings, and the repeated removal of certain species to lower and lower diameter limits, have resulted in some species being less abundant today. These include black walnut, butternut, white oak, cucumbertree, and black cherry. In some locations, hickory, elm, and beech were cut heavily. Cutting to low diameter limits removed these trees before they had reached the age of heavy seed production.

Species often left in cutting operations included red maple, blackgum, black birch, sycamore and scarlet oak. This has increased the abundance of these species greatly over that in the original forests.

In many areas hardwood stands were cut-over repeatedly for small wood products. Today some of these are in the third or fourth rotation of sprouts, and have the familiar characteristics of repeated coppicing. These defects, however, are of little consequence until the sprout rotation is extended to a sawtimber rotation; a transition which is taking place at present in many hardwood stands.

Today lighter cuttings and better wildfire control are allowing many species to re-assume their original place in stand composition.

MARKETING AS A FACTOR IN THE MANAGEMENT OF IMMATURE HARDWOOD STANDS

Gary W. Zinn

Associate Professor of Forest Management
Division of Forestry
West Virginia University
Morgantown, WV 26506

ABSTRACT

Management of immature hardwood stands is always a marketing operation, because management decisions made now will affect a stand's future character and value. The marketing aspects of immature stand management are especially crucial when future effects on the stand are the main rationale for present management actions. In making management decisions, resource analysis and product-market analysis together provide the information that allows the manager to make choices among alternatives. Fundamentals of predictive market analysis are discussed. Brief illustrations of practical analytical approaches are given and key sources of information useful in product-market analysis are noted.

Introduction

When the term "market" is mentioned, most of us tend to think of a place where something is bought and sold. Similarly, the term "marketing" conveys the idea of doing certain things to sell something. Although these are valid concepts of the terms, they are incomplete and limiting. Marketing, especially, may be viewed in a context much broader than the act of selling, and the broader context is more useful to the landowner who wants to manage an immature forest with both present and future marketing considerations in view or to the practicing forester who is consulted to help the landowner in such a situation.

> What is marketing? There is no one answer to the question. The term has economic, social, legal, and managerial connotations. Modern business management has evolved from a production-oriented activity to a sales-oriented one and finally to one that is marketing-oriented, with firms confronting three basic questions:
>
> 1. What to produce and sell, and how?
> 2. Where to buy, and how?

3. What prices to anticipate?
(Bentley et al. 1979)

For the owner or manager of an immature forest, another basic question may be added:

4. How will marketing decisions made and implemented now affect the future character and value of forest--i.e., its future marketability?

This last question goes to the heart of managing immature hardwood stands, since the traditional justification for undertaking cultural operations in immature stands is to "improve" them--i.e., to increase their value (marketability) in the future.

Management of immature stands which goes beyond routine protection and maintenance to involve more specific cultural operations is a marketing operation, whether or not something is sold immediately. Therefore, management decisions for immature stands should incorporate both immediate and longer-term marketing considerations. This is especially important since, in many cases, revenue from sale of products from immature stands is unlikely to be substantial.

What is the Problem?

If a forest landowner or manager is contemplating short-term cultural operations for an immature forest (say within 5 years), the basic questions to be answered are: (1) What can potentially be produced and marketed, and how, and (2) will the income received or other benefits gained be sufficient to justify the operation? Suppose the operation in question is a thinning. If there are good markets for wood from thinnings and wood prices promise to make the operation profitable, then the only marketing problem is "operational marketing"--i.e. planning, marking, and calculating yield of the thinning, contacting prospective buyers, negotiating terms of sale, arranging and overseeing the cutting, etc. If the forest landowner cannot handle these things personally, then consulting, service, or industrial foresters can do so on the owner's behalf. So this situation is not a particularly difficult or perplexing management problem.

But more typically, active markets do not exist for products such as wood from thinnings; where markets do exist, the prices paid for such material are often so low as to make it difficult to cover the costs of the operation. Consider a 200-acre even-aged, second growth, mixed species, 45-year-old Appalachian hardwood forest. Suppose the forest is overstocked, with a substantial component of lesser-desired species and poor quality stems. An improvement thinning would be an obvious silvicultural prescription for such a forest. But if the negative market factors for wood from thinnings mentioned above exist, the owner or manager of the forest may wonder whether the operation is feasible. Will revenue from the thinning pay for the cost of the operation? If not, will the improvement in the residual stand

increase its future value enough to pay for current investment costs? Will doing the thinning operation facilitate, or reduce the costs of, future operations (say by putting in a forest road system now)? The decisions to be made in this situation are more challenging and their results less immediate and obvious than in the previous example.

Management of immature hardwood stands with a sensitivity to marketing considerations is a problem in decision making. The decisions to be made and implemented will have both immediate or short-term and longer-term effects. Since the longer-term effects may be substantial and in many cases may largely form the rationale for present management actions, it is important that the decision-making process which determines management actions takes clearly into account relevant marketing factors. The decision model below does this.

A Decision Model for Forest Management Planning

Conceptually, the decision-making process is quite simple and almost universally applicable. It involves three basic components or steps:

1. Establishment of goals.

2. Identification of alternatives.

3. Evaluation of the alternatives against the goals to make a choice. (Duerr 1979a; Kepner and Tregoe 1965.)

This statement of the decision-making process is, of course, too simply structured to be directly applicable to a substantial real problem, such as managing a forest. The components of the process must be more fully developed to make them useable, but bear in mind that each of the steps in the forest management planning process is a part of or provides a transition between one of the three basic steps listed above. A generally applicable model for forest management planning is sketched below. A model such as this is especially useful when the decisions to be made will have long-term consequences.

A. Establish goals that are to be accomplished, to guide the rest of the process and provide standards of performance against which to judge alternatives (Duerr 1979b). For instance, a general goal is to minimize cost for a cultural practice. A better, more specific goal would be to spend no more than an average of $10/acre on cultural practices in the current year.

B. Define alternatives--basic ways in which the tract may be managed, including such factors as varying intensities of management and emphasis on management of different resources to produce various products.

C. Conduct resource and product-market analyses to obtain the information needed to complete the rest of the analysis. (Since marketing is the focus of this paper, product and market analysis will be discussed in depth below.)

D. Analyze land use suitability--identify areas of the tract which are well suited for intensive timber management, forest road location, etc.; determine whether the tract is suitable for producing products for which markets exist or are expected to exist in the future. Analysis of land-use suitability involves a coordinated study of the implications of both the resource and product-market analyses, relating the findings of these back to the goals and alternatives.

E. Reevaluate goals and alternatives--recheck and, as necessary, revise goals and alternatives in light of added information and insight now available.

F. Select tentative best alternative--judge how well each alternative may be expected to perform in relation to the goals, using only nonfinancial goals at this point. Decide which alternative promises to best meet the goals. This alternative is the tentative best choice, which is subjected to final analysis.

G. Develop management plan and financial analysis for tentative best alternative--specify each activity that will generate significant costs, revenues, or other measurable benefits carefully and completely as to nature, timing, and quantity (acreage, volume, man-days, etc.). Monetize these activities and conduct a financial analysis to determine whether the tentative best alternative will meet financial goals.[1]

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[1]One should not attempt a financial analysis without being familiar with the principles, mathematical techniques, and conceptual problems involved. Information and guidance on financial analysis may be obtained from sources such as Christiansen (1979), Segur (1979), and Gunter and Haney (1984). The latter is an especially useful workbook which covers principles and techniques of financial analysis one by one, with examples and self-test exercises.

H. Analyze tentative best alternatives against financial goals--if the tentative best alternative meets the financial goals, then it is an acceptable choice and may be implemented. If the alternative does not meet financial goals, then some replanning is indicated. Possibly management plans can be adjusted to give better financial results, basic alternatives can be restructured, etc. At worst, the manager may be left with no good "action" alternative, which means that simple custodial management (or even disposal) of the forest is indicated. But better to know this before a lot of unproductive investment is sunk into it![2]

The Importance of Product and Market Analysis

The outline above shows that together resource analysis and product-market analysis provide the essential information which allows the decision maker to evaluate alternatives in relation to goals, in order to make a rational, informed choice.

Most practicing foresters and many experienced forest landowners are comfortable with forest resource analysis. But most are not so confident when it comes to analyzing markets. The volume of timber that one may expect buyers to "demand" at a given time is much harder to measure than is forest inventory; growth in a timber stand is much easier to predict than stumpage price trends; etc. But if product-market analysis plays a role in forest management planning equal to that of resource analysis, the planner must face the necessity of doing a product-market analysis which will yield useful information for making decisions. How can one do this without having an advanced degree in forest economics? Hopefully the following guidelines will help.

Basic Concepts and Definitions

What is a product? Products are of two general types--goods and services. A good (or commodity) is something of value which is a distinct physical entity (e.g., a sheet of plywood, a chair). A service is something of value which is not, in terms of its valuable attributes, a distinct physical entity (e.g., permission to hunt on another's property, the services of a lawyer).

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[2]A detailed explanation of this decision model would take more space than can be justified here. The author has detailed explanatory material and several practical examples of forest management planning documents which utilize this model and can assist anyone who is interested in its application.

Products may also be distinguished by their position in the production process. A final product is one which is acquired and used by the final customer (consumer) in a production-distribution process or chain (e.g., a table bought from a furniture store; a campsite occupied by a family). A primary product is one which is produced and made available to some customer by the initial producer in the production-distribution chain (e.g., timber stumpage, coal at the loading tipple). An intermediate product is one at some intermediate point in the production-distribution chain (e.g., sawn lumber, steel beams, an interpretive trail ready for use). These distinctions are important to analyzing products and markets, as will be seen shortly.

Another important set of distinctions involves the concept of economic demand. Technically, demand is the relationship between any particular value (price) of a product and the quantity of the product demanded at that price--i.e. the quantity consumers would like to acquire from suppliers at a given price. Thus demand is an expression of a price-quantity relationship.

"Demand" is often confused with the term "level of consumption." The latter is the actual quantity of a product which consumers take (buy) at a particular time, given the value (price) of the product. An expression of this concept would be, "During year N, the level of consumption of product X was Y units at an average price of P dollars." This concept is important because it is commonly used in predicting future market relationships for products--e.g., historical levels of consumption are projected into the future, usually along trend lines. However, market forecasters tend not to identify such predictions as "predicted levels of consumption." but instead often label them "demand projections". For instance, expressions such as "we predict that the demand for hardwood dimension lumber in the year 2000 will be X billion board feet," are quite common in forest economics and industry literature. But what is actually being expressed is a predicted level of consumption.

Finally, it is useful to distinguish between "final demand" and "derived demand." Final demand is the demand for a final product, while the demand for an intermediate or primary product is said to be "derived" because it is derived from (dependent on) the demand for the final product(s) that may be produced from the intermediate or primary product in question. The importance of this is that if one wishes to predict the future demand (or level of consumption) for an intermediate or primary product, some attention must be given to predicting demand or levels of consumption for the relevant final products. Since most forest products are primary or intermediate in nature, the derived demand concept plays a key role in market analysis for forest products.

Product Definition and Classification

The first step in a product-market analysis is to carefully identify the products which may be produced from a forest over the time frame of the management plan. This may be done by answering a series of questions:

--What products are of interest? List distinct products separately and be specific.

--Specify whether each product is a good or a service.

--Specify whether each product is a final, intermediate, or primary product. For any intermediate or primary product, list types of final product(s) into which it would likely be converted.

--Where do customers take, or "consume", each product, on the site of production or off of it?

--Is the product bought and sold in a conventional market, or is it provided free of direct charge or at "token prices" (prices not intended to cover production costs).

--What is the practical market area for each product; i.e. how far may the product reasonably be shipped to customers or how far may they reasonably travel to consume products on-site?

Product definition and classification is the basis for an efficient predictive analysis of markets. With products well-defined, one better knows what sorts of marketing information are important and confused or misdirected work is avoided.

Predictive Analysis of Markets for Final Products

The crux of market analysis is predicting, as best one can, the likely future demand, supply, and price relationships for given products, and thereby their probable future levels of consumption. If a final product is in question, then the focus of analysis is obviously that product. But even if one is dealing with intermediate or primary products, the prospects for future consumption of final product(s) into which they will be converted must be studied. This is because of the derived demand relationship between final, intermediate and primary products. Thus the first consideration in predicting levels of consumption of any product must be those factors which influence "final demand," or consumption of final products. These factors include:

1. Geographic area of market. For most commodity-type final forest products, market areas may be nationwide or even international in scope; by contrast, products consumed on-site (which includes most services) can usually be fairly readily associated with a definite, relatively limited market area. In the former case, it is futile to attempt to exhaustively define market area, for the information gained is not very useful. But if one

concentrates on defining where the most significant portions of the market are, the findings can be useful indeed. For instance, the United States is the world's largest consumer of wood products, so if one is interested, say in the market for hardwood furniture, much insight may be gained by studying the market for hardwood furniture within the United States. (However, one should not ignore major export markets if these exist or appear to be developing.)

2. Population structure and demographic trends. The consumption of many products is keyed to specific age groups or social classes within the general population of any country or region. For instance, population in the young adult (household forming) age class is a key indicator of demand for new residential housing, furniture, and related products. Population increases in the higher socio-economic classes indicates a strong demand for single-family housing, while increases in the lower-income classes implies more of a demand for multi-unit dwellings. Factors such as these, along with their general implications, can be understood with a reasonable amount of thought and information gathering.

   When a reasonably well-defined geographic market area exists for a given final product and when the general demographics of that area are known, the basis exists for making an initial estimate of potential market for the product in question.

3. Trends in key economic indicators. Basic economic parameters such as gross national product (GNP), disposable personal income (PI), the rate of inflation, and interest rates indicate the prospective buying ability and patterns of consumers. For instance, predictions of low rates of growth in GNP, stagnant levels of PI, and high inflation rates would indicate low levels of consumer purchasing power, especially for nonessential or luxury items.

   The production-distribution factors which influence geographic market areas have an inherent stability which causes changes to be fairly gradual and reasonably predictable; the same holds for demographic trends. Thus predictions involving these factors can be made with some confidence, even when the predictions span a few decades. This cannot be said, though, for predictions of key economic indicators. Economists and weather forecasters share the curse of trying to predict the behavior of systems which are complex and often

behave in ways which are not well understood, so that their most careful predictions frequently prove to be highly inaccurate. Economic indicator forecasts which span the next few weeks or months are usually reliable, but those which predict conditions throughout a decade or more are likely to not be very accurate in the actual event. Yet when planning for management of an immature forest, time horizons of perhaps 15 to 40 years would be typical. Thus the likelihood of inaccuracies in economic indicators makes them the weakest link in the prediction of market conditions.

4. Competitiveness of substitute products. How well products compete as substitutes for one another depends on several factors, but for a basic market analysis the most important of these is the technology of producing the products. Production technology affects two important characteristics of a product--its ability to satisfy consumers' needs and desires and its price. If product A will serve consumers as well as product B and if product A is cheaper, then the bulk of consumers may be expected to buy A. For instance, particleboard--structural panel products made from wood chips or flakes--is presently making substantial inroads in markets traditionally dominated by plywood (just as plywood largely replaced sawn wood in these same markets). This substitution of particleboard for plywood is based on two main factors: (1) production technology has developed to the point that particleboard performs as well as plywood in many of the latter's major uses and (2) efficiencies in production of particleboard give it a price advantage relative to plywood. (A large part of this is because particleboard can be made from small sized and low quality wood raw material, while plywood is mostly made from increasingly scarce and expensive "peeler logs".) So if trends in the relative production technologies, use interchangeabilities, and prices of competing products can be discerned, the likely future competitiveness and market shares of these products can be predicted fairly well.

These are the most basic and essential factors to consider in predictive market analysis for final products. Information on these should be sought out and the findings should be studied in a combined or interrelated fashion when doing a market analysis. It is not necessary to be a specialist to do this; what is needed is access to required information, interest in studying it to find the facts and estimates relevant to the problem at hand, and the ability to apply these in a practical way.

Predictive Analsyis of Markets for Intermediate or Primary Products

Most forest landowners and managers will be mainly interested in marketing primary or intermediate forest products. Thus investigation of final product markets provides background for, but does not directly solve, the problem of primary interest.

The first step in studying and predicting markets for primary or intermediate products is, again, to determine geographic market area. In the case of wood products from the forest, this involves the familiar concept of the timbershed. The question is, who are the potential buyers of the various products which may come from this particular forest? Potential buyers within whose timbersheds the tract falls (or may be expected to fall during the time period covered in planning) should be listed, product by product.

Timbershed and potential buyer definition form the basis for the rest of the market analysis. Suppose a timberland owner has identified as a prime alternative the future production of high-quality sawtimber from a presently immature forest (assume the forest will become mature in 20 to 25 years). A review of sawmill timbersheds within which the tract falls has found that there are four relatively large, continuously operating sawmills who would be potential buyers of sawtimber from the tract. Assume also that an analysis of markets for final products from high quality sawtimber has yielded the basic conclusions that these may be expected to grow slowly in the next 15 to 30 years, with prices remaining stable or perhaps increasing slightly in the real-dollar terms. It could reasonably be inferred, then, that there will be a "demand" for the landowner's sawtimber at the time it is ready for harvest.

But one should not be fully satisfied with this information. If the sawtimber will not be marketable for 20 to 25 years, will these potential buyers or others still be there at that time? One must study some additional factors to be confident of this.

The first is the apparent competitive positions and business intentions of the sawmills in question. Suppose that one of the four mills is owned by a large and still growing wood products corporation with multi-state operations and a reputation for innovative and aggressive marketing of its products. Suppose further that this mill has recently been overhauled, with a new headsaw installed and other production equipment upgraded. These conditions would imply that first, the company is in a good and likely sustainable competitive position in the industry, and second, the company is committed to operating this mill for some time to come; otherwise, a substantial capital investment would not have been made so recently.

Suppose study of the other mills finds them to all be independently-owned enterprises, which have operated for many years. One of these mills has just added a pallet-making operation and another has just changed ownership from an entrepreneur who is

retiring to two young but well-trained and experienced partners. These two mills are likely to continue operations and may even grow in the future. The last mill, though, may be in trouble; its equipment is old, its management erratic, and its production and sales have been falling in recent years. This mill may not be in operation long, though there is always the possibility that it may be taken over and run by another enterprise.

Besides the local area's potential sawtimber markets, one should also examine local timber supply. What are the stumpage supply conditions and trends in the timbersheds in question? Are many forest landowners showing active interest in managing their lands to produce timber. Is forest land in the area mainly in large ownerships, or are there mostly small, fragmented tracts? What happens when lumber markets are strong--do stumpage buyers have trouble finding adequate timber to supply the mills? Do stumpage prices rise dramatically? What about when lumber markets are weak--is there still a reasonable demand for open-market stumpage or do the mills get most of their logs from their own lands or from a few "preferred" suppliers? Considering factors such as these helps the planner predict future market prospects for timber from a particular forest just as much as do the demand-side factors discussed previously.

Analyzing markets for primary and intermediate forest products is easier and more definitive than is the case for final product markets. The market area and all other relevant factors for primary and intermediate products are narrower, and often the analyst will have considerable personal knowledge that reduces the amount of information-gathering to be done. However, familiarity should not breed complacency. One should still think through local market circumstances carefully, with close attention to how these are evolving--remember that the object is to make an informed prediction of what is going to happen in the markets in question in, typically, the next 10 to 30 years. Back up general knowledge or impressions with facts wherever possible and check conclusions and judgments against those of others with knowledge and experience.

Sources of Information

Anyone who is even moderately experienced in predicting and planning knows that these activities are ultimately exercises in making judgments. But the judgments made, if they are more than simply guesses or expressions of intuition, must be based on substantial information. It is useful, then, to be aware of some of the major sources of information relevant to studying and predicting forest product markets.

Recently, major studies of forest product markets have come mainly from the U.S. Department of Agriculture, Forest Service. Primary ones which I have found useful include "An assessment of the forest and range land situation in the United States (1981), "An analysis of the timber situation in the United States 1952-2030" (1982), and "Trends in the production and consumption of major forest products in the

United States" (McKeever and Hatfield 1984). These may be found in many larger libraries (or they can obtain copies through interlibrary loan) or may be obtained from the U.S. Government Printing Office, Washington, D.C.

Forest Service research bulletins, along with those from forestry schools, include many good in-depth market studies for specific forest products or particular states or regions. These are too numerous to list. A good way to find relevant studies of this type would be to request publication lists from the U.S. Forest Service, Northeastern Forest Experiment Station, Broomall, PA: The U.S. Forest Service, Forestry Sciences Laboratory, Princeton, WV; and from nearby forestry schools--at West Virginia University, Virginia Polytechnic Institute and State University, etc. Also, the monthly newsletter of the Hardwood Research Council, Asheville, NC, usually contains notes on recently released studies and reports, many of them with a marketing orientation. The Council also maintains a reprint service for its members; a list of reprints available may be obtained on request.

Trade and industry periodicals also provide good information. Magazines such as the Wood Products Journal, Northern Logger and Timber Processor, Southern Lumberman, etc., often contain valuable articles and columns on topics related to marketing. A less obvious source--but one of the author's favorites--is Fortune magazine. This biweekly includes regular analysis of economic conditions and forecasts of key economic indicators, frequent articles explaining governmental economic policy and its probable effects on industry and business, and, more frequently than might be expected, articles covering major developments in the wood products industries.

Market reports are another information source, though their use is limited and specialized. Since market reports such as the Hardwood Market Report and Ohio Timber Prices tell what has happened recently, rather than what will happen years from now, they are not readily suited to long-term prediction and planning. However, continuous monitoring of market reports to discern any apparent trends, cycles, or other patterns in forest product markets can sometimes be useful in making short-term marketing strategy.

Finally, personal sources of information should not be overlooked. The forest landowner, especially, is urged to take every opportunity to seek information and opinions from consulting, service, industrial, and academic foresters. These professionals hold a wealth of experience and insight, often gained from many years of involvement with forest management and forest product production and marketing. It is worth the landowner's time to seek out these persons and determine what sorts of information and help they can give and at what cost, if any.

Conclusion

Marketing is probably the most neglected aspect of managing and using forest resources. There are several reasons for this. First, forest

management has always been a resource-oriented discipline, with most concentration in both training and practice on measuring and manipulating the resource. Second, as mentioned earlier most forest managers are uncomfortable in dealing with the uncertainties associated with predicting future economic and market conditions. Since prediction over long time periods seems so difficult and unreliable, managers often fall back on expressions of faith: "There has been a market for sawtimber for as long as I remember, so I believe this market will be there in the future." Finally, there is a common viewpoint that studying markets and their economic foundations is so difficult and technical that it is a job for only the highly trained experts.

The explanations, guidelines, and examples in this paper are an attempt to lessen the latter obstacle. The author has tried to approach the subject in a nontechnical, common sense manner, within a framework (the decision model) which if followed will not lead the practitioner astray. There are of course technical details and refinements not covered here that could sharpen the analysis, but one must learn to walk before running is attempted. It is hoped, then, that the reader will find some useful ideas, principles and techniques in this paper.

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Rotation ages 60-70 on coves
80+ on upland sites

1st thining age 40 in Appalachian

CHARACTERISTICS OF AND MANAGEMENT FOR VENEER QUALITY HARDWOOD LOGS

Allen L. Kesner

Log and Timber Buyer
Atlantic Veneer Corporation
Romney, WV 26757

ABSTRACT

Several points concerning veneer quality log requirements, stand management, log management, and price comparisons are discussed. Precise machinery during the manufacture of veneer requires veneer logs of any species to meet six general requirements: a well centered heart, good shape, minimum of internal defects, uniform color and texture, and proper trimming and cleanliness. At present the most popular log length and size is 9 to 10 feet and 16 to 20 inches in diameter. Improvements for forest managers and proper log managment are keys to the future supply of veneer logs. Higher log values provide an excellent incentive to produce veneer logs. Logs from some species can be sold for three to five times the price if sold as veneer versus sawlogs.

Introduction

The majority of us attending this workshop are well aware of timber products such as pulpwood, firewood, rails, mine timber, posts and sawlogs for lumber. I have been asked to develop your awareness another step--hardwood veneer logs. Quality in some form is the key in nearly all timber products produced by our forest. The better the quality the higher the dollar value and more money in everyone's pocket.

We are living in an era in which an increasing population is demanding more and more high quality products manufactured from wood for use in homes and businesses. As this increased demand creates a greater draw on our nation's timber resources, it is important and wise to utilize the trees we harvest to their fullest potential. Production and utilization of veneer is one very important aspect to conserving our limited supply of superior quality trees and logs. Each log that is sliced into veneer can cover 30 or 40 times as much surface area on furniture or panel products than it could if used as solid lumber to create the same products.

The manufacture of high quality veneer is a very exacting art, and logs used for this purpose must meet some very specific requirements. It is the purpose of this paper to define the most important of these

requirements, and to explain their relationship to the manufacture of veneer from logs. An effort will also be made to show what the rewards to log suppliers meeting the requirements for veneer manufacture. Then, in a third section of the paper, some specific suggestions will be presented to show how forest managers, loggers, and mill owners can obtain more and better quality veneer logs.

Characteristics of good veneer logs

First, let us look at six areas of general requirements necessary for a log of any species to meet in order to be utilized for veneer. Some of the requirements to be discussed are important considerations in the mechanical manufacture of veneer while others are directly related to quality and hence, to product value. Although the log requirements presented here are general in nature, it should be remembered that each species has some specific requirements unique to that species.

The first and probably one of the most important veneer log requirements is that of straightness. A log with sweep or crook can present several problems to the veneer plant. Flitching options are greatly reduced if a log is not straight, and this in turn generates other problems including veneer degrade and subsequent lowering in value of the sliced veneer from a sweepy or crooked log. When this type of log is flitched and sliced, heart defects (present in any log) will appear earlier in both flitches. Of course veneer slices with defects do not bring nearly the price of defect-free slices. Another problem that arises when a crooked log is sliced is that of grain alteration. Certain grain patterns are prized more highly than others by furniture and panel makers, and these patterns cannot be obtained from logs which are not straight. Again, this results in veneer that is of a lower value than if it were from a straight log with the proper grain pattern. Unusual or defective grain patterns can lower the value of a flitch by 50 to 75% or more. Not only should the log be free of crook or sweep, but the grain should run straight within the log. Some logs have a grain pattern that runs in a spiral or twist configuration. This type of defect can cause both an alteration of the grain pattern and a problem in the drying process since veneer slices with this characteristic tend to roll or pull apart along the grain when dried.

A second requirement for veneer logs is that the heart be well centered in both ends, and that it run straight within the log. Flitches need to be as nearly equal as possible to ensure optimum yield and a desirable grain pattern which in turn makes the log price higher at sale time. Also, as with a crooked log, a heart being off-center can cause heart defects to appear in a greater percentage of veneer sheets, thereby lowering the value of the entire log.

The next criterion that must be met by a veneer log is that of good shape. Although it is the nature of logs to be unique in themselves, it is necessary that they be as nearly round as possible, and for the growth rings to be as concentric and evenly spaced as possible. Veneer sheets dry in pretty much the same configuration as the log is

shaped before it is flitched. A log that has rope-like ridges or creases will produce veneer that tends to wrinkle or break when it is dried. Logs having this defect usually have more unusual "wild" grain, and thus are less valuable than logs exhibiting regular grain patterns which produce slices that do not present drying problems. When shape is being considered, excessive taper is another undesirable trait for a log to have as this will result in both handling and manufacturing difficulties. A log with too much taper will yield veneer with a very exaggerated grain pattern not very representative of the species being sliced.

It is relatively easy to determine whether a log meets the first three requirements or not, but the fourth is much harder to determine, and requires a great deal more expertise on the part of the log buyer. It is necessary that a veneer log have a minimum of internal defects so that the smallest possible percentage of veneer sheets are adversely affected. Since the defects are internal and cannot be readily seen, the buyer must use external indicators to make a determination of this requirement. One indicator of prime importance is the bark. An experienced inspector can translate certain variations in bark color and patterns into the presence of knots, ingrown bark, "wild" grain, peck, worms, canker, pin knots, grubs, and other degrading defects. With a careful inspection of the log ends, mineral, shake, rot, flagworms, and poor color can be detected. Sometimes a pairing of observations, such as poor color in the end of the log and a particular variation in the bark pattern can tell the inspector a great deal about the quality of veneer a particular log will produce. Inspection of the bark and butt of a log will also reveal other defects such as frost cracks, lightning strikes, or even the presence of metal objects imbedded in the log. A determination of these problems either before the log is utilized or purchased for veneer can save a veneer mill a good deal of money.

Another very important veneer log requirement is that of uniform color and texture characteristic of the species. Each species has definite desirable traits that must be exemplified by a log before it can be used for high quality veneer. The color and texture displayed by the end of a log should be uniform over the entire surface observed. In most cases, ring increments of about 1/8-inch will result in a proper color and texture for a particular species. Rings closer than this will result in a dark color, and is an indication that worms or other internal defects will likely appear when the log is opened. Logs from these trees that grew much faster than this will produce veneer that has "wild" grain patterns, which is usually not uniform in color. Logs with ring increments of 6 rings/inch or less contain wood which is very hard, and difficult to slice and dry properly. A defect occurring in a log with a dark color and poor texture will usually cause degrade over a larger area of that log than does a similar defect in a log with the proper color and ring increments. Veneer from a poorly colored log will not price nearly as well as slices of a log with excellent color, as poor colored logs are often worth only half the value of a log with excellent color and texture. In the works of Herman Meyer, President of Atlantic Veneer, US, "In veneer, color and texture is everything".

The last area of general requirements that a veneer log should meet is that of log trimming and cleanliness. Although this may seem unimportant to some, I am including it because it is an area which can directly affect the value of a parcel of logs. Logs presented for a buyer's inspection should be as clean as possible, free of mud, snow, or ice. Root swells should be trimmed off, butts should be nearly flush, and the ends of the log should be clipped clean. No buyer wants to purchase something as variable as logs if they cannot be properly inspected. If the seller has good quality logs that are clean and well trimmed, the buyer can see this and will be more inclined to pay a better price. Since most buyers are cautious, they will assume that very muddy logs contain defects they cannot see, and will compensate for this by either rejecting a greater number of logs, or lowering the price of the parcel to adjust for the defects they cannot see.

Logs are not rejected from veneer parcels simply at the whim of a buyer. Each of the requirements discussed has a logical purpose relating either to the mechanical characteristics or the quality of a log. Veneer logs must meet these criteria that are much more rigid than for high grade sawlogs because they cannot simply rotate logs to another face if defects appear during processing, as can be done with sawlogs. Once a log is flitched for veneer, it can be placed on the slicer in a very limited number of ways, and must therefore have as few limiting factors as possible to degrade the veneer sheets in order that a high quality yield may be obtained. Buyers reject logs when they fail to meet all of the necessary criteria.

It should be noticed that "big" is not listed as one of the major assets of a veneer log. It is more desirable to obtain logs of average size (16 to 20 inches) that meet the listed requirements, than to have a larger log that does not. This is not to say that big logs are not in demand for veneer, because certain types of grain patterns such as rift requires large logs in order to be obtained. Big logs (over 24 inches) can present manufacturing difficulties if they are very far from perfect since additional time and equipment must be used to process them. It must also be remembered that very large trees have had more time to heal over defects that occurred years ago, but which are no longer apparent on the bark. Therefore, it is more difficult to determine the true quality of large trees, especially before they are harvested.

Current market trends and demands dictate the most popular log sizes so that a minimum of waste is realized. At present, log lengths most favored by a majority of buyers worldwide are in the 8- to 12-foot range, with 9- and 10-foot being most preferred. Multiples of these lengths are purchased by most veneer companies, although some will buy only butt logs 12 feet or shorter. Some larger logs are utilized in the 15- to 20-foot range, but this is on a limited basis. It is difficult to obtain logs of good enough quality that can be sliced in long lengths because most are not straight enough, or free of defects on the top portion. Large logs that are sliced in 15- to 20-foot

sections that yield architectural quality veneer command very good prices at sale time. Veneer from these logs may bring 20 to 30% more than standard AA grade.

The most utilized log diameters are currently in the 15- to 20-inch range, primarily due to availability of the resource. It is much easier to obtain logs of good quality within this range than it is to find either larger or smaller logs of comparable quality. With advances made in veneer production, more and more small diameter logs (12 to 15 inches) are being utilized. But it is as difficult to find suitable small logs to slice as it is to locate large ones.

Price Comparisons of Veneer Logs Versus Sawlogs

There are some excellent monetary incentives to produce veneer logs, both for the forest landowner, and for the sawmill buying logs from loggers. These incentives are in the form of higher stumpage prices for the landowner, or in better log prices for mills who sell veneer logs. It should be kept in mind that a veneer rotation does not have to be any longer than a mature sawlog rotation, but that the return upon harvest is a good deal higher. For example, present stumpage prices for average sawtimber stands fall in the range of $80 to $100/M bf. Timber stands that have a high percentage of veneer trees presently can bring the landowner $100 to $300/M bf, depending on the species mix. This is a substantial difference in return for dollars spent on the same length rotation.

Now let's compare some specifics on log prices. Prime red oak sawlogs are currently bringing from $400 to $500/M bf delivered to sawmills. Many of these logs, if properly prepared, will bring $700 to $1,000/M bf if sold for veneer. In many cases, this price is paid at the mill or purchase site, with delivery costs being additional. At the same time, red oak FAS lumber is listed in the Hardwood Market Report at $715/M bf. Although some mills will receive a premium to deliver the lumber, production costs must be deducted, bringing the actual profit realized by the mill well below that realized on veneer logs. Prime white oak sawlogs are currently bringing only $300 to $400/M bf while good quality white oak veneer logs can sell for three to five times that amount. Prime white ash sawlogs are presently bringing $300 to $400/M bf while prices paid for high quality white ash veneer logs are in the $1,000 to $1,800/M bf range. Black walnut sawlogs at present will bring around $500 to $600/M bf whereas, black walnut veneer logs can sell regularly for $1,000 to $4,000/M bf. These are just some examples of the high values veneer logs can sell for compared to what the same logs would be worth if they were classified as sawlogs. There is quite a difference, although it must be kept in mind that not every prime sawlog is suitable for veneer, and hence, not every prime sawlog of any species would double or triple in value if sold for veneer.

Recommendations to Ensure Future Veneer Logs

What can forest and mill managers do to improve and ensure future supplies of veneer logs, while increasing the value of their timber stands and log piles? The answer has two parts, one that can be affected most by the forest manager, and the other by loggers and mill managers. The first part of the answer deals mostly with proper management of potential veneer stands and has three areas of consideration.

Forest Manager

Recognizing veneer areas. First, a forest manager must recognize timber stands that are determined to have a high percentage of trees exhibiting present or future veneer qualities. It should be noted that not all of the trees in a stand need to be of veneer quality in order to consider a stand for veneer management. This situation would be the exception rather than the norm. The forest manager should instead look for smaller fairly even-aged stands containing a high percentage of "growthy" stems with a minimum of external defects evident. The higher quality trees within the stand should be closely examined to determine if most are actually defect-free on all four faces. A common mistake is to walk through a stand and observe a majority of the trees from a distance too great to really determine whether most of the trees are free of defects or not. Areas should be selected where trees have thin, smooth bark running in straight patterns along the boles. The average height to the first visible defects should be noted, and if it is lower than 10 to 12 feet, the stand should not be considered. Particularly in red oak stands, the boles should be checked for incidence of frost crack, since this proves to be a problem in some areas where this species attains the best growth rate for veneer.

The smart manager can reduce the time needed to locate potential veneer stands by limiting his search to the right types of areas. A larger number of good veneer areas occur primarily on northern, northeastern, and eastern aspects, and in cove situations. Middle and lower slopes usually produce taller, straighter stems having less defects. High flats which collect water and allow for good growth rate areas are also good areas to consider. Extremely steep, rocky slopes should be avoided unless an excellent stand is already in place, since areas such as this usually produce trees with excessive sweep or crook in their butt log. These steep areas also produce a greater number of logs with misshapen butts and off-center hearts. Areas managed for black cherry veneer should only be considered if they are 2,800 to 3,000 feet in elevation or higher. Black cherry at elevations lower than this usually contains an excess of gum (resin pockets), eliminating many trees from being used for high grade veneer.

There are several aids the forester can use to recognize potential veneer areas. Aspect, slope position, and elevation have already been mentioned. Soil is another factor that can be considered. Soils that

are moderately deep and well drained are a must for proper growth rates to occur. Soils that are poorly drained will produce logs with a color that is inferior and mottled. Chert or limestone based soils produce logs of superior color and texture in nearly all veneer species.

Timber types and associate species can be used as an indication of veneer potential. For example, it has been my observation that good white oak usually is found in association with average red or black oak, and reasonably good hickory, an indication that it takes slightly drier conditions to obtain the proper ring increments in white oak than it does in red oak. White oak found on good red oak sites tends to grow too fast and develops "wild" grain and a greater number of epicormic sprouts and dormant buds. Red oak on good white oak sites will many times display a higher incidence of mineral and more pin knots.

The best quality red oak is usually found associated with high quality yellow-poplar and black cherry. At the higher elevations where better black cherry is found, red oak does tend to be generally shorter, and white oak is present in very small quantities and has poor quality.

Ash throughout most of West Virginia tends to be too brown for use as white ash veneer. Better ash is usually found along the eastern border of the state and throughout a large portion of northern Virginia, Maryland, and central Pennsylvania. These areas have in common an abundance of limestone outcroppings on which is found a greater number of ash trees having very small brown hearts. In many cases, the best quality white ash is growing in proximity with black locust and redbud.

One of the most valuable veneer species, black walnut, also reaches a peak in quality on limestone base soils of eastern West Virginia and in the upper Shenandoah Valley of Virginia. When found growing in limestone areas, this species has a much lower incidence of internal defects such as peck and canker, and the color is more often the "mouse gray" that is favored over extremely dark colored logs. When in association with high quality red oak or black cherry, black walnut usually is excessively sappy and often contains more peck, canker, and ingrown bark.

Silvicultural techniques. A second area the forest manager must consider in managing stands for veneer is that of silvicultural techniques that will improve individual tree quality. Of course, thinning for more rapid growth is one of the first practices that is usually suggested to improve a timber stand. It is my belief that unless a potential veneer stand is recognized and the thinning done very early in the rotation, this practice should not be used. Thinning a stand being managed for veneer any later than during the early pole stage will cause a change in growth rate of the stand, which would degrade the logs at harvest by resulting in multi-texture veneer. The veneer sheets tend to break along the growth increment where the change occurs. This, of course, greatly lowers the value of

the veneer produced from logs or results in the log being rejected for veneer. Color will also be adversely affected by an abrupt change in growth brought about by a late thinning since wood grown at different rates will vary in color.

Pruning is another management tool usually thought of in association with upgrading veneer trees. Although I believe pruning is not a very effective method of improving red oak stands, I do feel it may serve a valid purpose in higher value species such as black walnut and white oak. Again though, it must be done at a fairly early age in order to keep the pruning scars as near the heart as possible. Also, one should not "reach for the sky" when pruning. Better results will be obtained if those doing the pruning strive for a clean 10 or 12 feet in length. This will allow the young trees to maintain a healthy top of sufficient size to ensure a uniform growth rate, and will minimize the amount and cost of work needed to complete the pruning operation.

Protection. The third and probably most important aspect to be considered by a forest manager is that of protection. This is an area where I feel more can be done for a greater number of trees, and with less cost, than with either of the other two methods discussed. It has been my experience that a stand of high density on a good site will pretty much take care of pruning and proper growth rates itself. One of the most beneficial things a manager can do, once a potential veneer stand is recognized, is to protect it from factors that could adversely affect the rate of growth or the amount of light reaching the tree stems. A young veneer stand must be protected from being opened up too much since rapid or excessive opening would result in a high incidence of epicormic sprouting, and a slowing of the natural pruning process. These two factors, along with the mechanical damage that would result during a thinning could degrade many logs from a veneer to a prime or even a number two sawlog, changing the value of these logs downward by 50% or more. For example, an $800/M bf veneer log could very easily drop in value to a $300 or $400 log as a result of mechanical damage or increase epicormic sprout defects.

Where possible, forest road construction should be routed away from stands being managed for veneer since road openings can cause many of the same problems associated with a late thinning. Environmental shock can also become a factor for several yards into stands along each side of a road opening. In many cases this can result in one or several dark growth rings in affected trees, and it follows that logs from these trees would probably not be selected for use in veneer production.

For the small woodlot manager, a great deal can be accomplished if potential veneer trees are protected from livestock grazing or loitering around them. The prolonged presence of livestock around trees will usually result in dark stains in the wood, and many small scars around the lower portion of the stems, thereby eliminating these trees from being considered for veneer. Therefore, fencing livestock away from stands containing high quality trees is a very valid method of increasing the value of a woodlot.

Wildfire is another enemy of any timber stand, and especially one that is being managed for veneer. Of course, many severe fire scars are evident in a stand that has been subjected to a hot fire, and a less obvious but important defect is the dark ring that results in the wood of many trees that have been exposed to only a light burn. It is difficult for a tree to heal over a fire wound, and a "wild" grain pattern is formed for many years after the wound itself is covered. Since some stands currently being harvested were present during the early part of this century when wildfire burned over large acreages, the large number of trees affected is clear evidence that not only veneer stands, but all timber stands need protection from fire.

One other area that forest managers might consider in veneer management involves making well placed clearcuts on good sites that have desirable species regeneration in place. Once the cuts are made, the tree tops and other slash should be left intact. This logging slash will afford many young saplings protection from deer browsing the tops and causing crooked growth patterns. Unbrowsed young trees will develop at a more rapid and uniform rate, resulting in a longer bole with fewer defects.

Log Management

As stated earlier, the second part of answering the question of how to improve and ensure future supplies of veneer logs concerns loggers and mill personnel. Foresters and mill management can increase the volume of logs meeting veneer specifications through education of the people who actually harvest the trees. This area is as important as proper stand management. It does absolutely no good to grow a veneer tree and have it ruined at harvest.

Not every logging contractor has the expertise to properly harvest a timber stand containing a high percentage of veneer quality trees. Once the proper contractor has been selected, there are four main areas of log management in which training should be given. The first of these is recognition of veneer logs. Extra time and special care need not be spent on trees with obvious external defects. The requirements for a veneer log should be clearly explained not only to the logging superintendent, but to those doing the felling and bucking as well.

Once a tree is determined to warrant special attention, certain precautions should be taken to maintain veneer quality. Notches should be kept as small as practicable to prevent unnecessary loss of length. It is very easy to lose a foot in length because of an excessive notch. This could result in $8 to $10 loss on an average size red oak log and double or triple that amount on a white oak, white ash, or a high quality black walnut log of the same size. It is also very important to fell a good tree in such a manner that no splinters are pulled from the log, and that the log is not split. An experienced feller should be used to harvest veneer trees.

A third area of importance in educating for good log management is that of proper bucking. Probably more logs are rejected from being veneer and more wood and time is wasted due to improper bucking than from natural defects. It has been my experience that loggers tend to cut logs 2 to 4 feet too long to make good veneer. A very popular length with loggers is 12 feet. In many cases logs of this length are too crooked, or defects are present in the top 2 or 3 feet. When this situation exists, the log must either be rejected, or a block cut off and wasted in order to obtain a veneer log. It would be better if logs intended to be shown for veneer were bucked in lengths 16 feet and longer. This enables the veneer inspector to mark off a veneer log of the proper length and still allow for a sawlog on the top instead of a short block. If logs are bucked to length for veneer by the logger, obvious defects and crooks should not be included.

The last area of proper log management needing consideration is that of trimming and cleaning. Once a tree is felled, and a potential veneer log is being prepared, there are some things that should be done to accomplish this. All protruding root swells should be trimmed before the tree is skidded. Small shakes or other butt defects (if any) should be cut off before the log is bucked up. This allows for a longer sawlog to be obtained if the defect does not clear up. Once the tree or log is skidded, both ends should be clipped free of mud so the buyer can inspect it quickly and easily.

If these points are followed, when sale time comes there will be fewer logs to handle and costs will be reduced. A higher percentage of logs presented to the buyer will sell, and the buyer will be more inclined to pay a better price if very few bad logs are seen, and he is able to make an inspection in a prompt manner. Most veneer buyers observe not only the logs they plan to buy, but also the ones they reject. If a large number of defective logs are shown, the buyer will assume the logs he is taking may not be as good a quality as they appear externally. This will be reflected in a lower price being offered for the logs.

Summary

Several points concerning veneer log requirements, stand management for veneer, price comparisons, and log management have been presented. The production of veneer is an important method of conserving our high quality timber resources. The manufacture of veneer requires very precise machining, making it necessary for veneer logs of any species to meet six general requirements: straightness, a well centered heart, good shape, a minimum of internal defects, uniform color and texture, and proper trimming and cleanliness. All of these specifications are directly related either to machining characteristics or veneer quality. At present, the most popular log length and size is 9 to 10 feet and 16 to 20 inches in diameter. Large logs are desirable only if they meet veneer log standards.

Higher log values at sale time provide an excellent incentive to produce veneer logs. Some species can bring 50% or even three to five times as much if sold for veneer rather than sawlogs.

There are some areas in which forest managers can improve and ensure the future supply of veneer logs. Some of these areas include recognition of potential veneer stands and subsequent use of thinning, pruning, and protection methods to obtain maximum volumes from these stands. Proper log management can directly affect the price received for log parcels harvested from veneer stands. If veneer trees are recognized and then properly felled, bucked, and trimmed into desired lengths, they are more likely to sell, and will usually command a better price than improperly prepared logs.

High quality veneer does not just happen. It must be planned and managed for, and these can result in greater returns for all involved in the chain of production. This same logic applies to all timber products produced by forest stands. Quality products must be planned products and their management emphasized.

CULTURAL PRACTICES IN APPALACHIAN HARDWOOD SAPLING STANDS--ARE THEY WORTHWHILE?

Gary W. Miller

Economist
USDA Forest Service
Northeastern Forest Experiment Station
Parsons, WV 26287

ABSTRACT

Forest managers often question the economic feasibility of cultural practices in hardwood sapling stands. Investment factors, including initial treatment cost, required rate of return, investment period, and stand response to treatment are discussed in terms of how they affect the outcome of early investments in even-aged hardwood stands. Attention is focused on precommercial thinning in hardwood sapling stands. Guidelines are provided to indicate the maximum allowable treatment cost under which precommercial thinning can be profitable. Data suggest that precommercial thinning is economical only in young stands containing relatively high-value species.

Introduction

Forest managers often question the need for cultural practices in hardwood sapling stands.

1. What can be gained by applying cultural treatments in young stands?

2. What is the rate of return on early precommercial cultural treatments?

3. Are cultural treatments in hardwood sapling stands economical?

Unfortunately, there are no universal answers to these important questions. A precommercial treatment in young hardwood stands is essentially a direct investment in timber production, and the profitability of that investment depends on many factors. These factors include initial treatment cost, required rate of return, investment period, and stand response to treatment. This paper provides basic information on each of the four investment factors. Guidelines are provided to assist forest managers in evaluating precommercial thinnings in hardwood stands. The guidelines indicate the maximum allowable treatment cost under which precommercial

thinning can be profitable--they indicate when early investments in thinning earn just as much money as other similar investments available to the landowner.

Initial Treatment Cost

Cultural practices in very young hardwood stands rarely yield merchantable products. Stems cut during weedings, cleanings, and crop-tree release are usually unmerchantable due to small average size and the high cost of removing, transporting, and processing the material. In herbicide treatments, unwanted stems are left standing in the woods. Thus, for most treatments in sapling stands, there is no immediate income to offset some of the treatment cost.

Regardless of the name given to a particular precommercial cultural practice, the effect on the landowner's pocket book is the same--the treatment costs money and the money spent should be viewed as an investment in an immature timber stand. Most precommercial cultural practices are timber stand improvement (TSI) operations such as removing undesirable trees or species and vines. Also included are precommercial thinnings to control stand density and redistribute growth to desirable residual stems. The goal in each of these practices is to provide the landowner with higher stumpage revenues in the future as a direct result of the early investment.

To determine the economic feasibility of a proposed cultural practice in a given stand, the forest manager first needs to know the total cost of the treatment. This provides a basis for determining the residual stand response needed in the future to recover the initial investment. In addition to the actual cost of carrying out the operation, the landowner must consider the cost of professional services directly related to the treatment. These services may include evaluating the initial condition of the stand and/or marking trees in the stand. When cost sharing is available, the total cost to the landowner will be reduced. The total cost to the landowner should include all expenditures related to the treatment minus any immediate income or cost-sharing that reduce the landowner's out-of-pocket expenses.

The total cost of a particular cultural practice will vary depending on the initial condition of the stand and the method employed to complete the operation. For example, vine control in immature stands can cost from $5 to $50/acre, depending on the severity of the vine problem and the method used to eliminate the vines (Smith 1984). Table 1 shows the possible range in total treatment cost for selected precommercial cultural practices. Those figures were derived from recent cost studies which provided treatment cost indicators such as man-hours; machine hours, chemical usage rates, and fuel requirements (Miller 1984a, b). Ranges are presented to illustrate the variability of investments in young hardwood stands. For some precommercial practices, the ranges are relatively narrow. A crop tree release treatment in a 15- to 20-year-old stand, for example, could cost from $28 to $45/acre using chain saw felling as the treatment method.

However, a chemical release in the same stand could cost from $38 to $75/acre.

Table 1. Treatment costs per acre for selected precommercial cultural practices.

Treatment	Method	Cost/acre
		Dollars
Crop-tree release	Chain saw felling	28-45
Crop-tree release	Stem injection	38-60
Crop-tree release	Basal spraying	47-75
Vine control	Cutting	5-50

Required Rate of Return

A precommercial cultural treatment in a young hardwood stand is only one of many investment opportunities available to a woodland owner. For example, the landowner could sell the woodland and invest the proceeds in stocks or bonds. However, for most landowners considering precommercial thinning in a young stand, the decision to continue producing hardwood timber has already been made. Thus, the landowner has to decide between two courses of action--invest in a precommercial thinning or allow the young stand to grow undisturbed.

To evaluate a proposed investment in a hardwood sapling stand, the forest owner or manager must identify the "required rate of return." The required rate of return can be determined by the source of the money used to pay for the stand treatment. If the landowner withdraws money from savings to pay for the treatment, the thinning should provide a return at least equal to the interest earned in the savings account. If the landowner takes out a loan to finance the treatment, the thinning should provide a return at least equal to the interest paid on the loan. To be economical, a long-term forestry investment is "required" to earn at least this rate of return. Otherwise, the landowner is losing money by investing in a precommercial thinning.

For most landowners, I recommend using 9 or 10% as the required rate of return. Sometimes, nonmonetary returns such as the development of wildlife habitat may justify a lower rate. The landowner may feel that a 7.5% return is satisfactory considering other management objectives. But from a strict economic standpoint, the required rate of return on precommercial cultural practices should be determined by the individual landowner's sources of funding.

Real rates vs market rates of return

Market rates are easy to understand because we all deal with them in our personal finances. Interest rates on car loans, mortgages, savings accounts, and money markets are all market rates. A real rate of return simply indicates how much an investment will earn without the effects of inflation (Foster 1984). This is useful in analyzing long-term forestry investments because with real rates of return there is no need to predict how inflation will affect stumpage prices over time. The following formula is used to compute the required real rate of return:

$$1 + r = (1 = m)/(1 + i)$$

where

r = decimal equivalent cf the real rate
m = decimal equivalent cf the market rate
i = decimal equivalent cf the inflation rate.

If inflation is expected to be 5%, and the required market rate of return is 9%, then the required real rate of return is about 4%. In other words, a forestry investment that earns a 4% real rate of return is equivalent to one that earns a 9% market rate of return when the annual inflation rate is expected to average 5% in the future.

Real rates of return are useful for computing the future growth and stand value increase needed for a profitable treatment without the effects of inflation. Today's stumpage prices can be used to determine the future volume increases needed to recover the initial investment. This simplifies the analysis and makes it easier to evaluate the treatment in terms of diameter growth, volume growth, and changes in species composition familiar to most foresters.

Though the required rate of return may not be the same for two landowners considering the same investment, the analytical procedure for evaluating a precommercial culture practice is essentially the same. The forest owner or manager must first determine the total cost of the investment and then determine the required rate of return on money invested in the stand. Once these two investment factors are defined, the analysis focuses on predicting the residual stand response and the potential for increasing net stumpage revenues in the future. The success of the investment will depend on the amount of stand value increase and the length of time the landowner must wait for the added value.

The Investment Period

The objective of a precommercial cultural practice is to increase the landowner's net income from the stand at some time in the future. As with all investments, the landowner must wait a given period of time for the returns on the investment. The length of time the landowner must wait for the added income is called the "investment period."

Together with the cost of the proposed cultural practice and the landowner's required rate of return, the investment period determines how much stand value increase is needed for an economical investment.

Precommercial cultural practices entail relatively long investment periods, from about 20 to 70 years depending on the initial age of the treated stand. For a given treatment cost and required rate of return, the longer the investment period, the greater the return must be to result in an economical investment. But estimating the exact length of investment period can be difficult. Thus, the length of the investment period depends on the owner's expectations about the growth response of the treated stand and the size of merchantable produces in local markets.

Because these factors are extremely variable among individual timber stands, it is wise to evaluate a particular cultural treatment using a range of investment periods. Using a range of investment periods simply provides more information for evaluating the proposed investment. For example, I would bracket the proposed investment period with two more investment periods--one 10 to 15 years shorter and one 10 to 15 years longer. This provides the landowner with an idea of future income in the event that harvests must be made sooner or later than originally planned. This also provides a clear picture of how the outcome of the proposed investment will be affected by the estimated growth response and the time required for future crop trees to reach merchantable size classes.

Stand Response to Treatment

Most young hardwood stands increase in value over time without help from a well-meaning forest manager. Simply, as the trees get larger, they are worth more money. The trick is to get the higher quality, more valuable species to be the larger trees. By favoring the most valuable trees in the stand through an early cultural treatment, the landowner expects to increase the revenues from future harvests. Because an early cultural treatment requires a cash investment that must be held for a relatively long period of time, the increase in future harvest revenues must be large enough to earn the landowner's required rate of return. Thus, the initial treatment cost, the investment period, and the required rate of return can be used to compute the return needed for an economical investment.

The dollar return needed for an economical investment is the difference between the future value of the treated stand and the future value of the untreated stand. In other words, it is the stand value increase that occurs as a direct result of the treatment. Once the needed increase in value has been defined, the forest manager can determine if such an increase in revenues is likely.

The dollar return needed to earn the required rate of return on the initial investment is computed by the formula:

$$FV = PV\ (1 + r)^n$$

where PV = initial investment in dollars (present value)

r = required real rate of return expressed as a decimal

n = investment period in years

FV = needed stand value increase in dollars (future value).

In Table 2, the stand value increase needed to earn a 4% real rate of return is presented for a range of treatment costs and investment periods. For example, if a proposed cultural treatment costs $30/acre, and the final harvest will not occur for 40 years, the treated stand must be worth $144 more per acre than the untreated stand at the final harvest, assuming no other intermediate cuttings are made.

Table 2. Stand value increase needed to earn a 4 percent real rate of return.

Investment period (years)	Initial treatment cost							
	10	20	30	40	50	60	70	80
	Dollars/acre							
10	15	30	44	59	74	89	104	118
15	18	36	54	72	90	108	126	144
20	22	44	66	88	110	131	153	175
25	27	53	80	107	133	160	187	213
30	32	65	97	130	162	195	227	259
35	39	79	118	158	197	237	276	316
40	48	96	144	192	240	288	336	384
45	58	117	175	234	292	350	409	467
50	71	142	213	284	355	426	497	569
55	86	173	259	346	432	519	605	692
60	105	210	316	421	526	631	736	842
65	128	256	384	512	640	768	896	1,024
70	156	311	467	623	779	934	1,090	1,246
75	189	379	568	758	947	1,137	1,326	1,516
80	230	461	691	922	1,152	1,383	1,613	1,844

Potential benefits of precommercial cultural practices

The final step in analyzing a proposed investment in a young stand is to determine the stand value increase that will result from the treatment being considered. Initially, the potential benefits of the treatment can be expressed in physical terms such as increased diameter growth and increased merchantable volume at final harvest. To complete the analysis, however, the benefits must be converted to dollars and compared with the dollar return needed for an economical investment. This step in the analysis requires the forest manager to make certain assumptions about the stand's response to treatment. In some instances, very little information is available to predict the outcome of a cultural treatment. But in most cases, published results of silvicultural studies can be used to make realistic assumptions about growth and value changes in treated stands.

Another way to analyze the proposed treatment is to determine the growth response needed for an economical investment. The future dollar return needed for an economical investment can be converted to board-foot volume or diameter growth using real stumpage prices. Once the needed growth response is defined, the forest manager can determine if such a response is likely based on current growth and yield information.

Figure 1 illustrates how this procedure can be used to evaluate a proposed precommercial thinning in a young hardwood stand. In this example, three graphs are combined into a nomogram (Seymour and Gadzik 1985) to compute the diameter-growth response needed for an economical treatment. Each graph represents a step in the analysis. The first graph (upper right) is used to compute the dollar return needed to earn a 4% real rate of return on the investment. The second graph (upper left) is used to determine the equivalent board-foot volume based on current stumpage prices. The third graph (lower left) is used to determine the increase in average diameter of future crop trees needed for an economical treatment.

To use the nomogram, enter the top of the first graph (Figure 1, upper right) at the appropriate treatment cost and draw a vertical line down to the curve that corresponds to the estimated investment period. In this example, the thinning cost is $30/acre and the estimated investment period is 40 years. At point A, the future dollar return needed to earn a 4% real rate of return, $144/acre is shown at the left. To determine the needed increase in stand volume, move horizontally from point A to the left, stopping at the curve that corresponds to the current stumpage price. In this example, the current stumpage price is $75/thousand board feet (M bf) and it is assumed that there will be no real increase in stumpage prices during the investment period. At point B, the needed increase in volume, about 1.9 M bf/acre, is shown at the bottom. To determine the needed increase in diameter, draw a vertical line from point B down to the curve that corresponds to the projected merchantable height of future

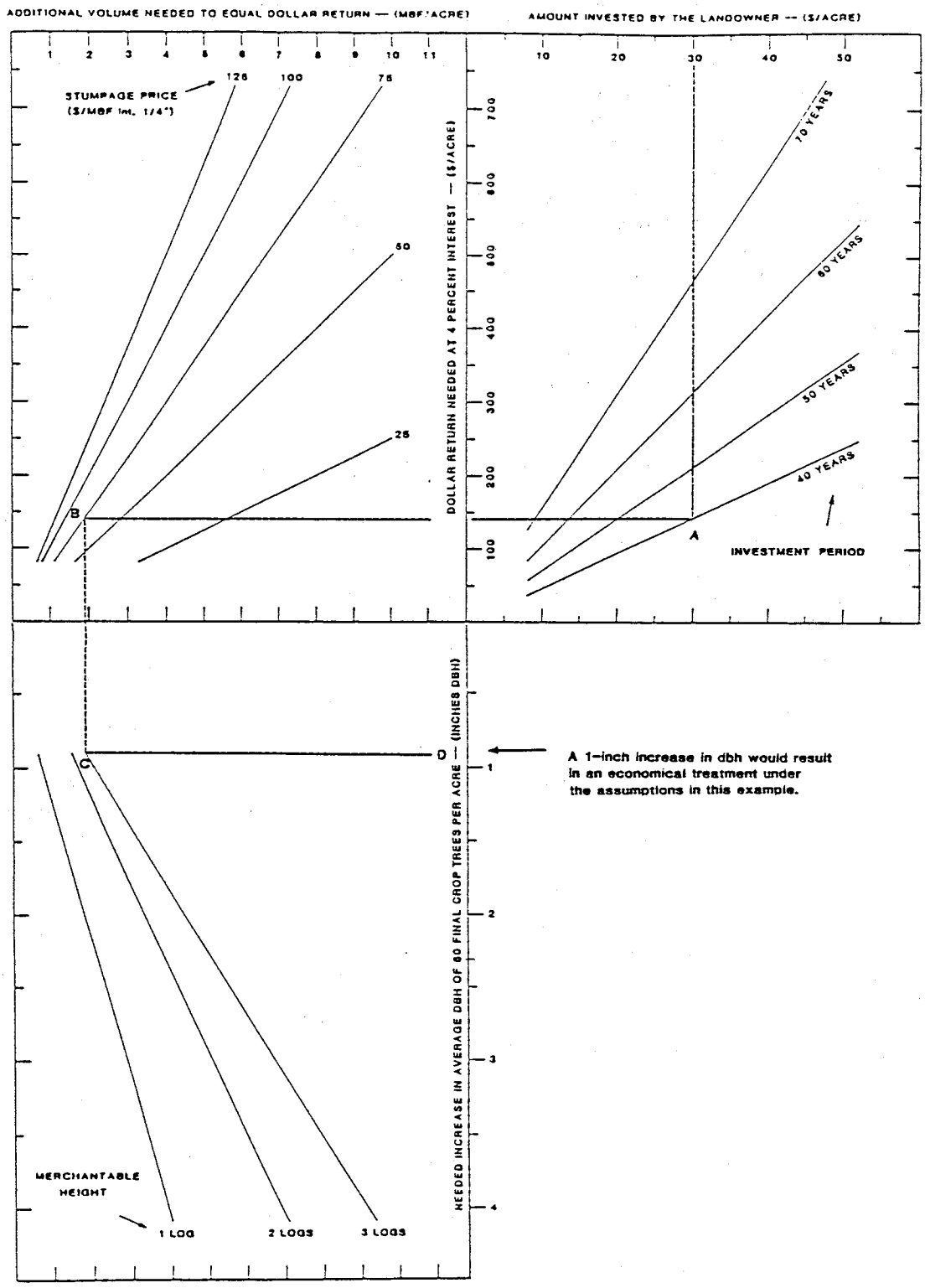


Figure 1. Sample graphical computation of the diameter growth response needed to earn a 4 percent real rate of return from precommercial thinning with an initial cost of $30 per acre.

crop trees. In this example, the projected merchantable height of future crop trees is 3 logs (48 feet). At point C, the needed increase in diameter at breast height (dbh) is shown at the right. Point D indicates that a 1-inch increase in the average diameter of future crop trees would provide the volume increase and dollar return needed for an economical investment.

The third graph (Figure 1, lower left) is based on the assumption that the future stand will contain 60 crop trees/acre that average 16 inches dbh without a precommercial thinning. In the example, precommercial thinning must result in a 1-inch increase in average dbh for an economical treatment. This will increase the merchantable stand volume and provide the additional stumpage revenues needed for a 4 percent real rate of return on the initial amount invested in precommercial thinning. The forest manager considering this treatment must now determine if a 1-inch increase in the average dbh of future crop trees is likely.

Precommercial thinning treatments in Appalachian hardwood sapling stands <10 years old have not resulted in significant increases in individual-tree diameter growth (Smith 1979; Beck 1977; Trimble 1973; Hilt and Dale 1982). In 10- to 20-year-old stands, however, diameter growth increased as a result of crop-tree release and other precommercial thinning techniques (Della-Bianca 1975; Church 1955; Smith and Lamson 1983; Stoeckeler and Arbogast 1947). While the diameter growth of selected trees can be increased by early cultural treatments, evidence suggests that the response is short-lived. Thinned trees grow significantly faster than unthinned trees for a maximum of 10 years. After 10 years, crop trees in the thinned stand are larger than trees in the unthinned stand, but the future growth of trees in both stands is about the same. Thus, the major benefit of an early thinning is a slight increase in the average diameter of future crop trees. On the basis of current information, the average diameter of selected crop trees can be increased by a maximum of 1.0 to 1.5 inches by crop-tree release. This means that at any point in time beyond the initial treatment period (10 years), released trees will be 1.0 to 1.5 inches larger than their unreleased counterparts.

What does this mean in terms of stand value added by the treatment? Since tree volume is a function of dbh, the growth response of released crop trees can be converted to board-foot volume and value. A 1-inch difference in dbh results in a difference of about 35 board feet (International 1/4-inch rule)/tree for trees 16 inches dbh with a merchantable height of 3 logs. In a stand with approximately 60 crop trees/acre, the early cultural treatment could add about 2,000 board feet/acre at the final harvest. Assuming a stumpage price of $75/M bf, the treatment could increase future harvest revenues by $150/acre. So, it appears that the precommercial thinning in this example can provide the landowner with a 4% real rate of return. The needed growth response is not beyond the capability of a young hardwood stand.

The benefits associated with other types of precommercial cultural practices are more difficult to quantify. Controlling grapevines in a sapling stand reduces the number of trees with broken crowns later in the life of the stand. The benefits associated with investments in grapevine control are actually a reduction in the number of lost crop trees or a reduction in lost growth on trees that survive but grow slowly due to the presence of vines. To evaluate the investment, the forest manager must estimate the total dollar value of losses reduced by early vine control. In a stand with a severe vine problem, the reduction in losses may be substantial, but the cost to treat a severe vine problem is also substantial. Conversely, a stand with few vines/acre will not require a large investment to control the vines, but the reduction in future losses resulting from the treatment will also be small.

Thus, it is extremely helpful to know what must be gained in the future to recover an investment today. By quantifying the future return needed to recover the initial investment, the forest manager knows how much he or she can afford to put into vine control. If the needed gain is beyond the biological capability of the stand, the forest manager can avoid the proposed investment and earn a higher return in an alternative investment.

Economic guidelines

Precommercial thinning is the most common cultural practice considered in young Appalachian hardwood stands. The objective in precommercial thinning is to increase the future stand value by favoring the most desirable trees in the stand. The landowner hopes to increase future harvest revenues by investing money in the young stand. Most cultural practices in hardwood sapling stands should be evaluated using a 4% real rate of return. This is equivalent to a market rate of 9 or 10% if inflation averages 5 or 6% in the future. To assist forest managers in evaluating cultural practices in young hardwood stands, economic guidelines were developed for precommercial thinning. The guidelines indicate the range of circumstances under which these treatments will earn a 4% real rate of return.

Current silvicultural information indicates that precommercial thinning can increase the dbh of future crop trees by about 1.0 to 1.5 inches. Because the potential gain in tree diameter is limited, the potential increase in merchantable volume and stand value is also limited. Assuming a hardwood stand at final harvest contains 60 crop trees/acre averaging 16 inches dbh, the maximum gain in stand volume from a 1-inch increase in dbh is about 2,000 board feet (International 1/4-inch)/acre. The maximum gain in stand value depends on the real stumpage price of future crop trees. In Table 3, the maximum gain in the stand value is shown for stumpage prices ranging from $50 to $150/M bf. If the stumpage price is $50/M bf, the maximum gain in stand value is only $100/acre. If the stumpage price is $125/M bf, the maximum gain in stand value is $250/acre. Figures in Table 3 do not include the effects of inflation. As a result, current stumpage prices can be used to estimate the maximum potential gain in stand value.

Table 3. Maximum allowable precommercial thinning cost for a 4 percent real rate of return--based on a projected 1-inch increase in dbh of future crop trees[a].

Current stumpage price of future crop trees (Dollars/M bf)	Maximum gain in stand volume[b]	Maximum gain in stand value	Maximum allowable precommercial thinning cost by investment period (Years)			
			20	30	40	50
	M bf/acre		----Dollars/acre----			
50	2.0	100	46	31	21	14
75	2.0	150	68	46	31	21
100	2.0	200	91	62	42	28
125	2.0	250	114	77	52	35
150	2.0	300	137	92	62	42

[a]Future stand without precommercial thinning contains 60 crop trees/acre averaging 16 inches in dbh.

[b]International 1/4-inch rule.

[c]Assumes that the average dbh of future crop trees will increase 1 inch as a result of the thinning.

A useful guideline for forest managers contemplating a precommercial thinning is the maximum allowable treatment cost/acre. How much can I afford to spend on crop-tree release? In Table 3, the maximum allowable treatment cost is provided for a range of stumpage prices and investment periods. For example, a forest manager is considering crop-tree release in a 20-year-old stand containing mostly black cherry. The current local stumpage price for black cherry is $100/M bf. If the investment period (years until final harvest) is 40 years, the forest manager can afford to spend $42/acre for crop-tree release. However, if the investment period is 50 years, the maximum treatment cost is only $28/acre.

Discussion

Precommercial thinning in young Appalachian hardwood stands can be a worthwhile investment for some landowners. For others, it is simply a losing proposition. To evaluate a proposed cultural treatment in a young stand, it is important to consider each investment factor and how it relates to a particular stand and to the landowner's objectives and financial resources.

The potential for economical precommercial cultural treatments is greatest in stands containing relatively high-value species. Research has shown that increases in dbh growth following precommercial thinning are limited and short-lived. Thus, for a given growth response, the total increase in stand value depends on the future

value of crop trees at final harvest. In addition to increasing diameter growth, precommercial crop-tree release can be used to influence species composition. Although species composition cannot be altered dramatically in 15- to 20-year-old stands, early release can improve species composition at final harvest and bring about some increase in future harvest revenues. This is in addition to increased revenues that result from faster diameter growth. Improvements in tree quality and log grade resulting from precommercial thinning can further increase future harvest revenues.

There are three ways landowner income can be increased by precommercial thinning--increased diameter growth, improved species composition, and improved tree quality. In this report, I focused on potential increases in tree size and stand volume in evaluating the economics of precommercial thinning. In a more comprehensive paper I will analyze the economic effects of changes in species composition and tree quality resulting from precommercial cultural practices. This report will include additional nomograms like Figure 1 for various rates of return, treatment costs, and investment periods. Field foresters will find these useful in dealing with individual landowners.

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CULTURAL PRACTICES IN APPALACHIAN HARDWOOD SAPLING STANDS--IF DONE, HOW TO DO THEM

H. Clay Smith and Neil I. Lamson

Principal Silviculturist; Research Forester
USDA Forest Service
Northeastern Forest Experiment Station
Parsons, WV 26287

ABSTRACT

Recommendations concerning the use of cleanings, liberation cuts, thinnings, and crop-tree release practices in Appalachian hardwood sapling stands are discussed. In general, cleanings are not recommended. Good judgment is necessary in deciding whether to use liberation cuts. When thinning fully stocked sapling stands by a low thinning technique, one-third to one-half of the basal area should be removed to obtain an acceptable growth response. Recommendations for crop-tree release include selecting 50 to 75 crop trees/acre and releasing them by a crown-touching method in stands where the average height of codominant trees is at least 25 feet tall. Guidelines are provided for selecting and releasing crop trees of both seedling and stump sprout origin.

Introduction

There are several questions concerning the use of cultural practices for managing Appalachian hardwood stands. Is there a need for these practices? What are the possible benefits and costs? If done, how are they applied? In this paper, we discuss the use and application of cultural practices in sapling stands--stands where the average dbh of the overstory trees is <5.0 inches. Based on number of years since clearcutting, sapling stands could be a maximum of 40 years old depending on the site. The key is economics. We must remember that these cultural practices are applied at a cost as trees usually are too small to sell (precommercial stands).

This paper is oriented toward the production of sawlog and veneer products. Schick (this proceedings) will address pulpwood (fiber) products. We discuss four cultural practices for sapling stands: cleanings, liberation cuts, thinning with basal-area control, and crop-tree release.

Additional cultural practices such as pruning, use of fertilizers, and grapevine control will be discussed by others (this proceedings). On the basis of available information and our experience, we will make

recommendations and, where applicable, provide guidelines for applying various cultural practices in Appalachian hardwood sapling stands.

Considering cultural practices in sapling stands

Cultural practices are applied in precommercial stands to:

- Increase the growth of residual trees to shorten the rotation length and/or increase the diameter at final harvest.
- Increase potential stand value by eliminating poor-quality, undesirable trees of the same age and concentrating growth on the better trees in the stand.
- Alter or maintain species composition.
- Remove older residual trees that interfere with the development of younger trees.

The basic concept in applying cultural practices to sapling stands is to release the more desirable trees. Trees are removed for such reasons as poor quality, low vigor, low crown class, spacing, or undesirable species.

Definitions

Because terminology can be a major communication problem, we will define each cultural practice. In reviewing terminology approved by the Society of American Foresters (SAF 1958), we note that cleanings or weedings are practices in young stands that allow selected trees of the same age to develop. Trees of poor quality or undesirable species are removed. No attempt is made to control basal area or release selected trees. In this paper, we restrict the discussion of cleanings to even-age stands <25 feet tall. The SAF notes that cleanings are used to liberate crop trees from other less desirable trees, but we will include this technique in our discussion of crop-tree release.

Liberation cuts release young trees from competition by removing older trees that are overtopping them. Technically, liberation cuts could be applied anytime in a sapling stand but most commonly are done during or immediately after logging but before the stand is 15 years old.

Thinnings by basal-area control relate to the reduction of stand basal area to a desired level by removing trees from the lower canopy. Most of the trees removed are in the intermediate to weak codominant crown-class position, though poor-quality, low-value and/or undesirable dominant-codominant trees also are removed as are some overtopped. Normally, this practice is not considered until stands have a well-developed, fully-stocked overstory canopy.

Crop trees are designated trees the landowner plans to sell in the future. Crop-tree release is the selection and release of a desirable tree by the removal of adjacent competing trees. Usually, the purpose is to stimulate growth and ensure survival, allowing the crop tree to become mature sooner and/or attain a larger size at harvest.

Cleanings

When Appalachian hardwood stands are clearcut, blackberries and other pioneer species quickly dominate the site. However, within 5 to 7 years after clearcutting, young hardwood trees fully occupy the site. At that time, the young stand is 10 to 15 feet tall and overstory stems average about 1 inch dbh. Tree crowns begin to form a closed canopy that shades the pioneer species.

In theory, a cleaning would improve the stand by eliminating undesirable species such as fire cherry, aspen, and, in some cases, black locust. Also, poor-quality trees would be removed. Eventually, most of these species will die or will be overtopped by faster growing intolerants, but at this young age they are competing with and can crowd the more desirable trees.

In applying a cleaning as we have defined it, undesirable species and trees of poor quality are removed without basal-area control or crop-tree release. There are several studies (Table 1) in which a crop-tree release or basal-area thinning was used in sapling stands. Some of these articles referred to this treatment as a cleaning or weeding. Hilt and Dale (1982) reported that for 22-year-old central hardwood stands initially thinned 8 years after clearcutting, no noncommercial species were present among the 125 largest stems in the treated or control plots. Also, the precommercial thinnings did not significantly alter species composition of these larger trees. On the basis of available information and our experience, we do not recommend a cleaning in Appalachian hardwood sapling stands <25 feet tall. Growth response will be questionable and most cleanings have not altered species composition. There are exceptions, such as removing sprout clumps of undesirable species, for example, red maple clumps.

Liberation cuts

Residual trees left after timber harvesting can interfere with the development of newly established sapling stands. The question is how many stems or how much basal area will be needed for these residual trees to influence stand development and reduce harvesting goals. As Marquis (1981) indicated, data are virtually nonexistent on the long-term effects of residual saplings on regeneration in the Appalachians.

According to data we have collected, if stands are clearcut to a dbh of 5.0 inches, it is not necessary to cut the residual stems. About half of these stems will be 1 or 2 inches in dbh and about two-thirds of these will be severely damaged during logging (Trimble and Rosier

1972). The intolerant stems and stump sprouts will compete well with tolerant stems and quickly move into the dominant-codominant crown positions. A mixed stand of tolerants and intolerants will be assured. And some of these residual trees can be considered for removal at the first commercial thinning. In fact, cutting some of these older residual trees at the first commercial thinning could be the difference in making a marginal cut more profitable. If the objective is to produce a maximum number of intolerant species, then removing all residual stems would be appropriate.

Table 1. Sources of crop-tree release information for hardwood sapling stands.

Source	Species	Stand age	Treatment	Response
		Years		
Church 1955	Northern hardwoods	13-18	12- to 15-ft tree spacing	Yes
Downs 1946	Sugar maple, white oak, yellow-poplar	7-14	3-ft crown	Yes
Stoeckeler and Arbogast 1947	Sugar maple, elm, white ash, basswood	11	5-ft bole	Yes
Conover and Ralston 1959	Northern hardwoods	11	2 1/2- and 5-ft bole	Yes
Trimble 1974 Smith 1977	Red maple	7	5-ft bole	Yes
Erdmann et al. 1981	Yellow birch	7	8-ft crown	Yes
Della-Bianca 1975	Mixed hardwoods	11	Free to grow	Yes
Smith 1981	Sweet birch, yellow-poplar, black cherry	10	Free to grow	Yes
Lamson 1983	Appalachian hardwoods[a]	10-12	Crown touching	Yes
Smith 1979	Northern red oak, yellow-poplar, black cherry, sugar maple	9	5-ft bole	No
Trimble 1973	Northern red oak, yellow-poplar, black cherry	7	5-ft bole	No
Beck 1977	Yellow-poplar	6	Free to grow	No

[a]Yellow-poplar, basswood, red maple, black cherry, northern red oak stump sprouts.

An example of pole and sapling response was documented in a West Virginia study on a good oak site (Smith and Lamson 1977). A 9-inch diameter-limit cut was done in a 40- to 45-year-old second-growth stand with old residuals from the 1905 to 1910 logging period. The average basal area before logging for the poles (6 to 8 inches dbh) was 24 ft^2/acre (110 trees/acre) and about 20 ft^2/acre in saplings. Oaks dominated the understory poles. About 35 years later, the overstory stand is dominated by good-quality oaks. Poles at the time of cutting responded. If oaks are desired by the forest manager, the pole-sapling resource could be an excellent way to obtain them.

Upland oak stands in Ohio were treated with a commercial clearcut, (trees 10 inches dbh and larger were removed), a complete clearcut and some partial cuts (Heiligmann et al. 1985). Residual stand basal area in poles and saplings (4.5 inches dbh and larger) averaged 28 ft^2/acre for the commercial clearcut area. After 28 years, the number of potential crop trees generally increased from the type cuts to the complete clearcut treatments. However, there was no significant difference in potential crop tree diameters among cutting practices for any species.

When only sawlog trees are cut during logging, residual pole and sapling trees usually are felled sometime after logging. There is little information on what basal area levels do or do not influence regeneration. Results from a mixed hardwood study in Indiana indicated that germinated yellow-poplar seedlings were negatively influenced by residual sapling stems (Williams 1976). Initial stand treatments were the removal of all trees over 6 inches dbh; removing all trees >5 feet tall. The >6-inch dbh treatment resulted in a stand with a residual basal area of about 17 ft^2/acre. After 18 years, the yellow-poplar stems were about twice as large on the >5-foot compared to the >6-inch dbh treatment. However, we do know that the tolerant pole stems will respond. We would not remove desirable pole trees, especially oaks and maples, though red maple is considered undesirable in some areas. If the understory sapling stand were <20 ft^2 before logging, we would not cut saplings. In an attempt to retain at least a two-age, two-species stand, Marquis et al. (1984) recommended retaining 10 ft^2/acre in saplings and poles (30 to 40 maple trees/acre) in cherry-maple stands.

In conclusion, when logging all sawlog and pulpwood products, generally ignore cutting sapling stems. Liberation cuts usually are not necessary. Normally, an abundance of intolerants will be readily available for management purposes. Site disturbance due to logging will provide an abundance of the intolerant stems to develop into dominant-codominant trees. It is not unusual to have 10,000 to 20,000 stems/acre a few years after clearcutting, and you need only about 150 to 200 well-distributed, desirable overstory trees to manage a stand successfully. When only sawlog trees are logged, be cautious about cutting all pole-size trees as many poles will respond to release and develop into good-quality trees.

Thinning with Basal-Area Control

The purpose of thinning with basal-area control, also called area wide thinning, is to improve the potential stand value and stimulate the growth of residual trees (Boyette and Brenneman 1978; Hilt and Dale 1982). Generally, thinning is concentrated in the lower crown classes (thinning from below). The trees removed are mostly intermediates along with some weak codominants and some overtopped trees. Of course, poor-quality, undesirable species of any crown class also are removed. Basal area is used to control the cut, and the basic concept is to reduce the residual stand to a desired level.

What residual basal area should be used in thinnings? Stocking guides (Gingrich 1967; Roach 1977) can be used to determine optimum residual basal area in older stands. However, most stocking guides do not perform well in sapling stands. Stocking guides have shown that residual basal areas of 50 to 60% of full stocking provide maximum individual diameter growth without reducing total per-acre production. Reducing stands below 50% of full stocking can seriously reduce stem quality in sapling stands (Sonderman 1984). Therefore, we recommend that thinnings with basal-area control be applied in fully stocked sapling stands and that one-third to one-half of the stand basal area be removed. The basal-area computation should be based on a minimum average dbh that includes the intermediate trees.

How is the stand marked for cutting? Since in young, even-aged stands many intermediate trees are intolerant and will not respond to release, nearly all intermediates can be marked for cutting. Also, any dominant or codominant trees that are of poor quality, i.e., low forks or excessive sweep, should be marked for cutting, as should the short-lived or undesirable species such as fire cherry or aspen. Overtopped trees above the minimum dbh for basal-area computations can be cut, too. If residual basal-area goals cannot be achieved by cutting overtopped, intermediate, and poor-quality or undesirable dominant and codominant trees, then some of the better codominant trees can be cut.

Before applying thinning with basal-area control, we suggest setting up a few small plots 0.25- to 1.0-acre plots. These plots will readily assist you in marking a stand. Use flagging to see what retaining one-half to two-thirds of the basal area looks like on the ground. In actual marking, record the basal area for the marked cut. Prism counts during the marking can be taken periodically to maintain the desired marked basal area.

Generally, there is a short-term stand response from thinnings in young sapling stands because there is a tendency to remove few trees from the upper crown canopy. If a reasonable time, at least 5 years for a growth response is desirable, then 40 to 50% of the basal area in sapling stands should be removed. But the more stems you remove, the greater the cost. In most cases, applying a basal-area thinning in sapling stands with a residual basal-area goal of one-half to two-thirds of the initial stocking can be achieved by cutting

intermediate and poor-quality, low-value codominants. Before applying a thinning, we would wait until the average height of codominant trees of seedling-origin is at least 25 feet. Trees <25 feet tall generally do not respond to release (Smith and Lamson 1983). And the older the stand, the easier it is to estimate basal area.

Crop-tree release

When thinning with basal-area control, markers often use a "crop-tree approach"--they look for the best trees. So why not use this crop-tree release technique of selecting individual trees and releasing them? This approach which has been applied widely throughout the Appalachians (Table 1), differs from thinning in that basal area is not used to control the cut. A specified number of trees are selected and released. Trees are not cut unless their removal would benefit a crop tree.

When a crop-tree release is used, desirable trees are selected with the intent to sell these trees at future periodic thinnings or final harvest. The selected crop trees are released to a free-to-grow crown class position. There are many types of bole or crown releases that have been tried; we recommend the crown-touching release technique, which is discussed in detail later. Too often, forest managers enter a young sapling stand, apply a crop-tree release and are disappointed several years later. Managers find it is difficult to determine which trees were released, or several of the released trees are no longer crop trees. Before applying a crop-tree release, we need to have guidelines for identifying crop trees. Then we need to know when and how to release them.

Selecting Crop Trees to Release

Select crop trees among the high-quality, vigorous, desirable tree species in the dominant-codominant crown class. Selecting intolerant-intermediate crop trees is not recommended because generally they do not respond to release and eventually die. We also do not recommend releasing intermediate crop trees except for some relatively tolerant species such as oaks or maples.

Crop trees should be of good form and capable of producing grade 1 or 2 butt logs. Slight bole crooks or slight sweep can be overlooked since these tend to straighten out as the tree matures. Crop trees should not have major crown forks in the lower 17 feet of the bole section and should be relatively free of surface defects such as large knots. Leaning trees should not be selected as crop trees. Crop trees in sapling stands should not have visible bole or stump rot. Also, disease damage to the bole is undesirable, particularly black knot on black cherry, Nectria canker on sweet birch, and Eutypella canker on sugar maple.

The question of favoring crop trees of seedling origin over those of stump sprout origin on the basis of internal rot from the present stump is not debatable. With the absence of fire, rot is not a major

problem in stump sprouts (Lamson 1976; USDA Forest Service 1983). Consider stump sprouts equal to seedlings based on origin. Sprouts are considerably taller and larger than seedlings in young stands and we can capitalize on this extra growth by selecting stump sprouts as crop trees.

Select stump sprout crop trees of low origin--the nearer the ground the better. High-origin sprouts are poorly attached and will break off regardless of how good they look. Never select a stump sprout more than 6 inches above groundline. On steep slopes, favor sprouts on the uphill side of the stump. If selecting more than one crop tree/stump clump, select widely spaced sprouts with a U-shape connection.

A major factor in selecting crop trees of seedling or sprout origin is one's own judgment. For example, within a selected portion of a stand, if you cannot find any good potential crop trees, do not choose any. The stand will continue to develop and nonreleased crop trees will emerge later through competition. Another example of using good judgment occurs where there are two excellent crop trees very close to each other. In this situation, leave both trees and treat the crowns as one--like releasing two crop trees of sprout origin on the same stump clump. But all good trees in the stand cannot be crop trees and where there are an abundance of potential crop trees, some good trees must be removed to allow the better crop trees room to grow faster.

Releasing crop trees--how to do it

The on-the-ground objective of crop tree release is to attain and maintain crop trees in a free-to-grow crown position. The following are suggestions and methods to use in releasing crop trees.

Crown-touching release method. With the crown-touching release, all trees adjacent to the crop trees are removed if their crowns touch the crown of the crop tree, or if their crowns are above or below the edge of the crop-tree crown. Questionable trees close to the crop tree are cut. Generally, only dominant, codominant, or intermediate trees are to be cut during release. Removing overtopped trees probably will not help the crop tree. However, it is sometimes faster for the operator to cut some of the overtopped trees than to take the time to decide whether a tree is overtopped or intermediate. Also, in felling, some of the small overtopped trees are cut to get them out of the way. Depending on the number of crop trees released/acre, most will be released on four sides. In young sapling stands (codominants 25 to 35 feet tall), most crop trees will have at least a 5-foot relase area around the perimeter of the crop-tree crown.

Many types of the bole release also have been used, but the objective is to give the crown room to develop and a bole release does not always assure this. The crown-touching method guarantees that a large portion of the crop-tree crown will be released. Also, the feller (if trees are cut) can tell immediately if a tree should be cut. We recommend removing all questionable trees. After the trees have been

released by an operator, it is easy to evaluate the quality of the job or indicate trees that have not been released.

Release 50 to 75 crop trees/acre. The cost of releasing trees and the availability of good crop trees strongly influence this decision. Everyone wants to select a high number of crop trees/acre--100 to 125. But, often it is difficult to select 75 crop evenly distributed crop trees throughout a sapling stand; this is even more difficult when crown-touching release is used: the crop trees are not there. Selecting a higher number of crop trees (toward 75) will allow some products to be harvested during periodic thinnings and compensate for unexpected mortality. However, partially cut managed stands in the Appalachians often have <50 dominant-codominant or sawlog-size trees/acre at maturity. Also a few additional crop trees will emerge from areas that currently do not have crop trees to release.

The cost of selecting and releasing crop trees in sapling stands is about $30/acre by the cheapest method of release--felling (Miller 1984). Expected response for the crop trees would be a minimum increase in diameter growth of 30% over nonreleased crop trees for at least 5 years (0.5-inch in 5 years).

Before applying a crown-touching release, we suggest establishing a few temporary plots (0.25 to 1.0 acre) for selecting and identifying crop trees. This will help you get a better idea of what the number of selected crop trees looks like on the ground. And help with spacing, too. Also, these small plots allow you to apply a crown-touching release on a small scale. It takes a little time to establish a few plots but many questions and concerns are answered quickly.

The earliest possible time to enter a stand to select and release crop trees is when the average height of codominant trees of seedling-origin is 25 feet. By that time the stand is past the "briar stage" and tree-crown classes are well developed. And the possibility of crown-class regression after treatment is reduced. If trees are cut, sprouts from the cut stumps will not be able to compete with the crowns of the crop tree. Although stump sprout stems will be considerably taller than stems of seedling origin in young sapling stands (Lamson 1976), we suggest waiting to do a crop-tree release until the seedling-origin stems are at least 25 feet tall. More response is needed to recover the initial cost when discounting for a longer period (Miller, this proceedings). Thus, the longer we wait to do a precommercial cultural practice, the less response is needed to recover our investment.

There are several ways to remove trees competing with crop trees: felling, girdling, or injecting or basal-spraying herbicides. We recommend felling with a chain saw because you can see immediately what trees need to be removed. Also, felling is cheaper (Miller 1984) and the feller needs little instructions (fellers may prefer a chain saw with a long blade to reduce knee and back bending).

With girdling or herbicide release techniques, trees to be removed may not die for a long time or it may be difficult to identify stems that require treatment. Herbicides are risky to other trees; injection might be preferred over basal spraying as there is less risk of spillage and contamination to nontarget trees with this method. Also, basal spraying larger sapling stems is questionable and not always effective. Zedaker (this proceedings) discusses herbicides.

When possible, select and release crop trees during the dormant season. Selecting crop trees and determining which trees to cut is done quickly during this time of year because you can see throughout the woods. And it is easier to fell trees without leaves too (fewer top hangups).

When releasing stump sprouts, remove all sprout stems but the crop tree or trees. Apply a crown-touching release to these crop trees. If two crop trees are on the same stump clump, treat these trees as one crown. Do not use herbicides to remove sprout stems as there is too much risk to the crop trees. During felling, high stumps do not create a problem, but the feller must be careful not to cut into the sapwood of the crop tree during felling as this wound could be a source of decay to the butt log. The cut stump will sprout and/or rot, but this will not affect the crop tree.

If grapevines create a problem in sapling stands, do not do a crop-tree release and grapevine control treatment at the same time. The grapevine treatment entails cutting grapevines; if the stand is opened by a crown-touching release, the cut vine stumps will sprout and probably create even greater problems. Do the grapevine control treatment first and wait 4 to 5 years before applying a crop-tree release. Additional information on grapevines is discussed by Smith and Lamson (this proceedings).

Summary

There are a number of reasons to do cultural practices in sapling stands. Basically, the residual stand will be improved, but to be practical, the tree response should at least recover the cost of applying a cultural practice. The following are our general recommendation for the four cultural practices (cleanings, liberation cut, thinning with basal area control, and crop-tree release), considered for sapling stands.

Cleanings

We do not recommend cleanings in sapling stands where the codominant stems of seedling origin are <25 feet tall. A possible exception would be removing undesirable sprout clumps such as red maple in the southern Appalachians.

Liberation Cut

When all pole and sawtimber products down to a dbh of 5.0 inches are felled, a liberation cut is not necessary so long as a mixture of tolerant and intolerant species is acceptable.

For stands where only sawtimber stems (11.0 inches in dbh and larger) are removed, the pole timber and saplings will influence the next stand. Leaving 10 ft^2/acre in poles does not create problems in regenerating and developing cherry-maple stands. We believe this is true for the major hardwood timber types in the Appalachians. Pole stems, especially tolerant species, will respond to release. We do not recommend cutting maple or oak poles of high quality, i.e., good form and free from logging damage. Cut the undesirable pole stems and leave oak and maple stems of high quality. In some areas, especially in the southern Appalachians, red maple is considered an undesirable species. Do not cut sapling stems unless the objective is to obtain a maximum number of intolerant stems in the future stand. Regardless of what is done with the sapling stems, there still will be sufficient intolerant stems available for the future stand.

Thinnings with Basal-Area Control

If a thinning is applied in fully stocked sapling stands, at least one-third to one-half of the basal area should be removed by thinning from below. Codominant trees should average at least 25 feet tall. The markers leave the best trees by removing all the undesirable or poor quality and nearly all of the intermediate stems.

Crop-Tree Release

We recommend crop-tree release over thinning because there is a better chance of concentrating the residual stand growth on the best trees. Also, a crop-tree release is easier to use in sapling stands. And if money is limited, a few crop trees can be released and still help the stand.

Here are guidelines to follow when applying a crop-tree release:

- Select dominant-codominant trees.
- Choose desirable tree species of high quality and vigor; they should have good form and no major bole forks below the first 17 feet of tree bole.
- Select trees with no major crooks or visible defects that would reduce butt log grade when the crop tree is sawlog sized.
- Do not select trees with dead upper crown branches and/or visible disease wounds on the tree bole.

- Do not discriminate against trees of stump sprout origin on the basis of internal rot as rot is not a significant factor when fire is absent.

The following are considerations for crop trees of stump sprout origin:

- Select low-origin trees near groundline, and never more than 6 inches above groundline.

- Select one or two crop trees/stump clump; if two sprouts are selected, they should be spaced widely with a U-shape connection.

- On steep slopes, favor sprouts on the uphill side of the stump.

The following are current guidelines for releasing crop trees:

- Use the crown-touching release technique. Remove all intermediate-codominant-dominant trees that interfere with the crop trees (except another crop tree).

- Fell trees with a chain saw as this method is cheaper than spraying or injecting herbicides. Also, with felling it is easier to evaluate the degree of release during treatment and the quality of the job after treatment. Sprouting from cut stumps does not affect the crop trees and cut stump height is not a concern in young stands.

- Apply a crop-tree release in stands where the average height of codominant trees of seedling origin is at least 25 feet; stems of stump sprout origin will be taller.

- Before doing the job on a widescale basis, establish small 0.25- to 1.0-acre plots. Use them to develop techniques for selecting and identifying crop trees.

- When possible, release crop trees during the dormant season.

- For stump sprouts, treat a two-sprout clump as one crown and apply the crown-touching method. In many cases, felling all of the other stump sprout stems will be sufficient.

- Do not use herbicides to remove stems in sprout clumps and be careful when cutting stump sprouts with a chain saw--do not cut into the sapwood of the crop tree.

Where grapevines are a problem in young stands, the first cultural practice we recommend is a grapevine control treatment when the stand has a well-developed shade canopy. A crop-tree release can be done 4 or 5 years after the grapevine treatment. Cultural practices should be restricted to the more accessible areas and should be concentrated on the better sites first as opportunities to recover costs are greater in a precommercial stand with more of the valuable, faster growing trees.

Crop-tree release seems to us an economical method where you can select as few or as many trees as your economic situation allows and still stimulate the development of better trees in future stands. Remember, a crop-tree release in sapling stands is not picking crop trees and cutting all other trees. The only trees that are cut are those whose removal help the crop tree. Depending on the number of crop trees released, some portion of the stand will not have any trees cut. So we are not putting all our eggs in one basket, for other crop trees will emerge from among trees not selected for release at the present time. It is important to do an additional release to keep the crop trees in a desirable crown-class position (Bessel 1985).

Good judgment is perhaps the most important factor in applying cultural practices in Appalachian sapling stands. There are no exact answers, and you will find that your situation is never the same as that of someone else, if only because of differences in stand and site conditions.

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STAND STOCKING - WHAT DOES IT MEAN AND HOW TO USE IT

Bruce B. Brenneman

Research Center Leader
West Virginia Forest Research center
Westvaco Corporation
Rupert, WV 25984

ABSTRACT

The purpose of this paper is to review stand density and stocking methods applicable to Appalachian hardwoods. Absolute stand density methods such as number of trees, basal area, or volume per land area have limitations in that these values will vary as the stand develops. Relative stand density methods such as the central hardwood, Allegheny hardwood, or northern hardwood stocking charts are applicable to stands in the Appalachians and give constant relative stocking values over the range of stand development conditions. On these charts the average maximum competition level found in undisturbed stands is the 100% or A-level of stocking. The lower level of full site occupancy is the B-level. The C-level is the lower limit from which the average stand could grow into full site occupancy within 10 years. Use of the charts requires that the instructions for each chart be followed and that all diameter classes of trees used in the development of the specific chart be included when using the chart.

Introduction

Some expression of stocking is needed as a tool for forest managers to compare conditions in stands being managed to some ideal or potential standard for that type of stand. Managers need to know if a stand contains enough trees or volume to manage or to produce maximum individual tree growth or maximum total stand growth. Managers need to know when a stand contains too many trees and how much stocking to leave when making partial cuts. Stocking expressions, supported by research and practical results, are designed to answer these needs.

The purpose of this paper is to review existing stocking information to make readers familiar with the stocking terms used in the papers which follow.

Stand density is the broader term which includes stocking. Stand density is a quantitative measure of stand condition which may be expressed either relatively, as a proportion of normal or optimum numbers, basal area, or volume, or absolutely, in terms of numbers, basal area, or volume per unit area. Stocking is the relative measure

of the proportion, or percentage, of the area actually occupied by trees (Society of American Foresters 1971).

Absolute Stand Density

Absolute stand density might be expressed as number of trees, amount of basal area, or volume of trees/area of land. Number of stems/area of land is a very useful expression for regeneration or small sapling stands. A desired number of stems is perhaps more useful than full stocking for these stands. We might consider that the main product of a sapling stand would be a manageable pole stand; therefore, we really only need those numbers of desirable stems which would provide a well-spaced stand of pole-sized stems. While nature might provide 7,000 to 10,000 or more stems at full stocking of 1- or 2-inch saplings, we might be content with 1,000 to 2,000 well-spaced stems of desirable species.

Basal area/area of land has been and continues to be widely used to describe stand density. This unit has several limitations. First, optimum or normal basal area will vary with site quality; with basal area being higher on areas with higher productivity potential. Second, optimum basal area will increase as tree size increases. If a small sawlog stand is considered optimum at a basal area of 100 ft^2/acre, the same stand should have had about 80 to 85 ft^2 in the early pole stage and will have perhaps 110 ft^2 when it is in the large sawtimber stage to reflect the same degree of average stocking. For basal area to be a meaningful indicator of stand density, we also need to know other values such as average tree size and diameter distribution.

Stand volume levels are also used as a measure of density; however, these are usually used in an economic rather than biological sense. It may be stated that a stand must contain 2,500 bf/acre in order to support an economic harvest or that 70 tons of fiber must be left after sawtimber harvest to support a pulpwood harvest within the next 5 years, etc.

Relative Stand Density - Stocking Charts

Stocking charts and equations express the proportion of the area occupied by the trees in the stand in relation to some standard reference value. The most common reference value is the average maximum competition level; however, the level of full site utilization with no inter-tree competition is also used. The full site utilization level is that level where the combination of maximum individual tree growth and maximum total productivity occurs; each tree has full use of growth resources and the site is fully occupied. As number of trees increases above this level, individual tree growth decreases due to crowding, but the total growth remains about constant. Eventually, when the maximum competition level is reached, some trees must die so that others can grow and, above this level, total productivity may decrease due to stagnation. A fully stocked stand has stocking within the areas bounded by the full occupancy with no

competition level and the average maximum competition level. Relative stand density provides meaningful comparison among stands that differ in average tree size, age, site, and associated characteristics (Ernst and Knapp 1985).

The determination of the average maximum competition level is usually made for different forest types using the tree-area ratio equation developed by Chisman and Schumacher (1940). A range of measured plot variables from undisturbed fully-stocked stands are used to develop the coefficients in the equation:

$$\text{Tree Area} = aN + b\,D + c\,D^2$$

where a, b, and c are coefficients
N is the number of trees/area
D is the sum of the diameters
D^2 is the sum of the squares of the diameters.

Once the equation coefficients are determined, the resulting equation can be used to determine total area used by selected stands or may be used to set the average maximum competition level for a timber type (Gingrich 1967; Roach 1977).

The full site occupancy with no competition level may be determined from measurement of crown area of open-grown trees (Gingrich 1967) or by "estimate (guess, really) of the minimum stocking that is needed for full utilization of the site" (Roach 1977).

Gingrich (1967) developed the widely used stocking charts for central upland hardwoods (oak types). Roach (1977) followed Gingrich's format in developing stocking charts for Allegheny hardwoods as did Leak et al. (1969) in developing charts for northern hardwoods. Gingrich's guide has been adopted as the National Forest System's standard for stocking guides (Ernst and Knapp 1985).

A general representation of the Gingrich guide is shown in Figure 1. On the Gingrich-type charts, the average maximum competition level is the 100% stocking or A-level. Stands over this level are overstocked in that some trees must die to decrease competition so that others may grow; total stand productivity is probably decreased. The B-level is at about 55 to 60% stocking and is at the lower level of full site occupancy. Stands between the A- and B-levels are fully stocked and site productivity is at a maximum. Individual tree growth is greatest in the lower part of this range; however, while individual growth decreases as stands approach the A-level, there are more trees available to compensate for the reduced individual growth. Below the B-level, there are not enough trees to fully occupy the site, although the individual trees should be growing at maximum rates. Open grown trees, however, may be of poor form and limby. The C-level is the lower limit at which an understocked stand would be expected to grow in a fully-stocked condition within 10 years (Gingrich 1967).

The management zone is the area on the chart between the upper and lower bounds of acceptable stocking for the purposes of the forest manager (Ernst and Knapp 1985). This zone will have different bounds depending upon landowner objectives. If full stocking in 10 years is the objective, then any stocking above the C-level would be within the management zone.

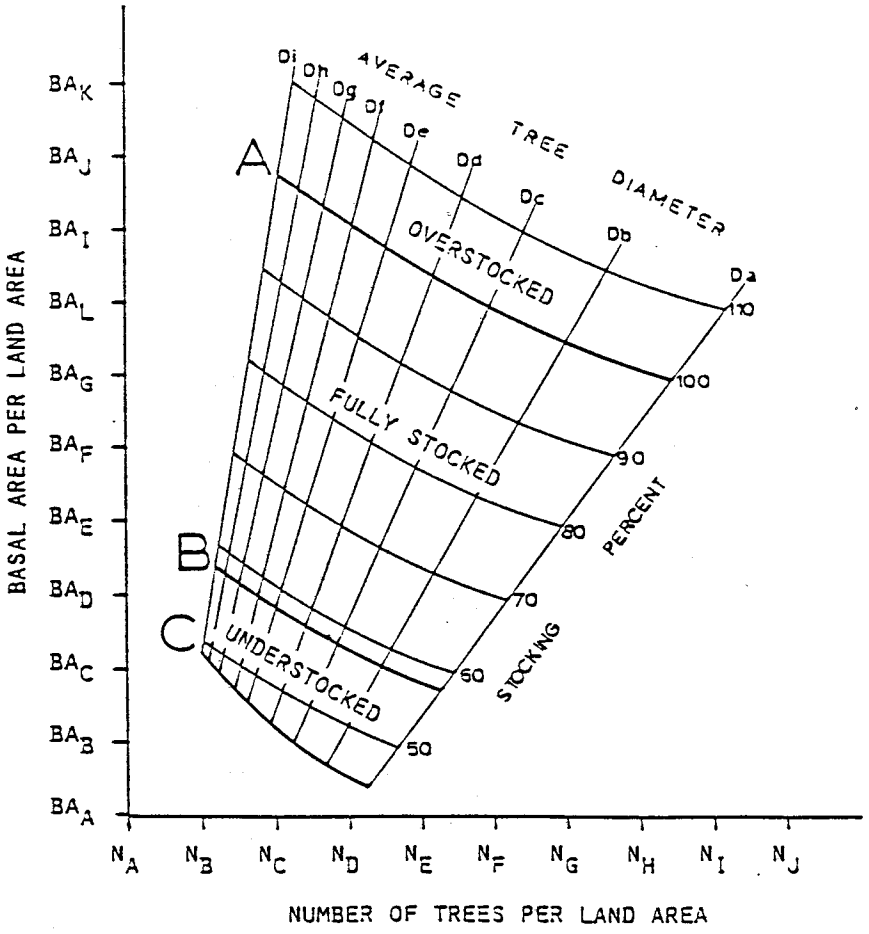


Figure 1. General format of the Gingrich stocking guide.

Gingrich (1967) determined that age and site did not significantly affect stocking. He found that "the average tree of a given diameter will utilize the same area at a given level of density". It was further concluded that as long as most of the trees in the stand were oaks, species did not significantly differ in space needs. Leak et al. (1969) were also able to use single A- and B-levels for the mix of species found in the northern hardwood type in the Northeast. However, Roach (1977), working with Allegheny hardwoods, found that species composition did affect stocking in this type and developed different A- and B-levels depending upon the proportions of cherry, ash, and yellow-poplar in the stands.

Stocking charts applicable to the Appalachian hardwood region may be found in the following sources:

Chart	Reference
Upland Central Hardwoods (Oak Type)	Gingrich (1967) or Roach and Gingrich (1968)
Allegheny Hardwoods	Roach (1977)
Northern Hardwoods in the Northeast	Leak et al. (1969)

Any two of the three entry variables on the stocking chart determine the third. Since it is difficult to accurately determine average stand diameter without determining basal area and number of trees, these last two items are usually used to enter the stocking charts. Basal area may either be determined from fixed plots or, more commonly, from prism plots. Tree counts/acre can also be made from prism plots. To determine the number of trees, tally trees must be counted by dbh class and conversion factors used to expand each class to per area values. This method of tree count has several disadvantages: the diameter class must be estimated accurately, and small diameter trees have a very low sampling frequency (and must be very close to the cruiser to be counted). Both Gingrich (1967) and Roach (1977) recommend counting trees on 1/20-acre plots rather than determining number of trees from prism cruises.

To use the stocking charts, the same classes of trees must be tallied and entered as were used to develop the stocking chart. Gingrich (1967) and Roach (1977) included small trees down to the 1-inch diameter class while Leak et al. (1969) used only those trees in the main canopy. Failure to include the small trees when using the Gingrich or Roach charts results in underestimating stocking. Basal area is not greatly affected but the number of trees is underestimated and the average diameter is overestimated.

The use of stocking charts becomes somewhat difficult when several types are found in the same area. To overcome this problem in the Allegheny hardwood area, relative density tables and equations have been developed which give centacres of crown area needed by each individual tree by diameter class and species group. This allows summing stocking area from the cruise sheet in much the same manner as volume is determined (Marquis et al. 1984). This method uses the appropriate stocking charts as the base and it is a simplification of the stocking method rather than a new method.

Summary

The purpose of this paper has been to review the most commonly used stand stocking methods applicable to the Appalachian hardwoods. The various methods are reviewed and some limitations of each method have been discussed. To use any one of the stocking methods will require

further review of the chosen method in the appropriate reference. The systems have been covered, however, in sufficient detail so that the reader will have an understanding of the stand density and stocking terms used in the thinning papers which follow.

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THINNING ALLEGHENY HARDWOOD POLE AND SMALL SAWTIMBER STANDS

David A. Marquis

Principal Silviculturist
USDA Forest Service
Northeastern Forest Experiment Station
Warren, PA 16365

ABSTRACT

Thinning in Allegheny hardwood stands should begin when sapling basal area drops below about 20 ft^2/acre. Before that time, thinnings produce low yields and require investments in precommercial removal of saplings that are not economically justified. Once commercial thinnings are begun--at about 50 years of age--stands should be maintained at densities between 60 and 80% relative density, with emphasis on selection for removal of poor-quality trees within the smaller merchantable size classes to achieve an appropriate stand structure and species composition. Toward the end of the rotation, thinnings shift from a strict thinning from below to a combination thinning in the slower maturing species and partial harvest of the faster maturing species. A computer program called SILVAH is available to summarize stand data, make recommendations on the appropriate type of thinning in particular stands, and generate marking instructions that ensure the appropriate manipulation of stand density, structure, and species composition.

Introduction

According to the Society of American Foresters, thinning is any cutting made in an immature stand to improve the diameter growth and quality of the trees that remain. More specifically, thinnings in even-aged Allegheny hardwood stands are made to achieve some combination of the following benefits: a) increase yield by salvaging trees that would die; b) concentrate diameter growth on the best trees in the stand, thereby increasing stand value; and c) reduce the time required for the stand to reach maturity. To achieve these benefits, stand density, stand structure, and species composition must be regulated in appropriate ways. Let's first look at the responses of entire stands and individual trees to various levels of stand density.

Thinning Principles

Stand density

At very low relative stand densities (perhaps 0 to 30%), the trees are so far apart that they do not influence each other; each tree is essentially open-grown. Growth rates of individual trees are therefore at a maximum, and stand growth is directly proportional to the amount of growing stock present. Stand growth is less than the maximum because the available growing space is not fully utilized (Figure 1).

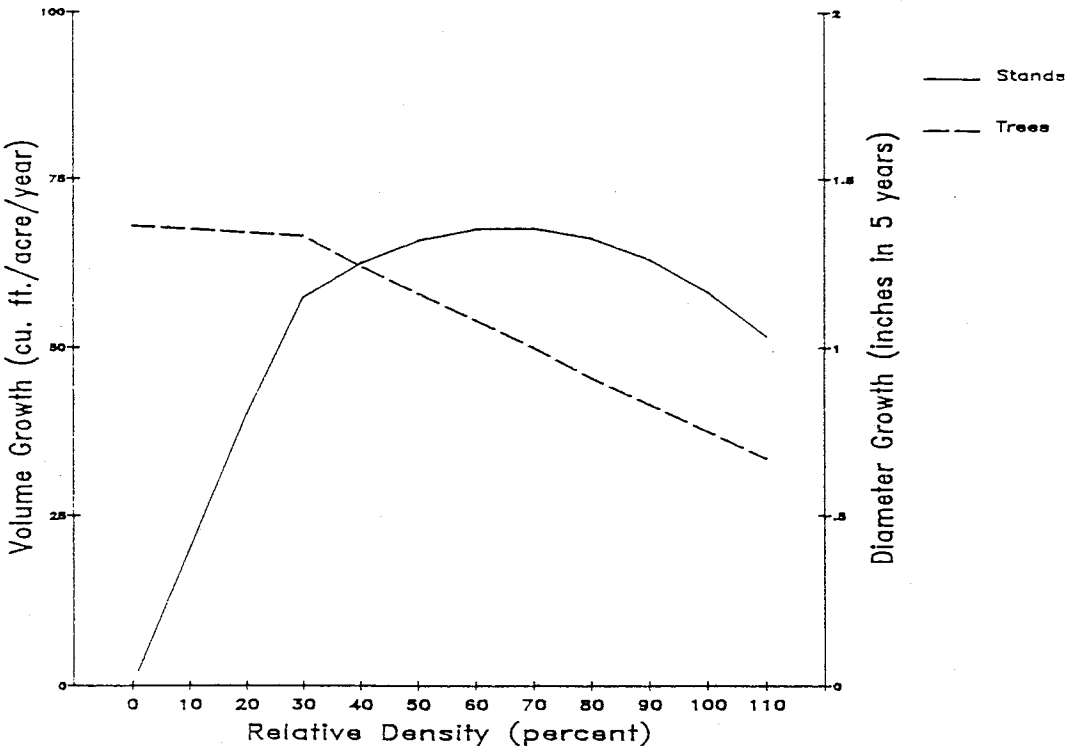


Figure 1. Comparison of total stand volume growth and individual-tree diameter growth as affected by stand density in Allegheny hardwood stands (values between 0 and 30 percent density are estimated).

Above about 30% relative density, trees are close enough to each other that their growth rate is affected by the competition. As stand density increases above 30%, stand growth continues to increase as the amount of growing stock, or capital, increases, but individual-tree growth declines due to the increasing crowding. At some point--usually somewhere between about 50 and 80% relative density--stand growth reaches a maximum. At higher densities, both stand growth and individual-tree growth decline due to the excessive crowding. At very high densities, the stand may actually stagnate (Figure 1).

This means that there is a fairly broad range of stand densities over which stand growth does not vary greatly. This range may extend from as low as 40% to as high as 90%. Thus, a stand that grows at the rate of 100 ft^3/acre/year at 80% density also may produce 100 ft^3/acre/year after thinning to 50% density, for example. The difference is that the 100 ft^3 of growth will be distributed over fewer trees at 50% density. Each remaining tree will grow faster, but there are fewer of them, so total growth remains about the same.

It is this range of densities that is of special interest to foresters, for within it we can manipulate the growth of individual trees without losing any total stand growth. The usual objective of thinning is to keep the growing stock within this optimum range.

Mortality is another concern, since one of the objectives of thinning is to capture the yield of trees that would die from crowding if the stand were not thinned. Mortality is strongly influenced by stand density, increasing dramatically above densities of 60 to 70% (Figure 2).

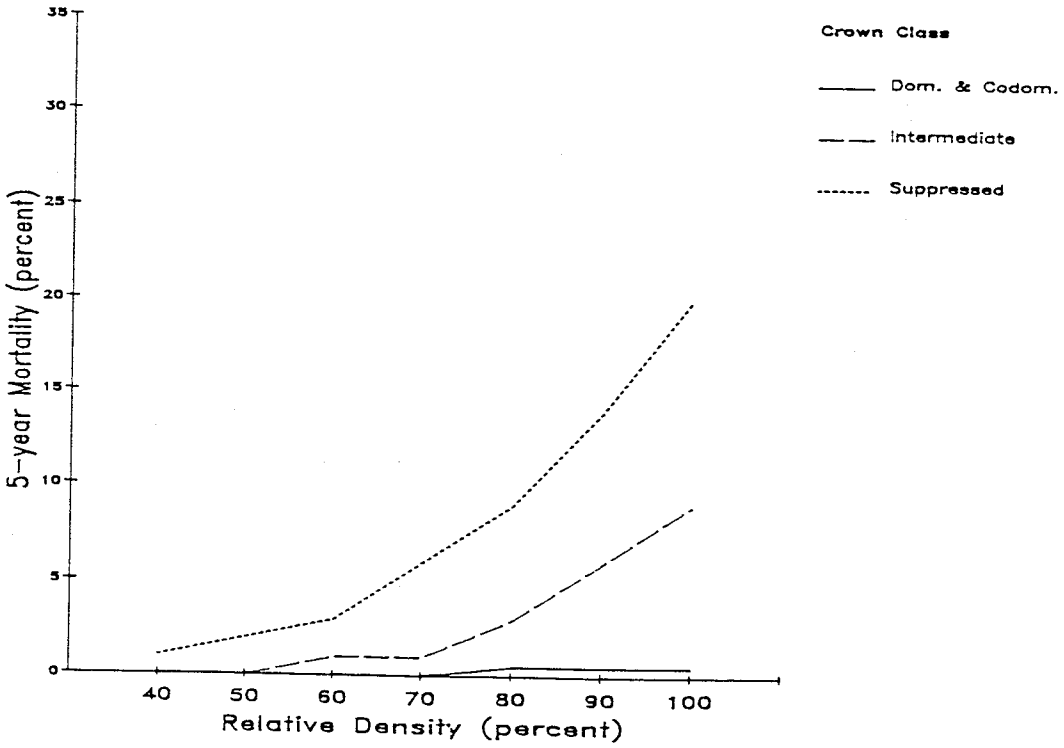


Figure 2. Mortality of individual red maple trees in Allegheny hardwood stands thinned to varying densities, by crown class.

But this mortality from crowding is concentrated in the smallest, most suppressed trees in the stand. Often these are sapling-size trees that would never grow large enough to make sawtimber during an even-age rotation. So their loss may be relatively unimportant in hardwood stands where most of the value comes from the sawtimber-size trees. For example, mortality in basal area (which includes trees as small as 1 inch dbh) may represent 50% of net growth at high densities, while mortality in board foot volume in the same stand is relatively insignificant.

As a result, net stand growth in basal area peaks at about 50% relative density and declines rapidly at higher densities where mortality is high among the small trees. But board foot volume growth peaks at much higher densities--about 80%--and declines relatively little even at 100% relative density since there is little mortality in sawtimber-size trees. Board foot volume growth declines, however, at lower densities (Figure 3).

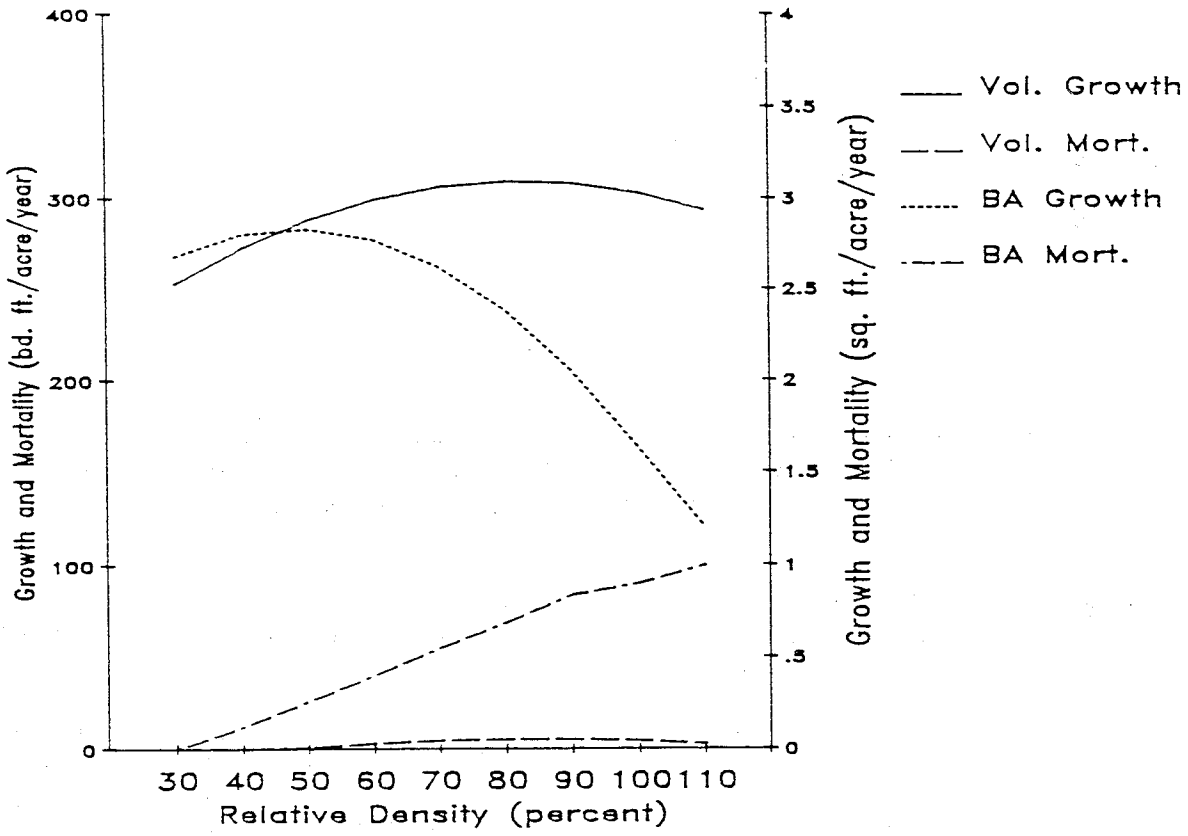


Figure 3. Net stand growth and mortality over a range of relative density in terms of basal area and board foot volume, in large pole and small sawtimber Allegheny hardwood stands.

Tree quality also is affected by stand density. Our studies show that the number of epicormic branches that form on the lower bole can be excessive when density drops below about 60%. Other quality factors, such as forking, and slow pruning of live branches also can be a problem at low densities (Figure 4).

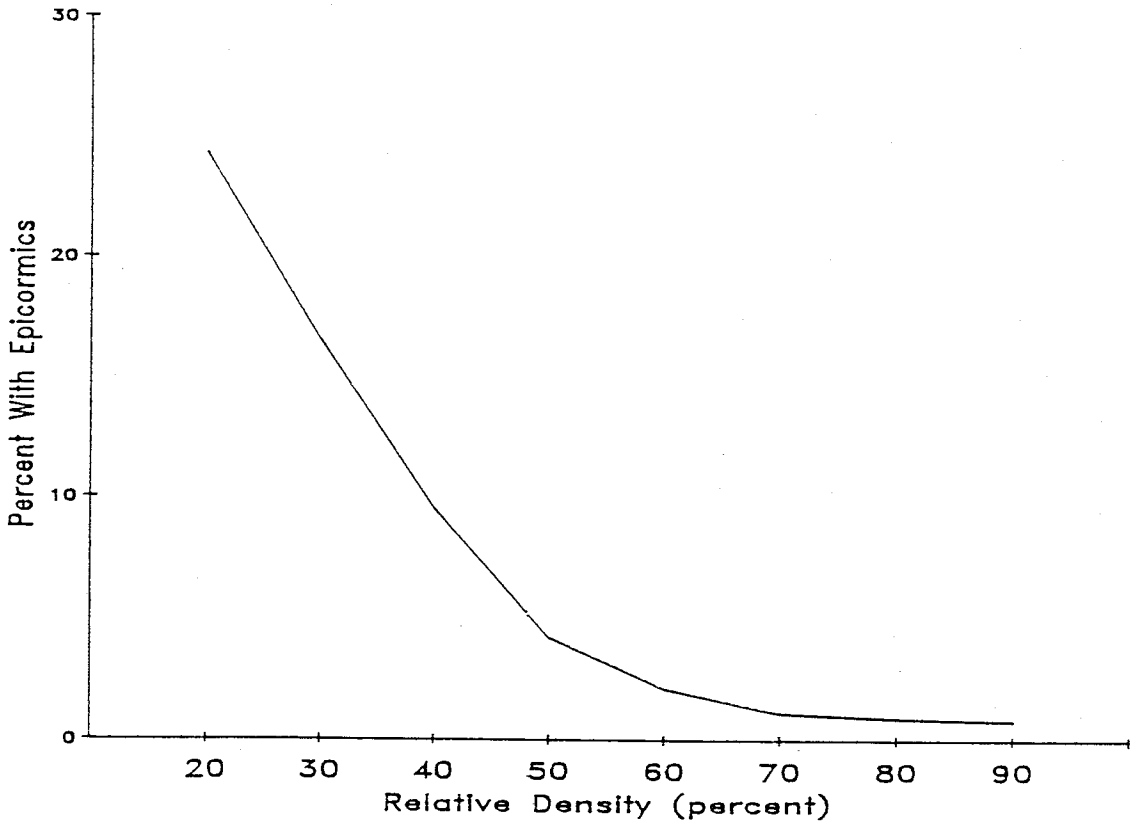


Figure 4. Epicormic branches that developed on black cherry and red maple trees 5 years after thinning in a 70-year-old Allegheny hardwood stand.

Understory vegetation of all kinds--tree seedlings and nonwoody plants--respond to the increased availability of light, moisture, and nutrients when density drops below about 60 or 70%. Below 50% density, the undergrowth may become lush and dense, signifying that a significant amount of the site resources are not being used by overstory trees. Thinnings on some sites may result in the invasion of ferns and other plants that interfere with regeneration establishment and may require herbicide treatment when it is time to harvest the existing stand and regenerate a new one.

Thus, the optimum density is a compromise among several factors. Best individual diameter growth occurs at densities of 30 to 50%, optimum stand growth in board volume occurs at 60 to 80%; tree quality may deteriorate and undesirable understories develop at densities below about 60%.

We recommend that residual density be reduced to about 60% during thinnings in Allegheny hardwoods, and that the stand be allowed to build up to 80% before another thinning is conducted. Maintaining stands in this range of densities will provide near maximum stand growth, good individual-tree growth with low mortality due to crowding, minimize undesirable effects such as reduced tree quality due to epicormic branching and forking, and avoidance of dense understories.

The 80% relative density level makes a good breaking point in deciding whether to thin. If the stand is at <80% relative density, individual-tree growth should be good and mortality low, and the volume available for thinning usually will be too small to provide a commercial cut. When the stand is over 80% density, growth rates will be slowing down, mortality will be increasing, and there should be enough excess volume in the stand to make a worthwhile commercial thinning.

There is one important exception to the general rule that stand density should be reduced to 60% during thinnings and other partial cuts. Fully stocked stands that are near maximum crowding will contain many trees with small crowns. When thinned to 60% in one cut, more growing space will be made available than the small-crowned residuals can immediately use, and it will be several years before crowns have expanded to fill all the growing space. In the interim, stand growth will be lost because the site is not fully occupied, and there may be some loss of tree quality or even mortality from the excessive exposure.

The rule in all cases is not to reduce density by more than 35% in any one thinning. If this rule is observed, excessive exposure and other detrimental effects of a too heavy first thinning will be avoided. So in some stands, the first thinning will reduce density to only 65 or 70%, and a second thinning will be needed before the stand is brought to the 60% level.

Another caution in any partial cutting is that there can be significant damage to residual trees by the felling and skidding operation. If care is not exercised, this damage can negate the beneits of thinning completely, i.e., decay that enters the logging wounds can cause serious degrade or even mortality. The more entries that are made into a stand for thinning, the more of this type of damage you are likely to encounter. For this reason, we tend to avoid frequent, light thinnings, and generally recommend against entry into a stand unless the benefits of the thinning clearly warrant the risks.

In Allegheny hardwood stands thinned to 60% relative density, it usually requires 15 to 20 years for the stand to return to 80% density. Thus, the usual thinning interval that results from our recommendations is 15 to 20 years.

Now that we understand the effects of stand density, we can readily decide what level of stocking to maintain in the residual stand, and when thinning is needed. Most foresters are reasonably proficient at marking stands to a specified residual density. But achievement of the desired benefits of thinning requires regulation of other stand parameters as well.

The manner in which the thinning is done will determine the extent to which these goals are actually achieved. Too often, I am afraid, thinnings are made in such a way as to work against these goals, because the forester marks to some density without understanding of how stand growth and yield are affected by stand structure and species composition. A high grading, a thinning, and an individual-tree selection cut may all leave a residual stand at 60% relative density. But differences in structure and composition make these cuttings entirely different, and will have important effects on long-term yields.

Stand Structure

To understand how stand structure is manipulated in thinning, we first need to review the theory behind the structures that are the basis of the two proven silvicultural systems. When numbers of trees are plotted over diameter class, a stand with a balanced all-age structure has an inverse J-shaped distribution. There are many ages present in the stand, with large numbers of young trees in the small diameter classes and relatively few older trees in the large diameter classes. By contrast, the diameter distribution of typical even-aged stands plots as a bell-shaped curve. All trees are the same age and, hence, approximately the same diameter (Figure 5).

In uneven-age silviculture, we attempt to constantly maintain the same stand structure over time. The forester decides on the form of inverse J structure desired, cuts in such a way as to establish that structure, then, in each succeeding cut, the forester removes the excess trees that have shown up in each diameter class. If the structure selected is within the silvical capability of the species, this procedure will produce sustained yield thereafter.

In even-age silviculture, stand structure changes over the life of the stand. The bell-shaped curve is narrow and high in young stands, where there are many trees in a few (small) diameter classes. As the stand ages, the bell-shaped curve moves progressively to the right on the chart, signifying an increase in average diameter. The curve also becomes flatter and wider as the number of trees decreases and the spread in diameters increases. When most of the trees reach mature size, the stand is harvested and the cycle repeated (Figure 6).

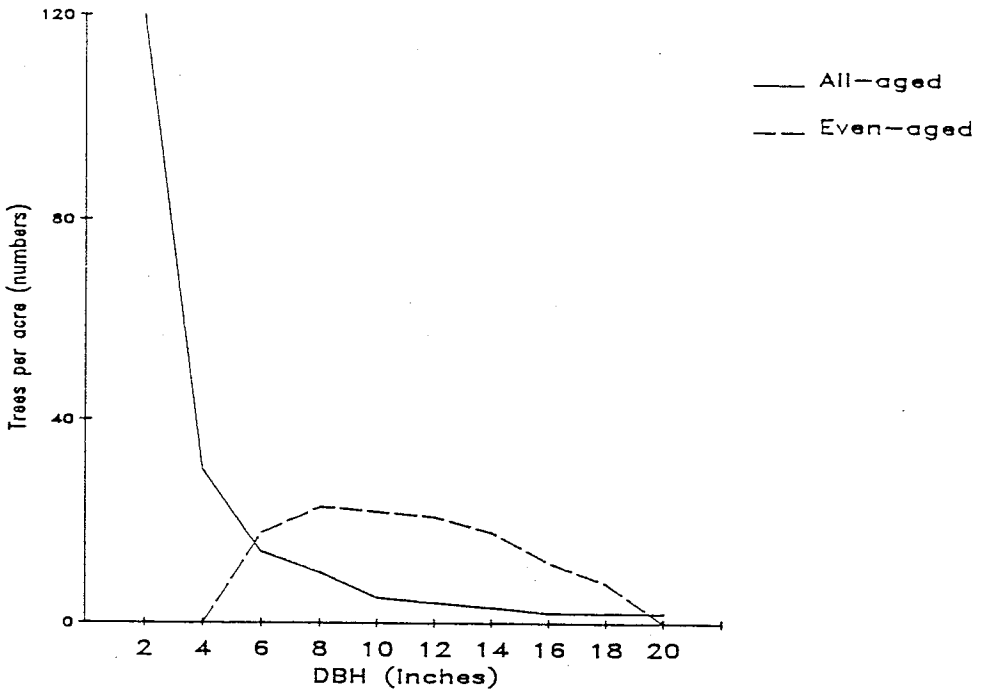


Figure 5. Theoretical stand structure under two major silvicultural systems.

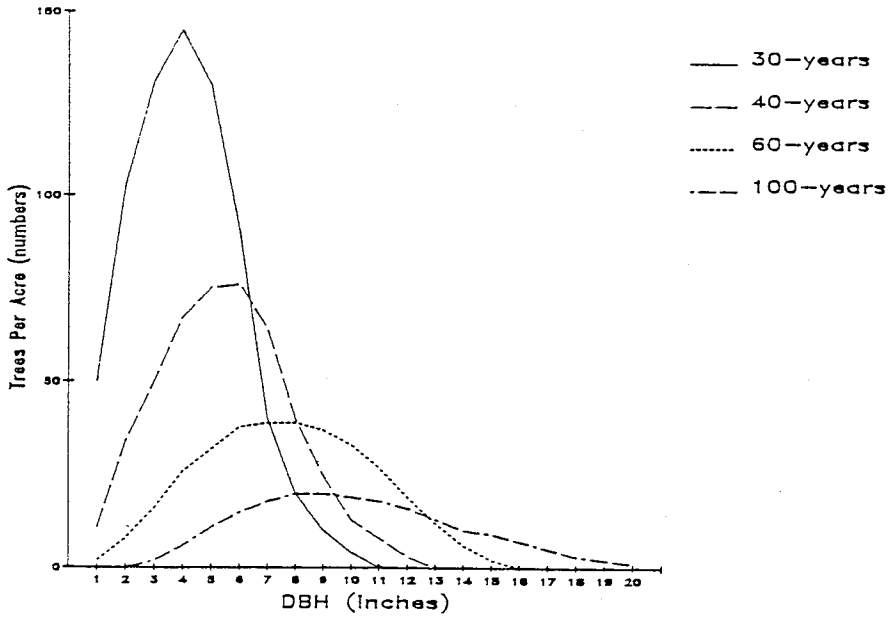


Figure 6. Change in stand structure with age in mixed oak stands (oak site index 70).

In even-age silviculture, we use thinning to speed the natural changes in stand structure over time--that is, to increase stand diameter and move the stand to the right on the chart toward maturity. The primary way we do this is by thinning more heavily in the small-diameter classes.

For example, in an oak stand that was thinned to 60% relative density by taking two-thirds of the cut basal area in trees smaller than the average stand diameter, the cutting alone increased the average diameter by 1.3 inches, and moved the stand to the right on the chart (Figure 7).

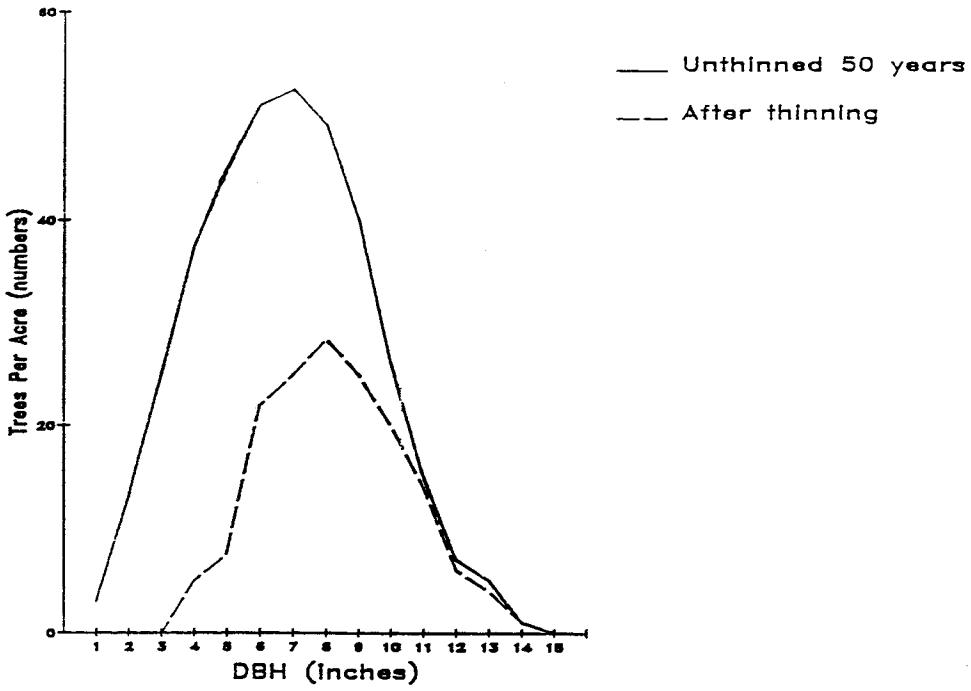


Figure 7. Effect of thinning on stand structure in a 50-year-old mixed oak stand.

The other way that we speed up the rate of increase in average diameter is, of course, that the thinning gives the remaining trees more growing space and increases their growth rates. The combined effect of these two factors can be significant. In a 70-year-old oak stand that has had two thinnings, the average diameter was increased from 9 to 12 inches over a comparable unthinned stand. For management purposes, the thinned stand can be considered equivalent to a 90-year-old natural stand.

From the standpoint of growing timber under an even-age cultural system, we would like to end up the rotation with a proper number of big trees uniformly spaced on every acre. Every thinning should be carried out with this goal in mind. We want our residual stand to contain the biggest and best quality trees that are now in it. The thinning should remove the bigger and better quality trees only if there is something wrong with them--or if some need to be removed to adjust spacing--to provide needed growing space for other equally good trees. Otherwise, they should be saved for that final harvest when the big payoff for the rotation is obtained.

What I have been describing is the theoretical goal of thinning. With stands of a single species, or group of similar species, it can be shown that cutting from below to push the large trees to maturity as quickly as possible will produce the greatest value return in the long run. But Allegheny hardwoods and some mixed oaks do not follow typical even-age theories very well. For one thing, the several species in our mixture have markedly different growth rates and tolerances to shade.

As a result, most Allegheny hardwood stands have naturally occurring diameter distributions closely approaching the classic inverse J shape. This is the result of the mixture of species and the presence of shade-tolerant stems in the small size classes and understory crown positions. Those small trees are the same age as the larger overstory trees in most cases. Once overtopped by faster growing stems, the tolerant saplings survive in large numbers without making much growth. They form the tail of the inverse J curve, but do not represent younger age classes. By contrast, the shade-intolerant species such as black cherry do not survive once overtopped, so they are not present in the smaller diameter classes; the diameter distribution for intolerant species alone forms a bell-shaped curve typical of even-aged stands (Figure 8).

Thus, the similarity between our Allegheny hardwood stand structure and the classic all-age structure is only superficial. If we are to manage these stands by traditional even-age techniques, we must somehow convert the J-shaped diameter distribution to a bell-shaped distribution. But how does one deal with all those small trees in the lower end of the inverse J distribution? If cutting is done strictly from below, the cut would be almost entirely noncommercial saplings even in stands 50 to 60 years old. Several such precommercial cuts would be required in most stands to develop a bell-shaped diameter distribution.

But if the saplings are ignored and thinning is concentrated in the merchantable sizes only, the thinnings tend to be high grading. Much of the residual growing space will be turned over to saplings that are the same age but much slower growing than the main part of the stand. Rotations are extended rather than reduced, and overall quality and value of the stand is usually decreased.

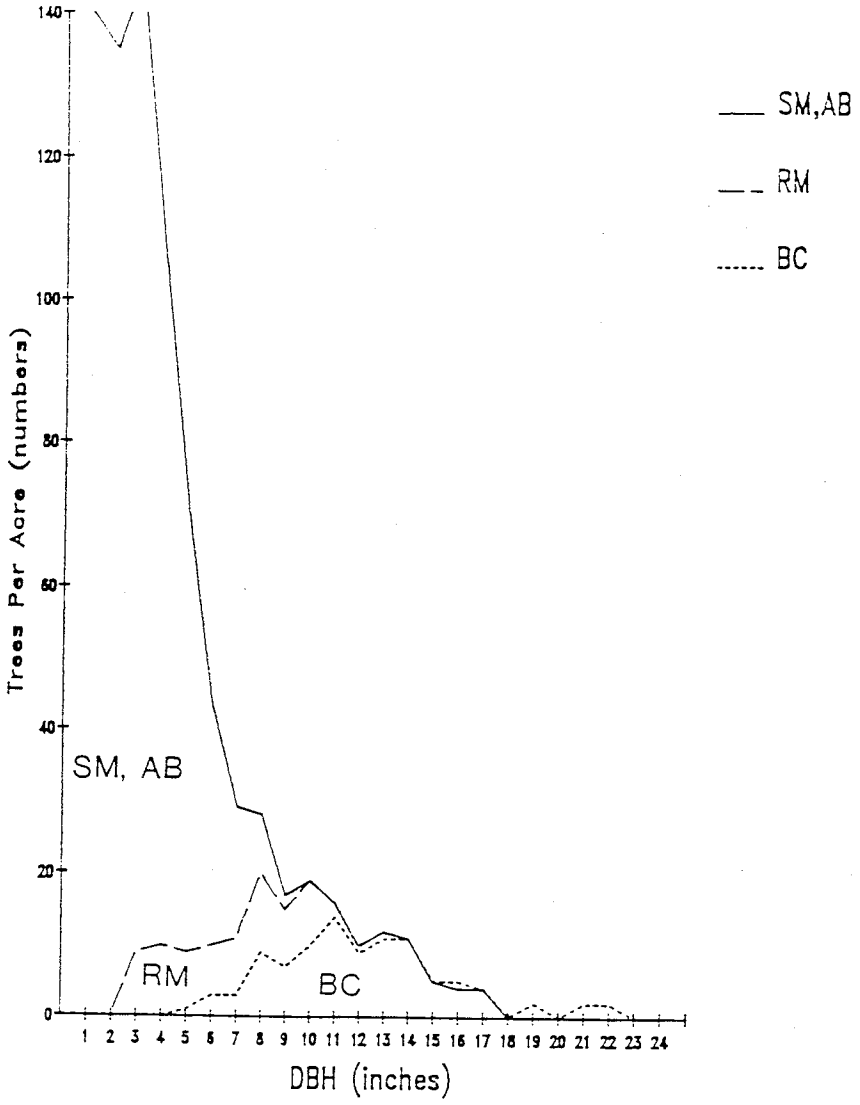


Figure 8. Stand structure by species in a 60-year-old Allegheny hardwood stand (RM = red maple; BC = Black cherry; SM, AB = sugar maple and American beech).

Further, the several species in these mixtures will not mature at the same time. When the black cherry reaches financial maturity at an average dbh of 18 inches, the sugar maple averages only 12 inches in dbh. So it may be desirable to manage the cherry on an 80- or 90-year rotation, while the sugar maple and beech may require 120 to 150 years to reach the same stage of development.

As a result, thinnings in these mixed hardwood stands can be very complex. Simple, textbook types of thinnings often do not work, and there are many options available in the way such stands might be handled. Many of the possible options have not been tested, and we still have much to learn. But, I will describe several thinning

schemes and rotation strategies that we have tested on our computer simulator that appear to be both biologically and economically sound for use in mixed hardwood stands in the Alleghenies.

First, let's consider the question of the small trees and how we deal with them. We have found that in stands with a high percentage of their basal area in the sapling size class, it is virtually impossible to make a commercial thinning without high grading the stand. Even if the thinning is concentrated in the smaller poles, so much of the good growing stock must be removed that future stand values are reduced considerably.

To illustrate, a 54-year-old stand containing 30 ft^2/acre of basal area in saplings was thinned to 60% relative density without removing any saplings. Two-thirds of the cut basal area came from trees below the average merchantable diameter, so the trees cut averaged only about 8 inches dbh. The largest and best trees were retained. Nevertheless, the middle size classes in the stand--the good growing-stock trees--were nearly eliminated, and a large percentage of the stand growing space was thereafter occupied by slow-growing, shade-tolerant saplings (Figure 9). As a result, total yields at age 100 were reduced dramatically. Since the thinning yielded only a marginal return from the pulpwood-size trees cut, the thinning was detrimental both in total volume yield and economic return.

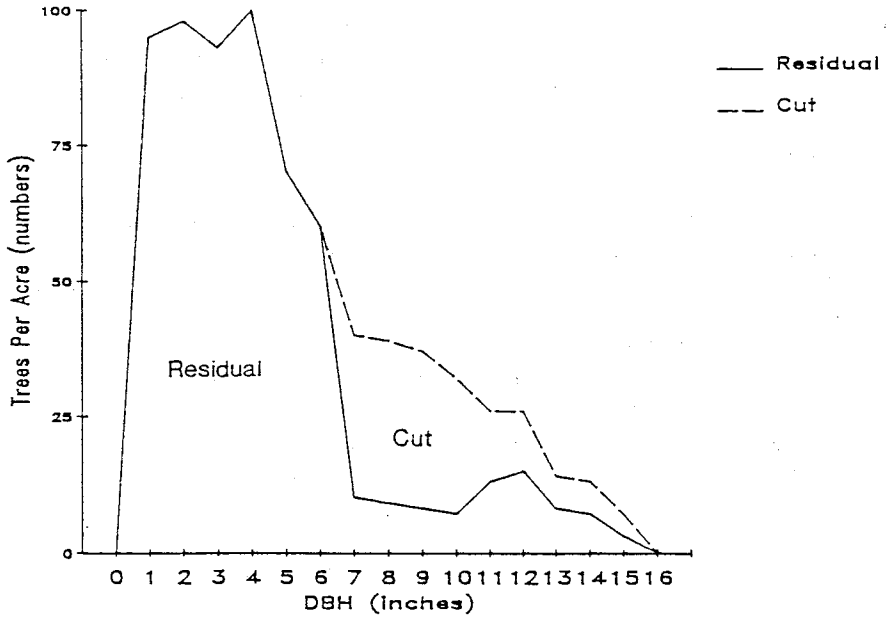


Figure 9. Commercial thinning in a 50-year-old Allegheny hardwood stand containing high sapling basal area.

Our computer simulation runs suggest that this negative effect of commercial thinning occurs when the stand contains more than about 20 ft^2/acre of basal area in the sapling size class. If there is less than 20 ft^2, a commercial thinning usually can be made without timber stand improvement in the sapling class, and long-term yields will be greater than if the thinning is not done. But if there are more than 20 ft^2 in the sapling class, any thinning attempted should include noncommercial removal of some of the saplings.

Many stands under 60 years of age, especially in the northern hardwood, Allegheny hardwood, and oak transition types, will have an excess of 20 ft^2 of saplings. If the stand is left uncut at full density, mortality will reduce the saplings and eliminate the problem. But if the stand is thinned, the saplings will survive and grow, continuing to occupy growing space, even though they will not grow large enough during the normal rotation period to qualify for high-value products.

For example, in one 60-year-old stand that we examined, there were 21 ft^2 of saplings at age 60. With no thinning, mortality from crowding reduced sapling basal area to 12 ft^2 by age 75. But when thinned, the same stand still contained 18 ft^2 of saplings at age 75.

So our recommendation is to simply stay out of younger stands that contain more than 20 ft^2/acre of sapling basal area, and let natural mortality solve the sapling problem. This avoids the need for investment in precommercial sapling removal, and produces essentially the same long-term yield.

In stands with <20 ft^2 of basal area in saplings, our simulation runs suggest that the saplings can be ignored in marking. In such stands, cutting is concentrated in the smaller merchantable size classes, though sufficient volume also is removed from sawtimber sizes to make an operable cut.

We recommend that commercial thinnings be designed to create a bell-shaped structure among the merchantable size classes. This is achieved by removing about two-thirds of the cut basal area from below the average (merchantable) diameter and one-third from above that diameter. In the development of marking instructions, we use a table that shows the proportion of the cut to come from each of four major size classes based on the existing average diameter (see page 72 in Marquis et al. 1984). Such cuts guarantee that the usual objectives of thinning are met: an increase in average diameter and a shorter rotation (Figure 10). In the stand illustrated in Figure 10, this thinning increased merchantable stand diameter from 14.3 to 15.2 inches, and reduced the time to maturity by 5 years.

Although the sapling class is unregulated and remains a part of the stand that eventually will have to be removed at final harvest, it does not significantly interfere with stand growth during the intermediate culture period.

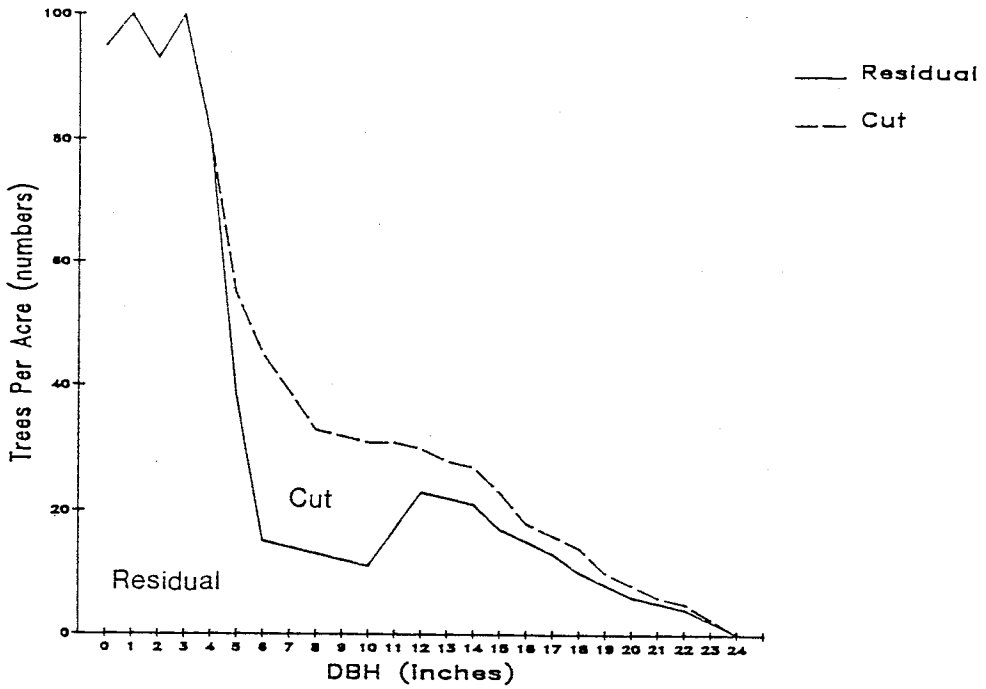


Figure 10. Stand structure in a 65-year-old Allegheny hardwood stand before and after commercial thinning.

I have so far ignored one major aspect of thinning--tree quality. In hardwoods, tree quality often is the major factor affecting value, and one that must receive priority attention in selecting trees to be removed. It is far more important to remove poor-quality trees than to achieve some theoretical diameter distribution. For this reason, we record tree quality during stand inventory. Once a theoretical distribution of cut has been made based on size classes, we check to see that this cut can be made without leaving poor-quality stems in one size class while cutting good-growing stock stems in another class. If necessary, adjustments are made in the cut to eliminate the unacceptable quality trees first. So quality takes priority over stand structure in deciding which trees to cut.

The thinning-from-below procedure I have outlined works well in truly immature stands where none of the individual trees have reached maturity. But toward the end of the rotation, many individual stems will achieve diameters of 22 to 24 inches or more before the stand as a whole reaches financial maturity. Holding these individually mature stems too long can reduce economic returns and expose them to increased risk from natural catastrophies. This situation is especially troublesome in mixed stands where one or more species reach maturity well before the slower growing species in the stand.

In simulation runs with some Allegheny hardwood stands containing about equal proportions of black cherry, red maple, and sugar maple, we found that the black cherry component reached financial maturity at about 90 years of age, but that the stand as a whole was not yet mature at that age. If all cherry were removed, a residual stand of adequate density dominated by maples in the small-sawtimber size class remained. It does not make much financial sense to clearcut at that stage, when many of the maples are increasing rapidly in value as they grow into diameters where they will qualify for grade 1 sawlogs and veneer. However, harvesting all of the black cherry at that time would eliminate the seed source of that species and make it difficult to regenerate another stand containing this valuable component.

The most profitable strategy in this stand turned out to be a period of several thinnings at age 90 and age 105 to gradually harvest the black cherry while continuing to thin from below among the maples. Our simulations suggest that many stands will benefit from one--or no more than two--such thin-harvests at the end of the rotation.

If done carefully, such cuttings should allow a minimum number of seed trees to be retained and at the same time facilitate the establishment of advance regeneration of the faster maturing species during the final thinnings. Thus, the economic benefits of the partial harvest probably can be realized without endangering regeneration of the next stand.

Species Composition

The procedures described for manipulating stand structure automatically favor the faster-growing species and individuals in the stand. These usually are the shade-intolerant and more valuable species. For example, in the example mentioned earlier, the proportion of black cherry was increased from 41 to 48%.

The manipulation of species composition can be one of the most important factors affecting stand yields. In our Allegheny hardwood stands, board volume growth of the entire stand can be 50% higher in stands that contain a high percentage of black cherry than in comparable stands with little cherry. When this faster growth is coupled with the significantly higher stumpage values of cherry, and with the fact that stands with a high percentage of cherry can carry higher densities, the end result may be as much as a tenfold increase in economic returns over the rotation from stands with a high percentage of cherry. Effects are similar with other fast-growing, shade-intolerant, high-value species such as white ash and red oak (Figure 11).

Control of Thinning in Practice

With that theory about the effects of stand density, stand structure, and species composition in mind, let's consider the procedures that

can be used to implement thinnings in immature stands. The first essential step is to determine the characteristics of the existing stand through some sort of conventional cruise, such as a prism cruise. On the basis of these measurements in the existing stand, we estimate relative density and determine whether a thinning is desirable. If it is, we calculate the density to be removed and convert that to a residual density goal. Then we calculate proportions of the cut to come from each major size class to ensure that the desired changes in stand structure and species composition are achieved when the stand is marked.

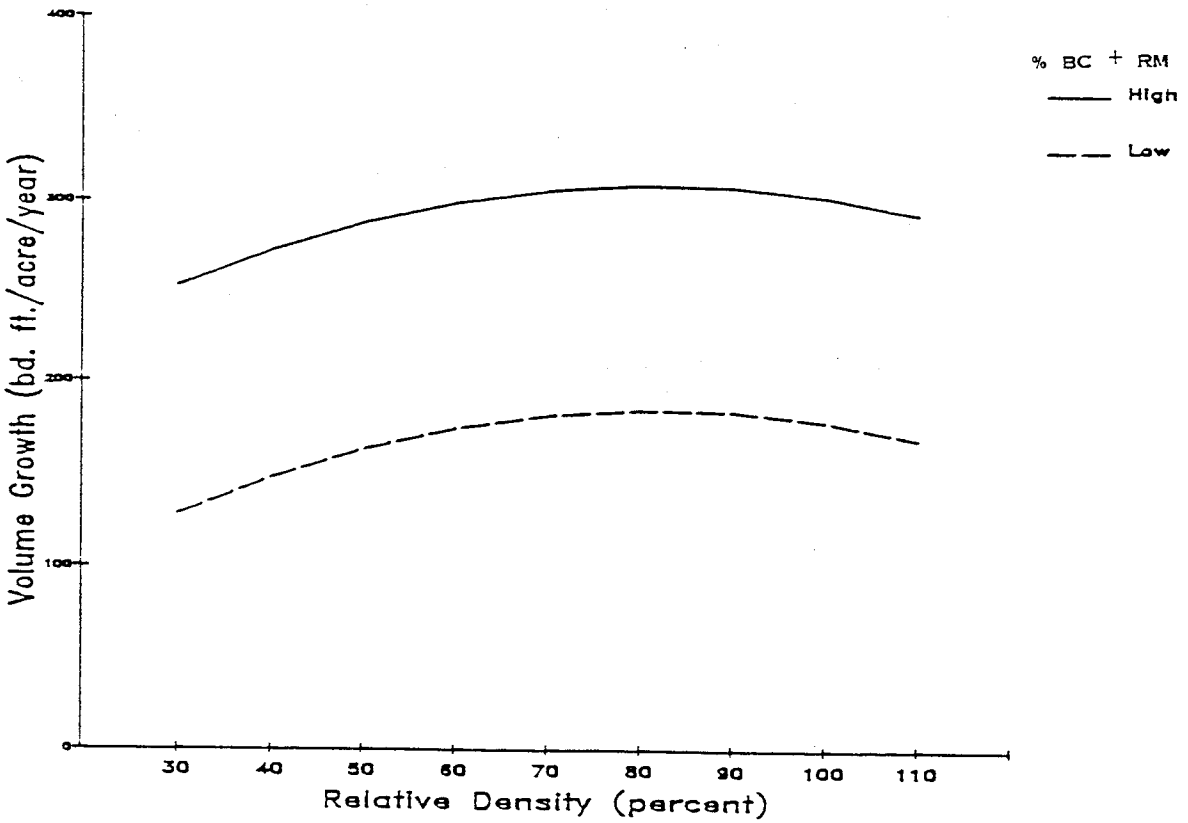


Figure 11. Net board-foot volume growth in Allegheny hardwood stands as affected by relative stand density and species.

A computer program called SILVAH is available to do all of the calculations and to print out the marking instructions. SILVAH also evaluates the need for thinning in the first place, and makes a recommendation on the appropriate silvicultural prescription, whether that be thinning or something else. Details on the application of all these thinning procedures and guidelines is contained in Marquis et al. (1984).

Conclusions

We recommend that thinning in Allegheny hardwood stands begin when sapling basal area drops below about 20 ft^2/acre. Before that time, thinnings produce low yields and require investments in precommercial removal of saplings that are not economically justified.

Once commercial thinnings are begun--at about 50 years of age--stands should be maintained at densities between about 60 and 80% relative density, with emphasis on selection for removal of poor-quality trees within the smaller merchantable size classes to achieve an appropriate stand structure and species composition. Toward the end of the rotation, thinnings shift from a strict thinning from below to a combination thinning in the slower maturing species and partial harvest of the faster maturing species. A computer program called SILVAH is available to summarize stand data, make recommendations on the appropriate type of thinning in particular stands, and generate marking instructions that ensure the manipulation of stand density, structure, and species composition in appropriate ways.

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THINNING APPALACHIAN POLE AND SMALL SAWTIMBER STANDS

Donald E. Beck

Principal Silviculturist
USDA Forest Service
Southeastern Forest Experiment Station
Asheville, NC 28804

ABSTRACT

The species that make up Appalachian cove hardwood stands respond to thinning with increased diameter growth over a wide range of ages and site conditions. Periodic thinnings that concentrate growth on large, high-quality trees of preferred species can substantially increase value yields.

The Appalachian hardwood region contains over 40 million acres of forest land that is characterized by steep topography and a wide range of site conditions. Frost-free days range from 120 to 240, depending on elevation and to some extent latitude. Annual precipitation averages from 40 inches in the intermountain valleys to more than 100 inches in the southwestern mountains. Rainfall during the growing season is usually about one-half the annual total. In short, climate for tree growth is excellent and the region is heavily forested. The timber types with which I am concerned occur on cove and moist-slope sites, which are the most productive in the Appalachians and among the most productive in the North Temperate Forest Zone. These sites probably comprise less than one-third of the commercial forest land but produce the majority of high-quality sawtimber and veneer in the region. There are an abundance and variety of tree species with different growth patterns, silvical characteristics, and dollar values of timber products. A dozen or more species may be present in a single stand. And the unit value of the most valuable species may be as much as 10 times that of the least valuable. Within a species, unit value may again vary tenfold due to bole quality. These timber types offer a major challenge to the forest manager, and an equally great opportunity.

When we talk about thinning eastern hardwoods, I assume the goals of management are to produce large high-quality trees for sawtimber and veneer products. Relatively large quantities of wood for fuel, paper, and other fiber products may be produced but not as a primary management objective. Since ultimate value is a function of volume produced, tree size, species composition, and stem-quality, these are the things we have to consider in any evaluation of thinning opportunities.

Before we decide on a course of thinning, it might be well to consider whether or not we need to thin to produce high-quality timber. First consider a typical natural, unmanaged stand toward the lower end of the site-quality spectrum for cove hardwoods (age 50 site index <70). Such stands usually are dominated by mixed oak species. Stand tables show that such a stand at 100 years of age would typically contain about 150 trees/acre with an average dbh of about 14 inches. The largest trees would be about 22 inches dbh, but most of the volume would be in the 10- to 16-inch diameter classes. Fully 40% of the basal area stocking would be in trees less than sawlog size. Only 25% would be in trees large enough to qualify as grade 1. At the other end of the site-quality spectrum we might have a nearly pure stand of yellow-poplar with a site index of 130+. As early as 70 years we might expect an average stand dbh of 21 inches with most of the volume in trees over 15 inches dbh. Thus, on the higher quality sites a substantial amount of large high-quality timber can be produced in a reasonable time without thinning. On the other hand, less than a third of the stand would be in trees large enough to qualify as grade 1. In both cases we could expect 25 to 30% of the stand volume to be of low value due to defects and the presence of the low-value species. I think we can safely say that most Appalachian cove hardwood stands will require some sort of intermediate cutting to meet management objectives of producing large high-quality products.

Response to Thinning

Individual Tree Response

Since one thinning objective is to increase the diameter growth of leave trees, we need to know if trees will indeed respond to increased growing space. We do not have complete response data for all the species we might encounter in cove stands, but there is some pretty good information on the major species. As you might expect, response varies among species, sites, residual densities, and ages of trees.

Figure 1 shows diameter growth response of yellow-poplar on a good site by age, tree size, and cutting intensity. Response is shown as the ratio of radial growth for the 5 years after thinning to the 5-year radial growth before thinning. A ratio >1 indicates an acceleration of growth after thinning. A ratio of 1 indicates no response and a ratio <1 indicates slower growth after thinning than before. In the 30-year-old stands, all three levels of thinning (23, 38, and 64% of the stand cut) created a positive growth response. In the older stands there was no response to the lightest thinnings (21 and 29% cut), but there was good response to the heavier thinning. Across all ages, there was a tendency for the smaller trees in a stand to respond the most. This does not mean that smaller trees should generally be favored. They are still growing at a slower absolute rate than the larger trees. For example, in the 30-year-old stand with 64% cut, 10-inch trees increased their radial growth rate by 40% as opposed to only 20% for 16-inch trees. However, the 10-inch trees were still growing only 2.4 inches in 10 years as opposed to 3.1 inches in 10 years for 16-inch trees. The absolute rate of diameter growth was 29% greater for the larger trees.

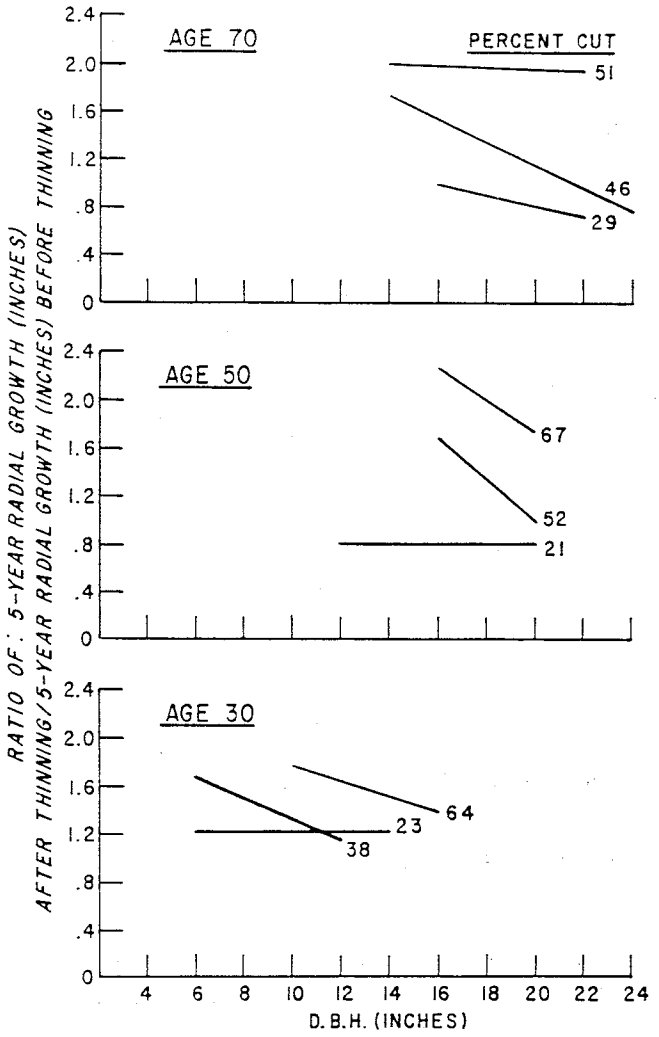


Figure 1. Diameter growth response varies with stand age, tree size, and thinning intensity.

Other major components of cove stands have shown similar responses to thinning. Northern red oak responded to thinning over a wide range of ages and diameters (Beck 1981; Carvell 1969, 1973; Oliver 1975; Trimble 1969). Red oak trees with an average age of 75 years and average dbh of 22 inches increased their average diameter growth by 55% in the first 5 years after thinning and maintained their growth advantage over adjacent unreleased trees for a period of 12 years. White, black, and chestnut oaks responded over a wide range of ages, but the best response was in the younger stands (Beck 1981; Dale 1968; Gingrich 1971; Hilt 1979; Minckler 1957; Trimble 1969). Red maple has shown the ability to nearly double diameter growth after thinning in stands from 7 to 50 years of age (Erdmann et al. 1985; Marquis 1969).

Other species like beech, sugar maple, hickory, and white ash have responded to thinning. Black cherry may be somewhat of an exception to the general rule. In several studies, dominant cherry failed to respond to thinning (Hough and Taylor 1946; Philip and Ward 1971; Trimble 1968).

Figure 2 shows diameter growth for several common cove species in relation to residual stand density after thinning. As expected, absolute growth rates are quite different (Trimble 1960, 1967), but the trends with basal areas are similar.

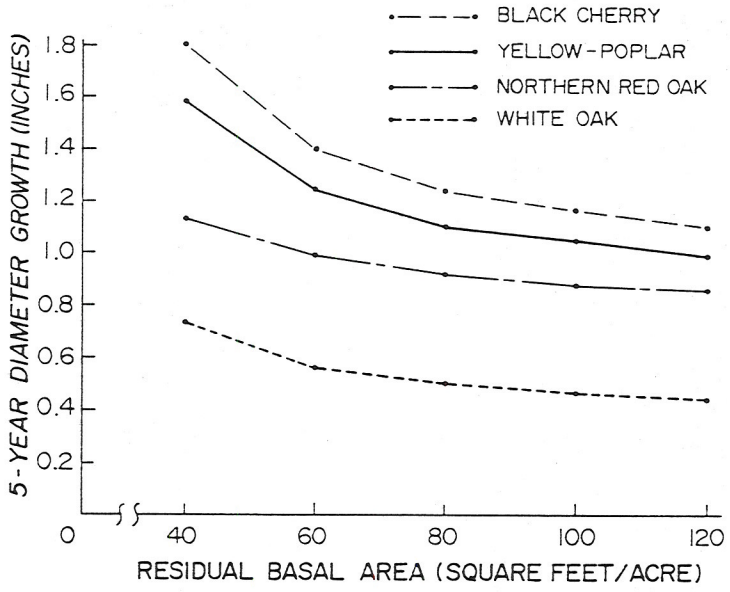


Figure 2. Diameter growth rates by species.

I think we can safely say that while response varies with species, tree size and vigor, age and site quality, we can expect the trees in Appalachian cove hardwood stands to respond to thinning with an increased rate of diameter growth over a wide range of conditions. Crop trees will most often be chosen from the dominant and codominant crown classes, because these trees will respond to thinning and maintain their superior growth rate over other trees in the stand. They are also usually the most desirable species. However, if trees from lesser crown classes must be left to meet species and potential quality criteria, they will respond and make suitable crop trees.

Cubic-Volume Growth of Stands

While it is evident that the diameter growth response of leave trees increases with the thinning intensity (Figure 3A), we must also be cognizant of total stand growth. Figure 3B shows annual cubic-foot volume growth of yellow-poplar in relation to stand density by age and site class (Beck and Della-Bianca 1972). Maximum rates of cubic-foot

growth are achieved at the highest densities. The same relationship has been demonstrated for numerous species. Thus, when we thin to enhance growth of individuals, we give up something in total cubic-foot volume growth. For example, on site 100 at age 40 when we thin to 60 ft^2 of residual basal area, we reduce cubic-volume growth to about 75% of maximum possible on the site (114 ft^3 as opposed to the maximum possible of 148 ft^3/acre/year). Salvage of mortality will offset the deficit somewhat, but one of the prices for increased diameter growth rates is a loss in total fiber growth.

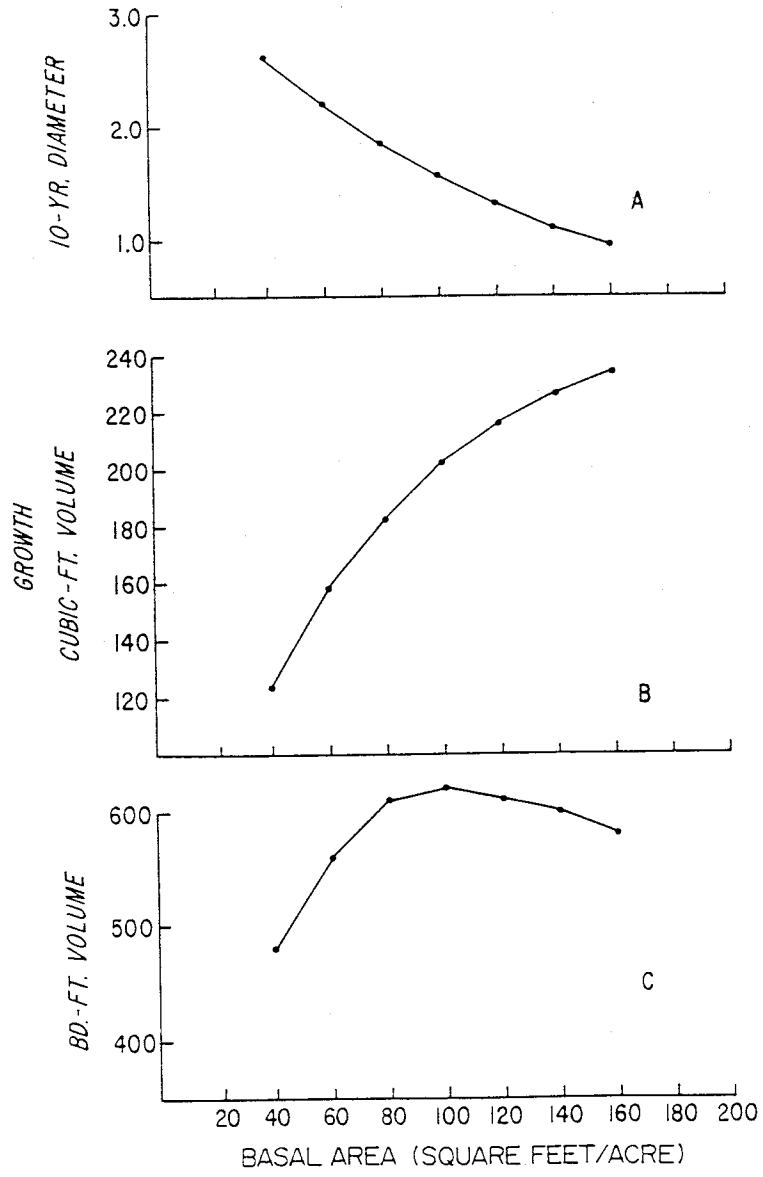


Figure 3. Volume and diameter growth rates in relation to stand basal area after thinning.

Board-Foot Volume Growth of Stands

Figure 3C shows board-foot volume growth for yellow-poplar in relation to basal area. It is evident that maximum rates of board-foot growth are achieved at much lower levels of basal area than that which is optimum for production of cubic-foot volume (Beck and Della-Bianca 1975).

Maximum board-foot growth is achieved at age 40 on site 100 land at a residual basal area of 100 ft^2/acre as opposed to 160 ft^2 for maximum cubic-foot growth. We could thin even more heavily, to say 60 ft^2, to accelerate diameter growth and still obtain better than 90% of maximum board-foot rate.

We can conclude for cove hardwoods in general that most unmanaged stands are far too heavily stocked for optimum diameter growth of individuals and board-foot growth of the stands. Increases in board-foot growth after thinning may not be large--in the neighborhood of 15 to 20%. But, at the same time, diameter growth rates may be increased by 50 to 100%. Note that the board-foot growth curve is relatively flat; i.e., board-foot growth rate is relatively constant over a wide range of basal area stocking. Consequently, there is a lot of latitude in thinning to meet management goals. There are several noteworthy points about the board-foot growth response. As a rule of thumb, the basal area stocking at which board-foot growth rate is maximized corresponds roughly to the site index for yellow-poplar (Figure 4). Trimble (1968) showed very similar trends for mixed cove

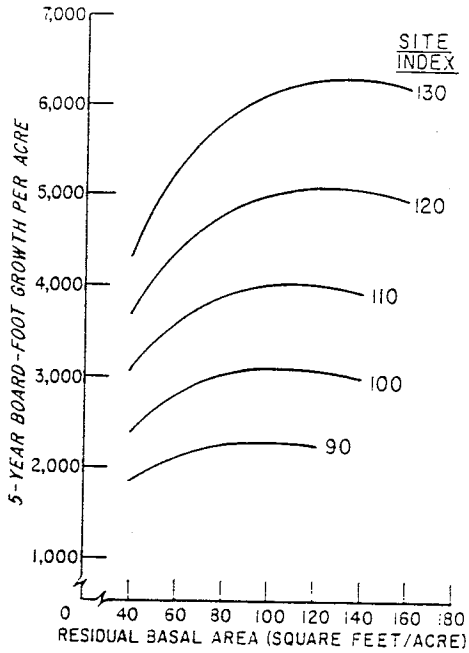


Figure 4. Board-foot growth rates by site class.

stands. This rule reflects the higher growth potential of the better sites and also reflects species composition. The better sites usually contain a higher proportion of smaller crowned species such as yellow-poplar, basswood, ash, and cherry that require less space for a given diameter. Lower quality sites usually contain a higher percentage of larger crowned species such as oaks. Another point to consider is that once stands reach the poletimber stage the level of residual stocking that maximizes board-foot growth changes very little with age.

Quality

Defect

By eliminating poor-quality trees and less desirable species and concentrating growth on the better trees, we can improve the quality of the stand through thinning. It is difficult to generalize about the amount of quality improvement through elimination of trees with crook, sweep, rot, etc. It is not uncommon, however, to have 25% or more of unmanaged stands in low-grade material with these sorts of defects (Frame 1981). Perhaps not all defect can be eliminated, but a substantial portion can. It has been estimated that percent defective could be reduced to 5% over a period of years by judicious thinning (Paxton 1981). Raising the value of 20% of stand volume by fivefold to tenfold is a goal worth seeking.

Limb-Related Defect

While much defect can be eliminated through thinning, it is also possible to create defect by encouraging development of epicormic branches on the residual crop trees. Studies of sprout development after thinning have brought out a number of points that can be used to lessen the impact of sprouting after thinning (Auchmoody 1972; Della-Bianca 1972, 1983; Erdmann et al. 1985; Keesee and Carvell 1974; Smith 1965, 1966; Trimble 1975; Trimble and Seegrist 1973; Trimble and Smith 1970; Wahlenberg 1950).

Sprouting:

1. Varies with species.

2. It is least likely on dominant and codominant trees of good vigor and is most likely on intermediate or suppressed trees of poor vigor.

3. Varies with intensity of thinning.

4. Is under strong genetic control--sprouters show the tendency to sprout before any release.

5. Is greater on poor sites than on good ones.

6. Is most on exposed faces of bole and on southerly exposure.

Trimble (1975) derived a relative ranking of susceptibility to sprouting for some of the most abundant cove species based on his own work and other published results (Table 1). All other things being equal, we would expect species like ash, red maple, and yellow-poplar to produce less sprouts than white oak, chestnut oak, and black cherry. For all species listed, more sprouts develop on second than on first logs and more sprouts develop on intermediate and overtopped trees than on dominant and codominant ones.

Table 1. Susceptibility to epicormic branching by species.

Number of branches	Species
Very many	White oak
Many	Basswood
	Northern red oak
	Chestnut oak
	Black cherry
Few	Yellow-poplar
	Sweet birch
	Red maple
	Hickory
	Beech
	Sugar maple
Very few	White ash

Some epicormic sprouts are going to develop after thinning, but we can greatly reduce the impacts of sprouting on quality by leaving vigorous trees from the dominant crown classes, and by favoring species with the least sprouting tendencies when a choice is possible. We can also favor those stems with the least number of branches prior to thinning. Trees with no visible epicormics before cutting generally will have few after cutting. Those trees that have many epicormics before thinning can be expected to "feather out" heavily after exposure. When thinnings are being made on lower quality sites where species such as white oak are prevalent, we may need to thin less heavily and leave overtopped and understory trees to shade the lower boles of the crop trees.

Development of Clear Bole

Another quality aspect of thinning is the effect on length of clear bole. In general, once thinning is begun, the rate at which clear length is formed will be lessened or perhaps halted altogether (Dale and Sonderman 1984; Sonderman 1984). In one study in stands thinned to 30% stocking, oaks and red maple halted development of clear length, and the clear length of yellow-poplar was actually lessened through growth of epicormics at the base of live crown (Sonderman 1984). In stands thinned to 50 and 70% stocking, clear length of all species continued to increase over the 6-year study period but at a slower rate than in comparable unthinned stands.

Species Composition

Because cove hardwoods typically contain a varied mixture of species, we may be inclined to assume that we can make great changes in composition through thinning. Research that deals directly with this subject is pretty scarce, but indications are that wholesale changes in species composition are not very likely (Carvell 1973; Hough and Taylor 1946). It seems logical that chances for affecting species composition would be best at an early stand age. In a West Virginia study, however, thinnings in 15- to 20-year-old cove stands gave only slightly better composition than thinnings in similar stands made 10 to 15 years later (Carvell 1973). By the time stands reach the pole and small sawtimber stages, species composition is not easily altered. However, in terms of value, even small shifts in volume may return large dollar yields.

Thinning Schedules

What does all this mean in terms of thinning schedules? When do we start? How often do we thin? How heavily?

There are several points worth considering when scheduling thinnings. The major benefit from thinning comes from concentrating stand growth on the highest value trees. Most of this benefit will be reaped at or near the final harvest. And in stands thinned periodically throughout their lives, most of the volume and value will be concentrated in a relatively few trees. For example, given a target mean dbh of 20 inches at rotation age, there will be only 50 to 60 trees/acre.

If the objective is to produce the maximum amount of wood suitable for high-quality products and funds for silvicultural investment are not limited, you should thin early, thin lightly, and thin often. Because of limited funds and other practical considerations, however, that adage will seldom apply.

Fortunately, Appalachian cove stands allow a lot of flexibility in thinning schedules to meet different objectives and economic restrictions. Because they are usually composed of varied species of differing growth potential, and of individuals of somewhat different

ages and modes of origin, cove stands do not stagnate because of density. If given enough time, they will differentiate into crown classes and develop reasonably well without much help. Given this fact and the wide range of conditions over which thinning response is possible, thinning decisions are largely controlled by markets and economics.

First Thinning

Because of the large impact of quality on value yield, most cove stands should be maintained in a relatively dense condition until the desired length of clear bole has developed. By "clear-bole" I mean free of live limbs. Dead limbs may still be present. In general, clear boles of satisfactory length will be present when stand height is approximately 50 feet. For some sites and species, this could come as early as stand age 20 to 30 years. At this stage, yields from thinning might run from 8 to 12 cords/acre. All the trees cut would be small, with average diameter not exceeding 5 to 6 inches. Given good access and good markets for small roundwood, such an operation could be marginally commercial. If no market is available, delaying thinning will lengthen the rotation, but you can usually afford to be patient. Loftis (1985) showed that an early noncommercial thinning improved yield, size, and quality somewhat over a stand in which thinning was delayed 7 years until a commercial operation was possible. However, even the delayed thinning resulted in a very substantial improvement over an unthinned stand (Table 2).

One circumstance where an early noncommercial operation might be mandatory would be where the most desirable species and best quality trees are being threatened by overtopping noncommercial species or trees of low-potential value. The earlier the release can be done the better. This operation would amount to a liberation cut rather than a thinning per se. I would release only a minimum number of trees per acre, say 50 to 60, and only those with potentially high value at rotation. It makes little sense to spend money releasing trees that will have to be cut in the next thinning for small low-value products. Based on Miller's (1984) estimates, that degree of release could be done with chain saws at a labor cost of 2.5 to 3.0 man-hours/acre.

Stocking Level and Thinning Interval

As previously noted, board-foot growth rates are maximized by basal area stocking that approximates site index for yellow-poplar, but the exact level is not critical from a stand-growth viewpoint. Stocking levels 20 to 40 square feet less can be carried to accelerate diameter growth. The exact level should be tempered by susceptibility to sprouting of the species in the stand. Thinning intervals will probably be in the range of 10 to 20 years, depending on age and site quality. At age 20, annual basal area growth will range from 3 to 6 ft^2/acre. By age 40, the rate will be halved and range from 1.5 to 3 ft^2. At age 60, we could expect annual growth rates of only 1 to 2 ft^2/acre. The thinning interval could be lengthened as age increases or stocking levels raised to account for the slower rates at which older stands close.

Table 2. Stand parameters at age 32 (10 years after thinning) under two thinning regimes.

	Treatment[a]	Treatment[b]	Treatment[c]
Volume (bd. ft./acre)	18,632	17,539	8,485
Mean diameter (inches)	13.0	11.6	8.4
Basal area (ft^2/acre)	113	115	146
Expected grade 1 + grade 2 trees (number/acre)	37	18	3

[a]Treatment 1--precommercial thinning at age 15 and commercial thinning at age 22.

[b]Treatment 2--commercial thinning at age 22.

[c]Treatment 3--unthinned.

Summary

Perhaps the key word that could be used to describe thinning in Appalachian cove hardwood stands is "flexibility". These stands can develop with a minimum of care, and given enough time, will produce considerable amounts of large, high-quality timber. On the other hand, they are responsive to thinning and allow concentration of the growth potential on high-value trees and shortening rotations by 30 to 50%. To paraphrase Smith (1962), in Appalachian cove stands, failure to thin should be looked upon as a lost opportunity rather than an invitation to disaster. I hasten to add, however, that the opportunity lost may be substantial.

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Rules of Thumb:

1) Basal area = Site Ind

2) Basal areas do not change w/ age

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THINNING POLE AND SMALL SAWTIMBER MIXED OAK STANDS

Martin E. Dale and Donald E. Hilt

Research Foresters
USDA Forest Service
Northeastern Forest Experiment Station
Delaware, OH 43015

ABSTRACT

The growth and yield of pole and small sawtimber mixed oak stands can be altered substantially by thinning. OAKSIM, an individual-tree growth and yield simulator, was used to study the timing, intensity, and frequency of intermediate thinnings in even-aged upland oak stands. Various thinning regimes were tested by projecting normal 30-year-old upland oak stands growing on sites 60 and 80 to rotation ages 80 and 120. Results indicate that one commercial C-level (40% residual stocking) thinning at age 40 provides a substantial increase in board-foot volumes and stand values for site index 60 stands at age 80. A second B-level (60% residual stocking) thinning can be applied to increase stand values. However, results indicate that a rotation age of 80 years is too short for site index 60 stands, regardless of the thinning regime. A rotation age of 120 years, with thinning, is much more realistic. A C-level thinning can be initiated at age 30 for site index 80 stands. A second B-level thinning and perhaps a third light thinning can be applied. These thinnings will produce a very reasonable 60 to 80 sawtimber trees at rotation age 80. Extension of the rotation age to 120 years greatly increases the number of grade 1 trees >16 inches in dbh.

Introduction

When we talk of thinning pole or small sawtimber stands in the mixed oak type, a number of questions arise immediately. Foresters want to know if thinning is a worthwhile cultural practice. If so, at what age should thinning begin? How heavy a cut should I make? And how much residual stocking should be left after thinning? Other questions concern the number of thinnings that are needed over a rotation and the timing and interval between subsequent thinnings.

In this paper we address timing, intensity, and number of thinnings, and discuss how these variables may vary with site quality, rotation age, and management objective. We also examine several typical

thinning regimes with respect to volume and value of yields generated from the thinnings and the final harvest cut. And we offer simple guidelines to help you decide at what stand age to thin, how much to thin or leave, and how often to thin.

Defining the Problem

Our discussion is limited to commercial thinnings as applied in the mixed oak type. Smith and Lamson (this proceedings) address precommercial options; Marquis (this proceedings) discusses commercial thinning of Allegheny hardwoods and Beck (this proceedings) covers commercial cutting of mixed hardwood stands.

We define a commercial thinning as one that will produce 5 cords of wood consisting of trees at least 5 inches dbh. A commercial tree must make a stick of wood at least 4 feet long with a minimum 4-inch top diameter inside bark (dib). Hence, our cord will be considered as 80 ft^3 of wood excluding bark.

We also limit our discussion to one type of thinning. That is a so-called "free thinning" that allows the timber marker to remove trees throughout all crown classes. In application, most of the cut is concentrated among the smaller trees, but this kind of thinning does allow for removing some of the larger cull, defective, or low-quality trees. This is often thought of as an areawide thinning, where the intent is to improve the spacing and upgrade the quality of the entire stand. By contrast, a crop-tree release cutting (Smith and Lamson this proceedings) is designed to improve growing conditions around a few specified trees.

Our management objective is to maximize landowner income by producing high-quality sawlogs and veneer products. We will look mostly at a fixed rotation age of 80 years but will discuss how longer rotations affect yields, both volume and dollars. Our yields are predicted for only two site quality classes-site index 60 and site index 80 for black oak, though trends could be extrapolated to other sites.

Basic Concepts of Thinning

Before proceeding to our results from thinning, we need to discuss why thinnings are so important in managing even-aged stands. Once an even-aged stand is established and up until the final harvest cut, intermediate cutting such as thinning is the most practical means of altering individual-tree or stand growth and yield.

Basic concepts of thinning are shown in Figure 1 (Davis 1956). This graph illustrates the generalized life history of an even-aged stand showing the characteristic features of a beginning and an ending. Curve A shows the maximum volumetric stocking that can be carried on the ground at a given age and site. Curve A is comparable to the A-level stocking curve in the upland oak stocking charts developed by Gingrich (1967) and discussed by Brenneman (this proceedings). The minimum curve for full site utilization shown in the figure as curve C

is comparable to the B-level stocking in the upland oak charts. Curve B depicts the effect of periodic thinnings that reduce stand stocking. Note that once a thinning is made, the stand responds quickly and has a faster growth rate than unthinned fully stocked stands.

The bar graph at the far right of Figure 1 shows that the total yield over a rotation may consist of both intermediate yields from thinnings and yields from the final harvest cut. Note that total production over the rotation is greater in thinned stands because of the added yields from the periodic thinnings.

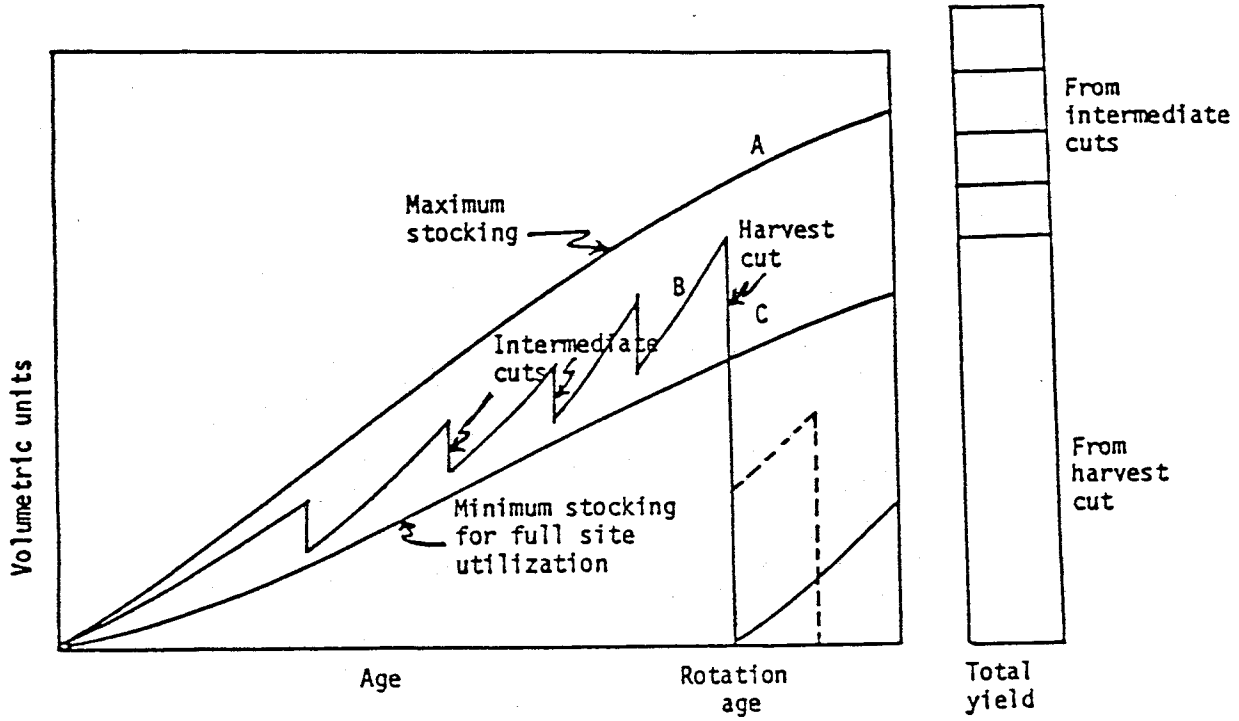


Figure 1. Generalized life history of an even-aged stand.

Most of the research in the oak type supports the theory of Moller (1954) that "within certain wide limits, the volume increment is not influenced by density of stocking." Therefore, stands between the A and C curve as shown in Figure 1 would produce essentially the same gross amount of wood per acre per year for a given age and site. However, the amount of net growth and mortality and the distribution of this growth among individual trees varies greatly between the A and C curves.

These points are well illustrated in Figure 2, which compares the periodic annual growth over a 5-year period of two stands--one an unthinned stand at 100% stocking and one thinned to 60% stocking. Notice that total wood production of the site is essentially the same or about 110 ft^3/acre/year. This means that the site is fully occupied by both stands. Individual trees obviously grow more rapidly in the thinned stands because this growth is distributed over 266

survivor trees compared to 408 trees in the unthinned stand. A larger part of the site potential is lost on the unthinned stand because of increased mortality. In this example, typical for stands on site 80 at age 30, we lose about 40% of potential production due to mortality in dense stands. Of course, most of this mortality at age 30 is in very small trees and of little commercial importance.

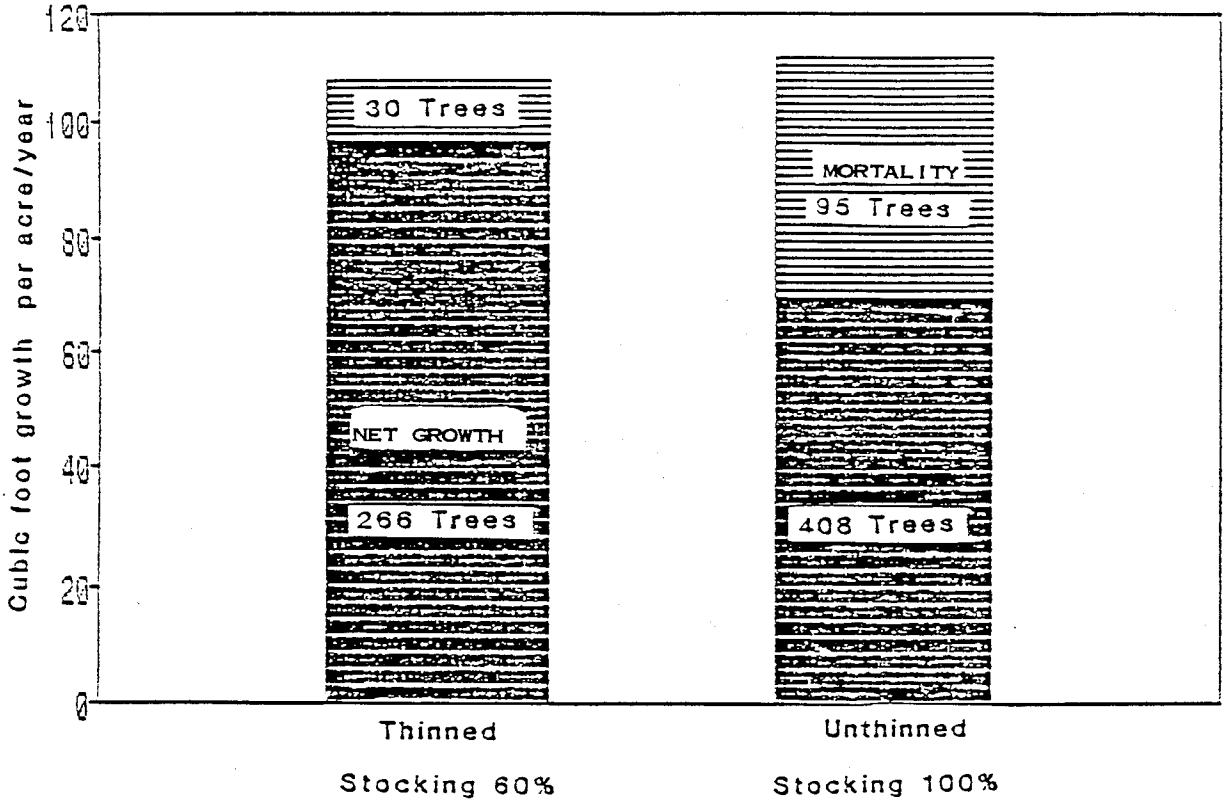


Figure 2. Comparison of net and gross growth of thinned and unthinned stands.

Reasons for Thinning

The following are some of the advantages of thinning:

1. The rotation length is shortened. It is well established that individual-tree growth is inversely related to population density. By altering stand stocking through thinnings, we can increase growth on individual trees (Figure 2) and produce a given-size timber product sooner. Or we could grow larger sized trees on a fixed rotation age by frequent thinnings that regulate stocking.

2. Stand quality is improved. The basic idea of a thinning is to remove the poor-quality, undesirable trees so that the potential growth of the site can be concentrated on the higher quality residual trees. However, extremely heavy thinnings can be detrimental to stand quality because they can stimulate epicormic branching on smaller codominant and intermediate stems, especially white oaks.

3. Species composition is altered. Lower value, undesirable, or slow-growing species can be removed in thinning and thereby concentrate growth on the more desirable, higher value species.

4. Mortality losses are reduced. Frequent thinnings usually remove low-vigor trees before they die, so we can use wood products which otherwise are lost to mortality. Heavy thinnings that are done less frequently also substantially reduce mortality losses. So thinning allows for greater utilization of the productive capacity of the site, as seen in Figure 2.

5. The timing of yields is altered. Without thinning there is only one time in the life of a stand where we can expect any yield or income--at the end of the rotation in the form of a final harvest cut. With thinning we can control the timing and quantities of yields. Altering this flow of forest products has significant economic implications, especially when compound interest rates are used over long periods such as a rotation.

Method of Growth and Yield Projection

Over the last 50 years, considerable information has been published on growth and expected yields from thinned and unthinned upland oak stands (Schnur 1937; McIntyre 1933; Gingrich 1970, 1971; Dale 1972). More recently, the results from long-term thinning experiments have been incorporated into computerized growth and yield projection systems (Hilt 1985a, b).

The OAKSIM model developed by Hilt and used here to project future yields is an individual-tree growth and yield simulator for managed, even-aged upland oak stands. The growth projection equations were based on more than seventy-five 1/2- or 1-acre plots, where growth had been monitored on every individual tree for 20 years or more. These plots represent a wide range of site, age, and residual stand densities created by one or more thinnings.

We ran the OAKSIM model for periods of 50 years starting at stand age 30 on two site quality classes--site index 60 and 80. OAKSIM produces periodic yields at 5-year intervals in cubic feet (both inside or outside bark) and in board-foot volumes international 1/4-inch rule. The yields given here are cubic feet to a 4-inch top dib and board-foot volume for trees 11.6 inches dbh and larger to an 8-inch top dib. OAKSIM allows for four species groups, so volume/tree varies for each species group depending on total tree height and bark thickness ratios. Approximate volumes are given in Table 1 for site 60 and in Table 2 for trees on site 80.

Table 1. Approximate per acre volumes and value per tree[a] from thinnings and final harvest on site 60.

Dbh	Volume		Thinnings		Final harvest		
	Cubic feet	Board feet	First	Subsequent[b]	Unthinned stands	Stocking <50%[c]	Stocking >50%
in.			Dollars				
5	2.5		.12	.12	.12	.12	.12
6	3.1		.16	.16	.16	.16	.16
7	5.4		.27	.27	.27	.27	.27
8	7.9		.40	.40	.40	.40	.40
9	10.8		.54	.54	.54	.54	.54
10	14.2		.71	.71	.71	.71	.71
11	17.9		.90	.90	.90	.90	.90
12	22.1	80	3.35	4.04	6.64	7.38	7.40
13	26.7	107	5.93	6.06	9.77	10.86	11.10
14	31.6	137	8.48	8.82	13.98	15.53	16.15
15	36.8	168	11.82	12.49	19.49	21.66	22.90
16	42.3	200	16.16	17.31	26.61	29.57	31.74
17	48.2	234	21.60	23.50	35.66	39.62	43.12
18	54.4	270	28.44	31.36	46.98	52.20	57.55
19	60.9	307	36.91	41.19	60.98	67.75	75.61
20	67.8	344	47.25	53.33	78.09	86.77	97.94
21	74.8	384	59.77	68.19	98.81	109.79	125.26

[a]Pulpwood value of trees 5 through 11 inches dbh remained constant at $4.00/cord or $0.05/ft^3 for all thinnings and final harvest.

[b]Sawtimber values are for logs delivered to sawmill based on their size and average grade. If preceding thinning reduced stocking below 50%, we used the value of the first thinning. In this case, the lower values are justified because we would be removing low quality trees with epicormic branches that developed after the first heavy cutting.

[c]If the most recent thinning reduced stocking below 50%, we used these values for the final harvest. These values are higher than unthinned stands that still contain low value species and some unmerchantable trees, but they are lower than stands where thinnings were light.

OAKSIM requires either a tree list or a stand table to start the initial yield projections. Since tree growth can vary greatly by species and size class, our projections are based on stand tables that separate trees into four species groups by 1-inch diameter class. We used the same starting stand conditions as given in Schnur's (1937) stand tables for age 30 on site 60 and 80. Our species groups consisted of white oak, black oak, other intolerant species, and other tolerant species. We realize that typical oak stands may vary

considerably for a given age and site in species composition as well as in the number and size of trees. By using Schnur's stand tables, we eliminated this natural variation in stand conditions. This will make the comparison between thinning regimes reflect the actual response of the thinning treatments rather than differences in initial stand conditions.

Table 2. Approximate per acre volumes and value per tree[a] from thinnings and final harvest on site 80.

Dbh	Volume		Thinnings		Final harvest		
	Cubic feet	Board feet	First	Subsequent[b]	Unthinned stands	Stocking <50%[c]	Stocking >50%
in.			----------	----------	Dollars	----------	----------
5	2.9		.14	.14	.14	.14	.14
6	3.7		.18	.18	.18	.18	.18
7	6.2		.31	.31	.31	.31	.31
8	9.2		.46	.46	.46	.46	.46
9	12.6		.63	.63	.63	.63	.63
10	16.5		.82	.82	.82	.82	.82
11	20.8		1.04	1.04	1.04	1.04	1.04
12	25.8	100	5.58	5.59	9.20	10.22	10.24
13	31.0	135	8.06	8.23	13.28	14.76	15.08
14	36.7	172	11.32	11.77	18.68	20.75	21.58
15	42.8	212	15.53	16.42	25.62	28.47	30.11
16	49.2	254	20.88	22.41	34.46	38.29	41.10
17	56.1	298	27.57	30.00	45.52	50.58	55.05
18	63.3	343	35.83	39.50	59.18	65.75	72.49
19	70.9	390	45.90	51.23	75.84	84.27	94.05
20	78.8	439	58.07	65.55	95.98	106.64	120.37
21	87.1	491	72.62	82.86	120.07	133.41	152.20

[a]Pulpwood value of trees 5 through 11 inches dbh remained constant at $4.00/cord or $0.05/ft^3 for all thinnings and final harvest.

[b]Sawtimber values are for logs delivered to sawmill based on their size and average grade. If preceding thinning reduced stocking below 50%, we used the value of the first thinning. In this case, the lower values are justified because we would be removing low quality trees with epicormic branches that developed after the first heavy cutting.

[c]If the most recent thinning reduced stocking below 50%, we used these values for the final harvest. These values are higher than unthinned stands that still contain low value species and some unmerchantable trees, but they are lower than stands where thinnings were light.

Our thinning regimes look at three intensities of thinning that leave 40, 60, or 75% stocking in the residual stand after thinning, plus a control or unthinned stand. One of our objectives was to find out the earliest stand age at which we could make a commercial cut, that is, a thinning that would remove at least 5 cords/acre of pulpwood. To help answer this question, we started our initial thinnings at three ages--30, 40, or 50--to see whether or not we could make a 5-cord cut.

Before we look at the results of these thinning regimes, we need to discuss the trees we remove in a thinning and how we placed dollar values on the trees and stand.

Selecting Leave or Cut Trees in Thinning

The intent of a thinning, as we said earlier, is to concentrate the growth potential of the area on the best trees. If we are making a light thinning, we would accomplish this by selecting and removing the cull, defective, and low-value species from the main stand canopy. In even-aged stands, the crop trees we want to favor are primarily the dominants and codominants in the main stand. These are the larger, faster growing trees in the stand that will reach a given product size quicker than the intermediates. Also, the dominants and codominants have a well-developed crown that will quickly utilize the additional growing space. Intermediate trees with their small crowns and straight stems may appear as good potential crop trees, but we must be cautious. Often, these trees will respond to a sudden increase in growing space by developing epicormic branches. Some species are more prone to develop epicormic branches than others (Smith 1966; Tubbs 1977), particularly small intermediate white oak.

When thinning to B- or C-level stocking, we usually select the best trees to leave and cut the rest. With such a heavy thinning we have to be especially careful about the leave trees. Try to leave dominants or codominants with well-developed crowns. If you have to leave some intermediates to fill in space, try to select those with larger healthy crowns. We prefer to leave several good trees in a clump rather than strive for more uniform spacing to fill in open spaces with questionable intermediate crop trees.

In the OAKSIM program we have a thinning rule that removes trees throughout all size classes. The rule removes a few of the larger trees but concentrates most of the cut in the smaller trees. Table 3 gives the percentage of trees cut from each dbh class for thinning to 40, 60, or 75% stocking. Thinning tends to increase the average stand diameter of the residual trees, and the heavier the cut, the greater the increase in mean stand diameter. This thinning rule was based on the relation between the cut and residual trees that we observed after thinning the permanent growth plots. Our actual thinning, however, was based on quality, size, species, and spacing.

Table 3. Number and percentage of trees cut, by dbh class, at different stocking levels at age 30 on site 80.

Dbh class	Unthinned Number of trees	75% stocked Number	75% stocked Percent	60% stocked Number	60% stocked Percent	40% stocked Number	40% stocked Percent
in.							
3	74	21	28	40	54	72	97
4	96	26	27	47	49	83	86
5	105	26	25	44	42	72	69
6	97	21	22	34	35	52	54
7	68	13	19	21	31	32	47
8	37	7	19	12	32	16	43
9	19	4	21	6	32	8	42
10	7	1	14	3	43	3	43
Total trees (No.)	503	119	24	207	41	338	67
Basal area (ft^2)	90	19	21	33	37	50	56
Mean dbh cut	--	5.4	--	5.4	--	5.2	--
Mean dbh residual	5.7	5.8	--	5.9	--	6.6	--

Tree and Stand Value

Timber prices vary greatly from one area to another according to accessibility, right of ways, terrain, haul distance, log size, quality, quantity, and species. Some of these variables, such as quality, log size, and species, are important because they can be altered by the thinning practices. Research has made great progress in modeling volume response associated with different thinning regimes, but much work is needed in modeling the changes in quality.

We have attempted to develop a price structure here that allows for different prices depending on the intensity of thinning and tree size. The values given in Tables 1 and 2 were developed starting with average sawlog prices for delivered white oak and red oak logs, by grade and size, as reported in 1985 by the Ohio Crop Reporting Service. Average price/M bf ranged from about $90 for small grade 3 logs to more than $360 for grade 1 logs over 16 inches scaling diameter. The average price/tree in Tables 1 and 2 was based on the relative proportion of trees in each of the log grades by 1-inch size

class (Dale and Brisbin 1985). The values in Tables 1 and 2 are not stumpage prices, but they are just as useful in making relative comparisons among different thinning options. Stumpage prices might be approximated if the manager knows the logging and hauling costs and allows a margin for profit and risk.

The value of trees at final harvest depended upon whether the stand had been heavily thinned, lightly thinned, or unthinned. Normally, we would expect the average value of residual trees to increase after thinning because the cull, defective, and low-value species are removed in thinning. When thinning reduced stocking below 50%, we did not allow tree values to increase as much as with light thinnings because such a heavy thinning might result in some trees developing new epicormic branches.

Site 60 Thinning Regimes

Yields in board feet and cords and dollar values are given in Table 4 for a number of thinning regimes. We will discuss thinning on site 60 first because the number of thinning options that will yield a commercial cutting is very limited compared to those for site 80. Some of the options shown in Table 4 will not provide a commercial cut. For example, stand 1 is thinned to 40% stocking at age 30 and yields only 3.6 cords/acre. Stand 4 is thinned to 60% at age 30 and yields 2.4 cords. These two options are listed merely to show that age 30 is too young to thin on site 60 and expect a 5-cord cut. Table 4 indicates that we can expect 5 to 7 cords/acre by delaying thinning to age 40 and thinning to 60 or 40% stocking (stands 2 and 5). We also see that we must delay thinning to about age 50 if we want to make a commercial thinning using a light cut (75% stocking, stand 7).

If we plan to make only one thinning in an 80-year rotation on site 60, it appears that thinning to 40% stocking at age 40 may be our best choice (stand 2). This option gives the largest board-foot yield, 5,890/acre compared to 2,650 from the unthinned stand. Final harvest of stand 2 yields $55 worth of pulpwood and $662 in sawtimber, or a total harvest of $717. This value is greater than any of the other options involving one thinning.

The value of sawtimber in stand 2 is actually quite low, only $112.40/M bf delivered to the mill. It is still higher than the control where the value of sawtimber is $251, or $94.57/M bf. Remember that the control still contains some cull, defective or low-value trees that were not removed by thinning.

Stand 2 values also are higher because the sawtimber trees are slightly larger. Table 5 gives the stand characteristics for each of the thinning options shown in Table 4. On the stand thinned to 40 percent at age 40 (stand 2) 52 trees are 12 inches or larger by rotation age 80. Average stand diameter is 11.0 inches compared to 9.1 on the control. There are about three trees that are 16 inches or larger compared to only one 16-inch tree on the control. The number

Table 4. Yields per acre for harvest age 80 on site 60.

Stand No.	Stocking after thinning at stand age					Thinnings			Final harvest			Cumulative yields			
	30	40	50	60	70	Number Cords	Board feet[a]	Value	Number Cords	Board feet	Value	Number Cords	Cubic feet	Board feet	Value[b]
	---------Percent----------							Dollars			Dollars				Dollars
Control	--	--	--	--	--	--	--	--	26.1	2,650	355	26.1	2,732	2,650	355
1	40	--	--	--	--	3.6	--	14	16.0	5,810	716	19.6	2,935	5,810	816
2	--	40	--	--	--	7.2	--	29	13.8	5,890	717	21.0	3,065	5,890	856
3	--	--	40	--	--	11.3	70	45	13.3	4,960	637	24.6	3,117	4,960	783
4	60	--	--	--	--	2.4	--	10	21.8	3,970	541	24.2	3,207	3,970	612
5	--	60	--	--	--	5.1	--	20	21.3	3,540	499	26.4	2,939	3,540	595
6	--	--	60	--	--	7.8	70	31	20.2	3,280	456	28.0	3,020	3,280	557
7	--	--	75	--	--	4.9	--	20	21.9	3,240	465	26.8	2,916	3,240	530
8	--	--	--	40	--	14.6	170	58	11.4	4,260	560	26.0	3,070	4,260	687
9	--	40	--	40	--	15.2	350	61	6.4	6,570	901	21.6	3,213	6,510	1,110
10	--	40	--	--	40	18.9	1,020	76	5.7	5,370	703	24.6	3,174	5,370	912
11	--	40	--	--	60	12.2	750	49	11.8	5,160	656	24.0	3,124	5,160	825
12	--	60	--	60	--	10.7	510	43	17.6	3,570	528	28.3	3,082	3,570	674
13	--	60	--	--	60	13.3	710	53	16.1	2,910	403	29.4	3,040	2,910	548

[a]If volume from thinning was <2,000 board feet/acre the sawtimber trees were included in the cordwood yield and evaluated as such.

[b]Includes final harvest plus value of thinning compounded annually at 4% from time of thinning to age 80.

Table 5. Per acre stand characteristics for site 60 stands at age 80.

Stand No.	Stocking after thinning at stand age					Number of trees	Basal area	Stocking	Mean dbh	Sawtimber trees		
	30	40	50	60	70					Total	Trees ≥16-inch	Maximum diameter
	--------Percent--------						ft^2	Percent	Inches	-----Number------		Inches
Control	--	--	--	--	--	249	112	101	9.1	26	1	16
1	40	--	--	--	--	174	102	88	10.4	51	3	18
2	--	40	--	--	--	142	94	80	11.0	52	3	18
3	--	--	40	--	--	125	84	71	11.1	42	2	19
4	60	--	--	--	--	208	107	94	9.7	36	2	17
5	--	60	--	--	--	206	102	90	9.5	31	2	17
6	--	--	60	--	--	184	95	84	9.7	30	2	17
7	--	--	75	--	--	216	102	91	9.3	30	3	17
8	--	--	--	40	--	105	72	61	11.2	36	2	19
9	--	40	--	40	--	88	73	60	12.4	51	7	20
10	--	40	--	--	40	73	61	50	12.4	41	5	20
11	--	40	--	--	60	117	81	68	11.3	45	3	19
12	--	60	--	60	--	159	88	76	10.0	30	2	18
13	--	60	--	--	60	149	78	69	9.8	26	1	17

of sawtimber trees 16 inches or larger is very important. To qualify as a grade 1 log, a tree must be a minimum of 16 inches dbh. Table 5 indicates that even with one thinning, an 80-year rotation on site 60 is not long enough to develop any quality in our timber stand. We would like to see 50 to 60 sawtimber trees (12 inches or larger) at the final harvest and would like at least 20 to 30 of these to be large enough to qualify as a grade 1 tree.

Five of the thinning options in Table 4 indicate two thinnings. Stands 11 and 12 barely produce enough wood for the second thinning to yield 5 cords. Stand 11 shows a combined yield of 12.2 cords/acre from the first and second thinning. Since the timing and intensity of this first thinning are the same as for stand 2, we expect 7.2 cords from the first thinning and 5.0 cords from the second. The 750 bf/acre thinned from stand 11 and 510 bf/acre from stand 12 are small sawtimber trees and undoubtedly would be processed as pulpwood rather than sawlogs in a logging operation. We show the board foot volume from thinnings in Table 4 merely to indicate that a few of the thinned trees are 12 inches dbh or larger. We converted the board feet to cords and evaluated it the same as pulpwood in Table 4.

Tables 4 and 5 seem to indicate that two thinnings are better than one in terms of board-foot and dollar returns. Thinning to 40% at age 40 and again to 40% at age 60 seems to give the best board-foot and dollar yields on an 80-year rotation. We are hesitant to recommend this thinning regime at the present time as heavy thinnings that leave less than 50% stocking may have a detrimental effect on quality because of epicormic branching (Dale and Sonderman 1984; Sonderman 1985). We believe that for young stands, 40 years or less, one thinning to 40% stocking may be acceptable. Not all trees will "feather out" at this young age and we still have many trees as potential crop trees for the final harvest. If two thinnings are planned, many of the trees that develop epicormics could be removed in the second thinning. Unless you are willing to accept considerable risk because of potential quality losses, we recommend the more conservative thinning options such as for stand 11 or 12. Tables 4 and 5 indicate limited thinning options on site 60 if we expect to hold to an 80-year rotation. All indications are that an 80-year rotation is not feasible on site 60 if our objective is to produce high-quality sawlogs or veneer.

Site 80 Thinning Regimes

Site 80 offers many more opportunities for commercial thinning than are found on site 60. Table 6 indicates we can expect 5 cords/acre or more from thinning as early as age 30. We get only 3.3 cords/acre from a very light thinning at age 30 (stand 7), but thinning to 40% (stand 1) or 60% (stand 4) yields 8.3 and 5.8 cords, respectively.

The intensity of thinning seems more important than the timing of the first thinning. This was also true at site 60. The heavy thinning to 40% stocking provides a greater yield at age 80 both in board feet or dollars than lighter thinnings to 60 or 75% stocking. This is true

for all three starting ages of 30, 40, or 50 years. The heavy thinning leaves fewer trees, as indicated in Table 7, which shows only 90 to 115 trees/acre at final harvest (stands 1, 2, and 3).

Thinning to 40% at age 40 apparently yields about the same board feet but more dollars than thinning to 40% 10 years earlier. There are fewer trees left after the thinning at age 40; hence, the stand does not close quite as rapidly so individual trees grow at a faster rate over a longer period.

As on site 60, two thinnings are better than one. If the first thinning is to 40% at age 30 (stand 1), a second thinning 10 years later to 40% will yield 4.8 cords plus 250 board feet of sawtimber (stand 10) or a total of 5.8 cords. The increase in board-foot yield of stand 10 compared to stand 1 is 2,210 board feet, or a 14% increase. The dollar increase is even greater, an additional $636, or 28% more.

Tables 6 and 7 indicate that on site 80, three thinnings may be practical with an 80-year rotation. Comparing the board-foot or dollar yield given in Table 6 may not be sufficient in deciding which thinning regime is best--the stand characteristics in Table 7 also should be considered. For example, the thinning regime for stand 16 may appear a good choice based on cumulative yields, but Table 7 shows that the final harvest has only 38 trees and 50% stocking, which is inadequate for a final harvest.

Even on site 80, one thinning that leaves 75 or even 60% stocking fails to develop a mature stand ready for harvesting at age 80. A heavy thinning to 40% at age 30 or 40 starts to approach the type of stand we want to harvest at age 80. We have many sawtimber trees >12 inches dbh and 20 or more of these are >16 inches. Quality, volume, and value increase rapidly as trees cross the 16-inch-diameter threshold. We believe that hardwood managers in the oak timber type should look carefully at these kinds of stand characteristics when setting the rotation age.

Timing of First Thinning

Timing of the first commercial thinning depends, of course, on what constitutes a commercial thinning. We defined a commercial thinning as one that produced at least 5 cords/acre. This is an arbitrary figure and will vary with location, terrain, logging chance, equipment, and individual operator. Table 8 shows the basal area, number of trees, mean dbh, and cubic-foot volume that could be cut from fully stocked stands using our thinning rule. This information is given for age 30, 40, and 50 for site 60 and 80. It can help you decide when to thin even though you may not have fully stocked stands and may require more or less than 5 cords for a commercial operation.

Suppose you know it takes at least 7 cords/acre to entice a pulpwood cutter into your woods on a thinning job. Your site 60 stand is only 80% stocked but it appears you can remove about 40 ft^2/acre of basal

Table 6. Yields per acre for harvest age 80 on site 80.

Stand No.	Stocking after thinning at stand age (30)	(40)	(50)	(60)	(70)	Thinnings Number Cords	Board feet[a]	Value	Final harvest Number Cords	Board feet	Value	Cumulative yields Number Cords	Cubic feet	Board feet	Value[b]
	Percent							Dollars			Dollars				Dollars
Control	--	--	--	--	--	--	--	--	17.4	12,030	1,482	17.4	3,972	12,030	1,482
1	40	--	--	--	--	8.3	--	33	7.8	15,330	2,234	16.1	4,418	15,330	2,469
2	--	40	--	--	--	14.7	150	59	5.5	15,110	2,442	20.2	4,651	15,110	2,725
3	--	--	40	--	--	19.5	640	78	6.1	12,700	1,938	25.6	4,632	12,700	2,191
4	60	--	--	--	--	5.8	--	23	17.4	11,350	1,618	23.2	4,262	11,350	1,781
5	--	60	--	--	--	9.9	150	40	15.6	11,240	1,585	25.5	4,419	11,240	1,777
6	--	--	60	--	--	13.4	640	54	12.0	11,340	1,602	25.4	4,469	11,340	1,777
7	75	--	--	--	--	3.3	--	13	17.3	11,490	1,534	20.6	4,129	11,490	1,626
8	--	75	--	--	--	6.3	70	25	17.0	11,010	1,570	23.3	4,253	11,010	1,690
9	--	--	75	--	--	8.7	210	35	14.4	11,390	1,570	23.1	4,305	11,390	1,684
10	40	40	--	--	--	14.1	250	56	1.6	17,540	2,870	15.7	4,689	17,540	3,215
11	40	--	40	--	--	20.2	1,230	81	2.3	16,240	3,350	22.5	4,823	16,240	3,740
12	40	--	60	--	--	12.7	700	51	4.3	15,980	2,622	17.0	4,600	15,980	2,915
13	60	--	60	--	--	15.7	550	63	9.5	12,820	1,948	25.2	4,575	12,820	2,240
14	--	60	--	60	--	18.6	1,210	74	8.6	11,820	1,735	27.2	4,656	11,820	2,002
15	40	40	40	--	--	19.8	870	79	1.0	17,170	3,546	20.8	4,850	17,170	3,965
16	40	--	40	--	40	21.5	4,960*	406	--	12,950	3,065	21.5	4,906	16,680	3,936
17	40	--	60	--	60	15.6	2,950*	246	1.7	14,490	2,501	17.3	4,727	17,440	3,083
18	40	40	--	--	60	21.4	2,000	86	1.4	15,490	2,870	22.8	4,786	15,490	3,259

[a]If volume from thinning was less than 2,000 bf/acre, the sawtimber trees were included in the cordwood yield and evaluated as such.
*Stand 16--third thinning yield of 3,730 bf/acre evaluated as sawtimber.
*Stand 17--third thinning yield of 2,250 bf/acre evaluated as sawtimber.
[b]Includes final harvest plus value of thinnings compounded annually at 4% from time of each thinning to age 80.

Table 7. Per acre stand characteristics for site 80 stands at age 80.

Stand No.	Stocking after thinning at stand age (30)	(40)	(50)	(60)	(70)	Number of trees	Sawtimber trees Basal area	Stocking	Mean dbh	Total	Trees ≥16-inch	Maximum diameter
	Percent						ft^2	Percent	Inches	Number		Inches
Control	--	--	--	--	--	168	122	102	11.6	74	11	18
1	40	--	--	--	--	115	111	90	13.3	79	20	21
2	--	40	--	--	--	98	102	81	13.8	73	23	22
3	--	--	40	--	--	90	91	73	13.6	64	18	22
4	60	--	--	--	--	148	116	96	12.0	67	13	18
5	--	60	--	--	--	141	111	92	12.0	66	11	18
6	--	--	60	--	--	127	103	85	12.2	70	6	20
7	75	--	--	--	--	163	119	100	11.6	72	8	17
8	--	75	--	--	--	157	116	97	11.6	70	8	19
9	--	--	75	--	--	148	111	92	11.7	71	10	18
10	40	40	--	--	--	83	103	80	15.1	76	32	22
11	40	--	40	--	--	65	92	71	16.1	57	31	25
12	40	--	60	--	--	98	105	84	14.0	80	21	22
13	60	--	60	--	--	120	104	85	12.6	72	15	22
14	--	60	--	60	--	106	95	77	12.8	67	12	19
15	40	40	40	--	--	58	93	70	17.2	55	37	27
16	40	--	40	--	40	38	67	50	18.0	38	25	27
17	40	--	60	--	60	73	87	68	14.8	66	28	23
18	40	40	--	--	60	66	88	68	15.7	60	34	22

area and still maintain adequate stocking. The information from Table 8 as displayed here in Figure 3 indicates that you could expect to make your first commercial thinning at about age 45. If you needed only 3 cords/acre, you could have started thinning just before age 30. As you can see in this example, the number of cords required in the cut has a major bearing on the timing of the first thinning.

Table 8. Trees removed per acre in thinning, by site, age, and residual stocking.

Stand age (years)	40 percent stocking				60 percent stocking				75 percent stocking			
	No. of trees	Basal area	Mean dbh	Volume	No. of trees	Basal area	Mean dbh	Volume	No. of trees	Basal area	Mean dbh	Volume
		ft^2	in.	ft^3		ft^2	in.	ft^3		ft^2	in.	ft^3
					SITE 60							
30	446	44	4.2	290	273	28	4.3	196	142	16	4.5	122
40	351	52	5.2	578	223	34	5.3	405	129	21	5.5	263
50	276	57	6.2	903	175	38	6.3	628	108	24	6.4	393
					SITE 80							
30	338	51	5.2	664	207	33	5.4	460	119	19	5.4	268
40	237	59	6.8	1,174	152	39	6.9	790	93	25	7.0	501
50	191	65	7.9	1,563	126	44	8.0	1,071	78	28	8.1	697

Table 9. Final harvest cut of selected stands at 120-year rotation.

Stand No.	Stocking after thinning at stand age					Board feet	Value	No. of trees	Basal area	Stocking	Mean dbh	Sawtimber trees		
	30	40	50	60	70							Total	Trees ≥16-inch	Maximum diameter
	-------Percent--------						Dollars		ft^2	Percent		-----Number-----		Inches
							SITE 60							
Control						10,400	1,073	163	122	102	11.7	75	9	20
1	40	--	--	--	--	12,700	1,648	129	118	96	13.0	74	20	21
2	--	40	--	--	--	13,950	1,764	114	115	92	13.6	84	22	21
11	--	40	--	--	60	14,240	2,128	98	108	86	14.2	80	25	23
13	--	60	--	--	60	11,210	1,540	121	108	88	12.8	67	20	21
							SITE 80							
Control						23,210	3,194	115	132	104	14.5	99	34	22
1	40	--	--	--	--	25,620	4,662	81	128	97	17.0	76	47	26
4	60	--	--	--	--	23,240	3,793	106	129	101	15.0	95	34	22
7	75	--	--	--	--	24,280	4,103	103	131	102	15.3	104	43	23
12	40	--	60	--	--	25,190	5,274	82	125	95	16.7	81	45	26

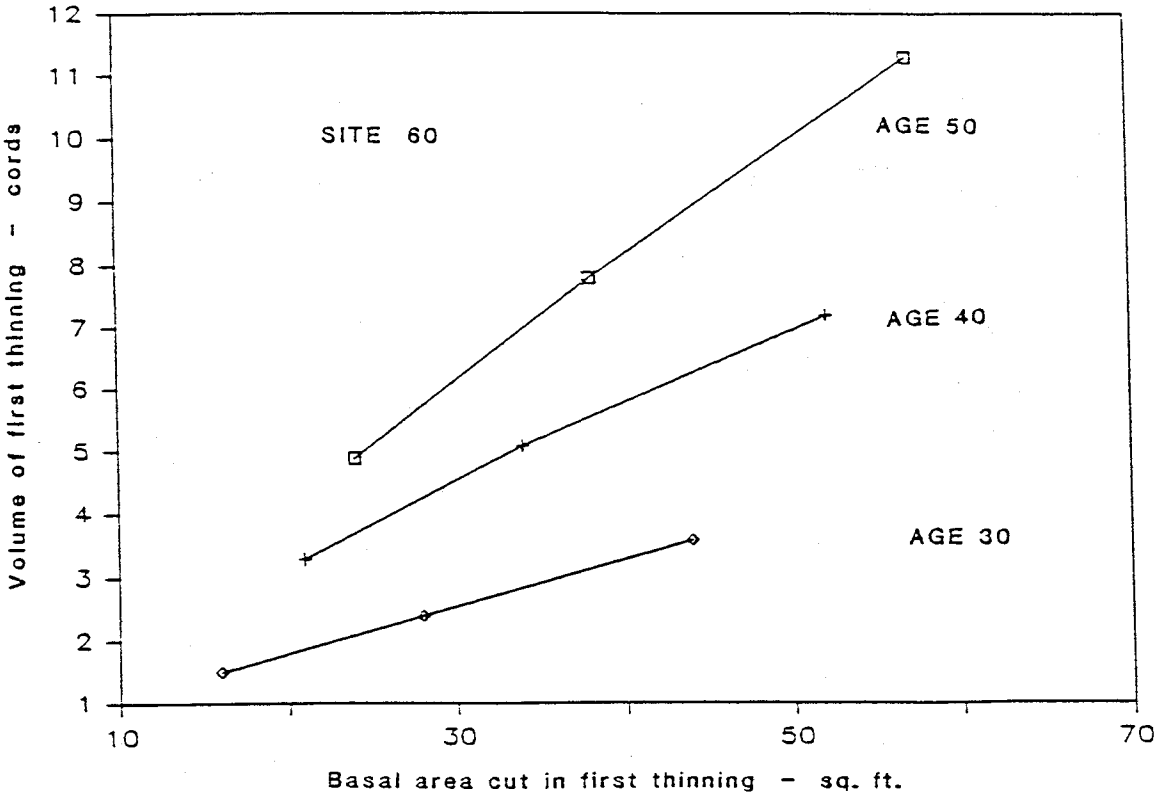


Figure 3. Relation between cordwood yield and basal area cut.

Rotation Age

As is seen in Tables 4 and 6, harvest yields are very dependent on the timing, frequency, and intensity of thinning; rotation age also is important. We have seen on site 60 that even with proper timing, frequency, and intensity of thinning, it would be difficult to produce a stand mature enough to harvest in 80 years. We simply cannot grow trees fast enough on site 60 to develop the size necessary to produce many grade 1 trees.

We looked at extending rotation age of a few stands to 120 years on both site 60 and site 80. Table 9 indicates that in 120 years with a thinning or two we do produce mature stands and greatly increase the stand value. Without the thinnings, a site 60 stand probably will have <10 trees 16 inches dbh or larger and, therefore, would yield little quality or value. On site 80, even the unthinned stand has reached sufficient size to be considered mature. We would expect more than 20 trees 16 inches dbh or larger and the board-foot volume to have about peaked. We could develop more appropriate thinning regimes for rotation age 120 but these tables illustrate that early thinnings do help shorten the rotation length.

Summary

This study indicates that timing, intensity, and frequency of thinning are extremely important silvicultural considerations in managing upland oak stands for higher quality sawlogs or veneer products. Many of the findings presented here will be useful in developing a set of comprehensive management guidelines for upland oaks. These guidelines will blend silvicultural practices with economic considerations for different management objectives. Such guidelines must examine other thinning options that include different rotation ages, sites, stand structures, and other thinning regimes. Nonetheless, these findings reveal some important silvicultural and economic considerations for managing upland oak stands. Some of these can be summarized as follows:

Timing of first thinning. It appears that commercial thinning may begin as early as 30 years on our best upland oak sites. This assumes no prior stand treatments such as weeding, precommercial thinning, or crop-tree release. Such practices would allow earlier commercial cuts, but would have to be made at the owner's expense. On poor sites we have to delay the first commercial cut by at least 10 and perhaps 15 years. On site 60 we should be able to start thinning by age 40.

Intensity of first thinning. Regardless of the site, it appears that our first thinning should be very heavy. If the thinning is done at an early age, we can reduce stocking to the C-level (or 40%) and the stand still will contain sufficient trees for later cutting and final harvest. These young stands close quickly when we leave at least 160 or more potentially good crop trees.

Frequency of thinning. The frequency of thinnings depends on the intensity of the first and subsequent cuts and on site quality. On good sites and a short rotation of 80 years, we probably can make a maximum of three thinnings, though two thinnings seem more practical. The last thinning before the final harvest should not be as heavy as prior thinnings.

At the time of the last thinning, the trees are larger, they are spaced farther apart, and they are fewer in number, so it takes longer for these stands to close. We do not want to risk epicormic branching on our potential sawlog trees. And we want to maintain stocking so that for the final harvest cut, we have a well-stocked stand with at least 50 good sawtimber trees/acre.

On site 60, we have a limited set of thinning options if we are limited to an 80-year rotation. Realistically,

we probably are limited to only one commercial thinning. We can make a heavy thinning by age 40 and stocking still will approach only 80% by age 80. One heavy thinning at age 40 followed by a thinning to B-level at age 70 leaves insufficient time for stocking to develop by rotation age.

Rotation age. This study indicates that rotation age should be geared to site index if possible. Very good sites may produce high-value sawlogs and some veneer in 80 years if thinnings are started early and repeated. On site 60 it is not possible to produce high-quality sawlogs in 80 years even with commercial thinnings. On the basis of our results, it appears that the rotation age on site 60 should be about 120 years; on site 80 the rotation might be 80 years. Most of the upland oak timber type is on sites between 65 and 75. We have not looked at site 70, but we would judge that the rotation age should be close to 100. These rotations assume at least one or two commercial thinnings.

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THINNING OAK STANDS IN VIRGINIA

Thomas A. Dierauf

Chief of Applied Research
Virginia Division of Forestry
Charlottesville, VA 22903

ABSTRACT

This report presents results of a paired-plot thinning study installed during the 1960's. Thinning was done to free crop trees, and was generally heavier than recommended by stocking guides. Many of the plots were thinned a second time. Thinned and non-thinned plots are compared for diameter growth, epicormic sprouting, crop tree crown class changes, mortality, and ice and snow damage. The site index relationship between yellow-poplar and red oak is discussed.

Introduction

This report is based on a small hardwood thinning study begun in the 1960's. It includes 32 plot pairs, widely scattered over the mountain and Piedmont areas of Virginia. We installed 5 pairs of plots in 1963, 7 pairs in 1964, 2 pairs in 1965, 11 pairs in 1968, and 7 pairs in 1969. Plots have been measured every 5 years, and we have 20-year results on 13 pairs, 15-year results on 17 pairs, and 10-year results on 2 pairs.[1]

One-fifth acre circular plots[2], with a suitable buffer, were installed in well-stocked, even-aged stands between ages 27 and 53, with site indices ranging from 66 to 96 for the red oak group (Schnur 1937 site index curves, base age 50). We tried to pick stands in which we could install two plots carefully matched by site index, species composition, and density. Suitable stands were hard to find, since most hardwood stands in Virginia have been high-graded or include scattered older trees from an earlier incomplete harvest; but overall, we were fairly successful in matching plots.

[1] Three of the plot pairs were prematurely clearcut by the landowners, one pair installed in 1964 and two pairs installed in 1968.

[2] Two of the 32 plot pairs were only 1/10-acre, due to limited useable area.

Basal area in trees 4.0 inches dbh and larger ranged from 68 to 145 ft^2/acre on the 64 plots, and averaged 98. Plot densities compared closely with Schnur's (1937) tables. The estimates of basal area from Schnur for these 64 plots ranged from 79 to 107 and averaged 95 ft^2/acre. Of the 64 plots, 35 had more, 2 had the same, and 27 had less basal area than predicted by Schnur (Table 1).

Table 1. Actual basal area compared to basal area predicted by Schnur (1937) for the same age and site index (trees 4.0 inches dbh+).

Predicted basal area (Schnur)	Number of plots
----------Percent----------	
31 to 38 more	2
21 to 30 more	7
11 to 20 more	5
1 to 10 more	21
Schnur same as actual	2
1 to 10 less	19
11 to 20 less	6
21 to 28 less	2
	64

The plot to be thinned in each pair was randomly selected. For the first 14 pairs, installed in 1963, 1964, and 1965, we had no specific level of basal area we wanted to leave. We selected crop trees at what we "judged" to be adequate spacing to provide growing room for the crowns, and removed all other trees. On 11 of these 14 plots, this resulted in rather heavy thinning, which left a residual basal area <60 ft^2 in trees 4.0 inches dbh and larger. The thinning removed all overtopped trees, most intermediates, and considerable numbers of codominant and dominant trees. According to Gingrich (1967) residual basal area on these plots was below the B-level; and in some cases even below the C-level. We installed 18 pairs of plots in 1968 and 1969, after the stocking guides had been published. Most of these were thinned in the same manner as the earlier plots, but on a few we deliberately thinned lightly, so that residual stocking was above the B-level.

Five to 10 years after the first thinning, a second thinning was done on 21 of the 32 plots. On the majority of plots, it was somewhat heavier than the first thinning. The second thinnings on all plots were done to select the best crop trees and provide adequate space for their crowns to develop. On the older plots, this was the final thinning, which left from 40 to 80 trees/acre; but on the younger plots, a third thinning will be desirable. Table 2 shows the

distribution of plots by residual basal area after the first and second thinning.

The number of cords removed in first and second thinnings was not strongly related to residual basal area (Table 2). The implication is that, regardless of initial basal area, about the same number of cords had to be removed to free the crowns of crop trees. Standard cords removed in the first thinning on all 32 plots ranged from 4 to 29 cords/acre, average 13, and exceeded 8 cords on 28 plots. For the second thinning, on 21 plots, an average of 9 cords/acre was removed.

Table 2. Plot residual basal areas and number of cords removed per acre after first and second thinnings for only trees that were 4.0 inches dbh+ when the plots were installed.

Basal area ft^2/acre	First thinning			Second thinning		
	Number plots	Cords Removed		Number Plots	Cords Removed	
		Mean	Range		Mean	Range
31 to 40	1	13	-	3	10	7 to 14
41 to 50	13	12	5 to 19	10	8	4 to 18
51 to 60	9	12	4 to 18	5	10	9 to 14
61 to 70	4	15	4 to 25	2	11	11 to 11
71 to 80	5	15	8 to 29	1		--
	32			21		

Crop trees were marked on the check plots to include the same amount of basal area as on the thinned plots. This was done so we could evaluate the growth and development of comparable sets of crop trees on both the thinned and unthinned plots.

We recorded the numbers of living epicormic sprouts on a large number of butt logs (<17 feet) on both thinned and check plots. Where two or more sprouts originated from one point on the trunk, as is often the case, especially with white oak, only one was counted.

Results to Date

Diameter Growth

As expected, diameter growth has been greater on the thinned plots than on the check plots. Mean annual diameter growth of dominant and codominant oak trees has averaged 0.17 inch on the check plots (ranging from 0.11 to 0.28) and 0.23 inch on the thinned plots (ranging from 0.14 to 0.37).

On the 17 pairs of plots that have been thinned heavily two times (both times to the B-level or less), mean annual diameter growth has

averaged 0.17 inch on the check plots (ranging from 0.11 to 0.28) and 0.25 inch on the thinned plots (ranging from 0.15 to 0.37). These average growth rates, for the entire period since plot establishment, tend to downplay the effect that thinning has had on diameter growth. Response has been gradual, and on many plots diameter growth for the second 5-year period after thinning was greater than for the first 5-year period. The probable explanation of this is that it takes time for crowns to expand and take advantage of increased growing space.[3]

On plots that were thinned only once, diameter growth has slowed again as basal area has increased. Plots that were thinned twice, on the other hand, have tended to maintain the increased rate of diameter growth.

Plots that have been thinned twice will probably continue to maintain their growth advantage over the check plots. Diameter growth is affected by crown size. It is our observation that for trees of the same diameter, those with deep, full crowns will generally grow faster in diameter than those with short, narrow crowns. Over periods of 15 and 20 years, we have developed some really nice crowns by thinning heavily. Most dominant and codominant trees on the check plots have relatively short and narrow crowns compared to trees on the thinned plots.

Diameter growth has varied by species (Table 3). Most of the dominant and codominant trees on the 32 pairs of plots are oaks: black, scarlet, white, northern red, and chestnut oak in decreasing order of occurrence. Yellow-poplar occurs as dominants or codominants on about 40% of the plots, and other species occur infrequently. Northern red oak has been the fastest grower and white oak the slowest; only minor differences exist among the other four species. Average growth rates have been slightly greater on red oak sites >80 (Table 3), for all species on both check and thinned plots.

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[3]Diameter growth information presented in this report is based on all trees that have been dominant or codominant at all measurements. More dominant and codominant trees occur on the check plots on all but four of the plot pairs. Differences between thinned and check plots would be slightly less, on the average, if equal numbers of dominant and codominant trees were compared on plot pairs.

Table 3. Average annual diameter growth by species of trees classed as dominant or codominant at all measurements for the 15- or 20-year period since plot installation.

Species	Check Plots: No. Plots	Check Plots: Mean	Check Plots: Plot Range	Thinned Plots: No. Plots	Thinned Plots: Mean	Thinned Plots: Plot Range	Prob.[a]
RED OAK SITE INDEX 80 AND BELOW							
Oaks							
Black	13	.15	.11 to .22	13	.21	.16 to .34	.0003
Scarlet	10	.16	.11 to .22	12	.22	.14 to .36	.0220
White	9	.13	.10 to .17	13	.19	.12 to .28	.0006
N. red	4	.22	.18 to .28	9	.27	.20 to .42	.2560
Chestnut	3	.13	.12 to .13	3	.22	.15 to .25	.0550
Yellow-pop.	3	.16	.13 to .20	6	.22	.15 to .29	.1700
RED OAK SITE INDEX ABOVE 80							
Oaks							
Black	14	.17	.11 to .21	12	.22	.16 to .28	.0010
Scarlet	11	.19	.12 to .30	10	.24	.15 to .33	.0310
White	2	.14	.12 to .16	6	.22	.14 to .28	.1010
N. red	6	.23	.20 to .29	4	.29	.26 to .36	.0410
Chestnut	3	.16	.13 to .21	1	.26	--	--
Yellow-pop.	9	.17	.09 to .23	7	.26	.20 to .39	.0030

[a]A t-test for unpaired plots was used to test for differences in average diameter growth separately for each species. The probabilities of a larger value of "t" are listed.

Epicormic Sprouting

We recounted epicormic sprouts 5 years after the initial counts (when the plots were installed). Number of epicormic sprouts decreased on the majority of trees on both check and thinned plots, but the decrease was greater on check plots. Table 4 presents the average number of sprouts on all plots at both times, and the number of plots on which average number of sprouts increased or decreased.

Table 4. Average number of sprouts per butt log and number of plots on which sprouts increased or decreased for dominant and codominant trees.

	Number of sprouts/butt log		Number of plots	
	At start	After 5 years	Sprouts increased	Sprouts decreased
Check plots	7.4	2.9	5	27
Thinned plots	6.7	4.4	14	18

Epicormic sprouting varied by species. Table 5 presents the changes in average number of sprouts/butt log over the 5-year period. Table 6 presents the number of trees on which sprouts either increased, stayed the same, or decreased over the 5-year period. White oak is the most prolific sprouter followed closely by black oak; scarlet oak and northern red oak are similar, and sprout considerably less than white oak and black oak. Yellow-poplar produces by far the fewest epicormic sprouts.

Table 5. Average number of epicormic sprouts per butt log for dominant and codominant trees from 32 paired plots.

Species	Number trees	Number of sprouts/butt log		
		At start	After 5 years	Change
		CHECK PLOTS		
Black oak	132	10.7	3.3	- 7.4
Scarlet oak	75	3.3	1.7	- 1.6
White oak	29	16.8	9.7	- 7.1
N. red oak	45	3.1	1.3	- 1.8
Chestnut oak	10	6.9	2.2	- 4.7
Yellow-poplar	28	0.3	0.2	- 0.1
		THINNED PLOTS		
Black oak	105	9.2	5.0	- 4.2
Scarlet oak	76	4.3	3.0	- 1.3
White oak	46	11.0	8.1	- 2.9
N. red oak	40	6.8	4.6	- 2.2
Chestnut oak	12	3.6	2.8	- 0.8
Yellow-poplar	37	0.1	1.0	+ 0.9

Table 6. Number of dominant and codominant trees where epicormic sprouts on the butt log increased, stayed the same, or decreased during the 5 years following plot establishment.

Species	Total	Number of Trees		
		Increased	Decreased	No change
		CHECK PLOTS		
Black oak	132	18	84	30
Scarlet oak	75	20	26	29
White oak	29	5	20	4
N. red oak	45	4	13	28
Chestnut oak	10	1	5	4
Yellow-poplar	28	3	3	22
		THINNED PLOTS		
Black oak	105	23	19	63
Scarlet oak	76	18	30	18
White oak	46	15	9	22
N. red oak	40	11	18	11
Chestnut oak	12	3	1	8
Yellow-poplar	37[a]	11	26	0

[a]Of the 37 trees, 32 had no sprouts and 5 had one sprout, so there was little chance for number of sprouts to decrease.

Many trees had no sprouts on the butt log when the plots were installed, and these trees generally remained free of sprouts even after thinning. Table 7 presents the percent of trees that had no sprouts either when the plots were installed or 5 years later. This table reinforces the species differences shown in Table 5, and suggests the desirability of selecting crop trees that have few or no epicormic sprouts. On thinned plots, the percent of trees with no sprouts on the butt log was not much different 5 years after thinning than it was before thinning.

There was considerable variation among plots. On some plots epicormic sprouts increased on most trees while on other plots they decreased on most trees. Also, there were unequal numbers of trees of each species on each plot. Some plot pairs were largely dominated by one species of oak: seven plots by black oak, two plots by white oak, and two by northern red oak. For these reasons, these data on epicormic sprouting should be viewed with caution.

Table 7. Number of trees with no sprouts on the butt log, when the plots were installed or 5 years later.

Species	Number trees	At start: Number trees with no spts	At start: Percent	After 5 years: Number trees with no spts	After 5 years: Percent
		CHECK PLOTS			
Black oak	150	31	21	54	36
Scarlet oak	80	39	49	38	48
White oak	56	5	9	6	11
N. red oak	50	31	62	34	68
Chestnut oak	13	2	15	3	23
Yellow-poplar	43	37	86	37	86
		THINNED PLOTS			
Black oak	123	30	24	34	28
Scarlet oak	84	38	45	34	40
White oak	69	9	13	7	10
N. red oak	46	24	52	21	46
Chestnut oak	15	3	20	2	13
Yellow-poplar	48	39	81	28	58

Thinning tended slightly to increase number of epicormic sprouts, but this tendency is probably not serious. What is, or could be, serious is the greater tendency on thinned plots for sprouts to persist and grow into branches. Most epicormic sprouts only live a few years. When they die, they may be replaced with other sprouts, but in densely stocked stands, very few of them grow into permanent branches, at least on the butt log. It is too early to assess the final impact of epicormic branching on log quality. In the second thinning, we favored trees with no or few sprouts. My impression is that epicormic sprouts will not be much of a problem on the majority of plots, but we will have to wait until the stands reach rotation age to evaluate this.

Crop Tree Crown Class Changes

On plots that have been thinned twice, practically all trees are dominant or codominant. On the check plots, on the other hand, many trees that were selected as crop trees 15 or 20 years ago have dropped down in crown class due to competition. Many codominants, which could have been helped by thinning, have dropped to intermediates, and in some cases all the way to suppressed trees. At the present time, 15 and 20 years after installing the plots, 19% (range 0 to 41%) of present dominant and codominant trees on the check plots were not marked as crop trees when the plots were installed. Therefore, bole

quality and species composition of the present dominant and codominant trees is not as desirable as it would have been had the stands been thinned.

Mortality of Dominant and Codominant Trees

Since the plots were installed, scarlet oak has suffered the greatest mortality, followed by black oak (Table 8). Mortality on check plots has been two or three times greater than on thinned plots. Mortality from the 1979 ice and snow storms is included, but accounts for only a small part of the total. We have had several serious drought years during the 15- or 20-year study period, and overall it has been a drier than normal period.

Several of the check plots seem to have reached the point where basal area growth levels off, with mortality offsetting growth. Five of the check plots supported between 140 and 145 ft^2/acre of basal area at the most recent measurement (including only trees 4.0 inches dbh+ when the plots were installed). Another four check plots have between 130 and 139 ft^2/acre of basal area. At this time, it appears as if the average basal area at which "leveling off" will occur, will be around 140 ft^2. However, there seems to be quite a bit of variation among check plots. For example, one plot on an exposed site seems to be leveling off at about 120 ft^2/acre, while several other plots, if they continue past growth trends, will probably reach 150 ft^2/acre.

Table 8. Mortality of trees that were dominant or codominant when plots were installed.

Species	Number at start	Number that died	Percent mortality
	CHECK PLOTS		
Black oak	341	38	11
Scarlet oak	206	45	22
White oak	99	2	2
N. red oak	80	2	2
Chestnut oak	28	0	0
Yellow-poplar	48	3	6
	THINNED PLOTS		
Black oak	242	10	4
Scarlet oak	123	13	11
White oak	83	0	0
N. red oak	69	2	3
Chestnut oak	16	0	0
Yellow-poplar	70	0	0

Ice and Snow Damage

During the spring and fall of 1979, we had two very unusual storms. The first was an extremely severe ice storm that occurred on Easter, and the second was a freakish snow storm that occurred October 10, at the peak of fall colors. When ice from the Easter storm had dropped off the trees, there was as much as 8 inches of ice on the ground. Some stands of susceptible species, such as black locust and yellow-poplar, were nearly devastated. The early snow storm occurred when trees were still in full foliage, and in places more than a foot of snow accumulated. It was a heavy, wet snow and it caused as much breakage, uprooting, and bending over, as the ice storm. Both of these storms occurred in the same general area, along the Blue Ridge Mountains, the Shenandoah Valley adjacent to the Blue Ridge on the west, and the foothills to the east. Thirteen pairs of our thinning plots were damaged by these storms.

At the next scheduled measurement after these storms, we recorded storm damage to the trees. Some trees were killed by being broken off or uprooted. Many trees sustained severe top breakage, but survived. We rated damage as severe on 8 of 13 pairs and moderate on the other 5. In all cases, the damage was somewhat greater on the thinned plots; and for some pairs, it was much greater on the thinned plot than on the check plot. A few of the stands containing our plots were damaged so severely that there was some sentiment to abandon them. In one case, the landowner clearcut the stand, including the plots. However, breakage from ice and snow is inevitable in Virginia. It is hard to imagine a hardwood stand going through an entire sawtimber rotation without sustaining serious damage at some time. We will continue to measure surviving plots and follow their recovery. Top breakage reduced subsequent diameter growth, as would be expected, but it is reassuring to see how rapidly most trees are rebuilding crown. My impression is that 10 years from now, we will have to look carefully to see evidence that these storms occurred.

Red Oak Versus Yellow-Poplar Site Index

We can compare red oak (black, scarlet, and northern red) and yellow-poplar site index on 26 of the 64 plots (32 pairs) that we installed. Doolittle (1958) and Olson and Della-Bianca (1959) published results of studies which showed that yellow-poplar is much more sensitive than the oaks to differences in site quality. On very good sites, yellow-poplar site index was much higher than red oak site index, while on poor sites yellow-poplar site index was considerably below red oak site index.

This relationship has not held up on our plots. Yellow-poplar site index has been plotted over red oak site index, for each of the 26 plots (Figure 1). We used the estimates of site index for plot measurements made within a few years of the index age of 50, so that possible biases in the site index curves for red oak (Schnur 1937) and yellow-poplar (Beck 1962) would have little affect on the estimates.

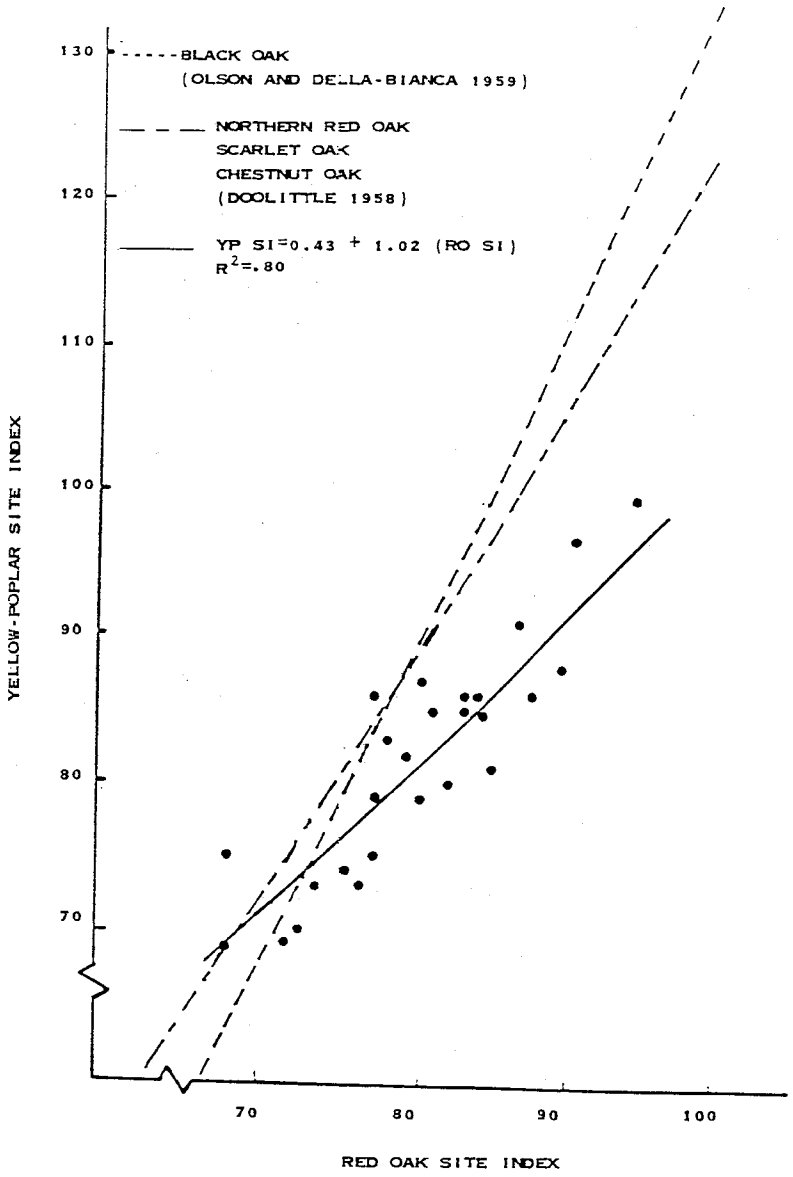


Figure 1. Comparison of yellow-poplar and red oak site index.

The linear regression fitted to these 26 plots has a slope very close to 1, meaning that over the range of sites represented among the 26 plots (from 68 to 96 for red oak and from 69 to 101 for yellow-poplar), yellow-poplar and red oak site indices, on the average, are very similar. For all 26 plots, red oak site index averaged 81.1 and yellow-poplar 82.7. Site index was higher for yellow-poplar on 15 plots, higher for red oak on 10 plots, and equal on 1 plot. Also in Figure 1 are plotted the yellow-poplar-red oak site index relationships (Doolittle 1958; Olson and Della-Bianca 1959).

I don't know why yellow-poplar and red oak site indices tend to be similar on our 26 plots. I wonder about the effect of ice storms. We have ice storms quite frequently in Virginia, but not the extremely severe kind of storm that occurred on Easter of 1979. This storm did not affect site index on our plots, since it occurred after the index age for the damaged plots. Yellow-poplar seems to be much more susceptible to top breakage than oaks. It is possible that periodic ice storms tend to keep yellow-poplar trees "broken back" to the general level of the canopy, and prevent them from expressing their potential height growth relative to the oaks.

This site index information has implications for managing mixed stands of oak and yellow-poplar in Virginia. The potential superior height growth of yellow-poplar, compared to oaks, on high quality oak sites may not be attainable. When marking mixed stands for thinning, our results suggest that it might be safer to assume that yellow-poplar and the red oaks will have about the same site index. The height growth patterns of yellow-poplar and oak, shown by the site index curves for these species, are quite different. Yellow-poplar grows faster than oak before age 50 and slower afterwards. As a consequence, yellow-poplars might be taller than oaks when a stand is ready for its first thinning, at perhaps 30 to 40 years of age; but late in the rotation the oaks may catch up to and overtop yellow-poplar. Rotations for mixed stands of oak and yellow-poplar are probably going to be at least 80 years. A forester might easily make the mistake of favoring yellow-poplar when the oaks might have a better chance to stay dominant or codominant until harvest age.

Whether these changes in relative height and dominance between yellow-poplar and oak really occur depends on whether the height growth patterns suggested by the site index curves are accurate. Over the 15- and 20-year period that we have been measuring our plots, oak site indices as estimated from Schnur's (1937) curves have stayed remarkably uniform on all plots. This indicates that the dominant and codominant oaks on our plots have been growing as Schnur's site index curves suggest. Yellow-poplar height growth has been more erratic. Site index estimates, as determined from Beck's (1962) curves, have tended to increase with age on the majority of plots, but have stayed the same or decreased on others. We have a few plots where loss of dominance by yellow-poplar seems excessive, but when I determined the percentage of oaks and yellow-poplar that had changed from dominant or codominant to intermediate or suppressed over the 15- or 20-year period, there was little difference between them. So, despite the differences in height growth patterns indicated by the site index curves, our plots, so far, have not exhibited any major replacement of yellow-poplar by oaks in the dominant and codominant component of the stand; but it may happen as the stands get older.

Discussion

My impression from these 32 pairs of plots is that thinning immature oak stands in Virginia is a desirable practice; but markets will have to improve substantailly before much can be done, and it should not

even be considered if considerable damage to residual trees will result. These two factors, weak markets, and the risk of damage to crop trees, as well as several silvicultural considerations, seem to favor the rather heavy thinning we did on many plots. These so-called heavy thinnings do not really seem heavy to me. They only appear heavy when compared to the B- and C-levels of Gingrich's (1967) stocking guides. If epicormic sprouting were of no concern, thinning to between the B- and C-level would seem normal and appropriate in many stands. As I said at the start, when we installed our first plots before the stocking guides came out, we had no particular idea of how much basal area we wanted to leave. We marked the stands to provide growing space around the crowns of potential crop trees. This approach offers several advantages:

1. A greater volume per acre can be removed so that a logger has a better chance to make a profit. Not only can more cords be removed, but more of the larger trees will be removed, thus increasing average tree size and reducing logging costs per cord.

2. Crop trees are left farther apart, so there is more room for the logger to operate and less chance of damaging crop trees when the wood is removed. We have had some bad experiences with basal damage to crop trees in operational thinning projects, and such damage can far outweigh the benefits from thinning.

3. Diameter growth of crop trees is increased, which permits shortening of the rotation or growing trees of a given diameter in less time. There are several advantages to shortening rotations. The first is obviously an economic one, but there are also some silvicultural advantages. One is that younger and faster growing trees are more resilient following stress from drought, insect attack, disease, and perhaps top breakage (they can rebuild crowns faster). They can overgrow dead branch stubs and wounds faster, thus reducing the amount of defect and degrade. Shortening the rotation is a particular advantage for the relatively short-lived scarlet oak, and to a lesser extent black oak. For these two species, it would probably be desirable to aim for a rotation of not over 80 years, because it may not be possible to maintain their vigor and growth rate over longer rotations on many sites (Table 8.). The same may be true for yellow-poplar. However, white oak and northern red oak are longer-lived species and can be grown in rotations considerably longer than 100 years.

On the 21 plots that have been thinned twice, a rotation of abut 80 years seems reasonable for growing final dominant and codominant crop trees to an average dbh of 18 to 20 inches. If we assume that growth rates over the past 5-year period will hold until rotation age, an average dbh of 19 inches for dominant and codominant trees will be attained in an average rotation of 81 years on these 21 plots. The estimated rotations for the 21 plots range from 67 to 112, the 112-year rotation (the only one over 100 years) was for a nearly pure white oak stand with a white oak site index of 64. If we make the same assumption about future diameter growth for the 21 check plots, it appears as if rotations, to produce dominant and codominant trees of the same dbh, will average about 20 years longer.

4. Selection for straight and well-formed trees of the most desirable species can be intensified. In Virginia hardwood stands, we rarely have a surplus of straight, well-formed trees of the most desirable species, and when marking for thinning, we frequently have to leave less desirable trees as fillers. With heavier thinning, fewer of these undesirable trees have to be left and more of the growth potential of the site can be allotted to better quality trees.

There are two disadvantages of thinning to below a B-level stocking:

1. Epicormic sprouting will be increased, and more sprouts will persist, grow, and become permanent branches. My impression is that the relative increase in sprouting, and particularly the tendency for sprouts to persist and grow into branches, does not outweigh the advantages of thinning. One thing to keep in mind is that log grade does not depend on surface defects alone. Log diameter also has a strong bearing on grade. Trees below a threshold dbh of 16 inches are not big enough to have grade 1 logs regardless of how free they are of surface defects. So a small increase in knot and branch defects may be offset by larger diameters.

2. Thinning to below the B-level stocking will reduce per acre volume growth below the potential for the site. This decrease in volume growth should not be as serious in hardwood stands, where we are trying to grow large, high-value sawlogs, as it would be in pine stands where diameter is less important. Stumpage prices for hardwood sawlogs are strongly

related to diameter, so a smaller per acre volume of larger diameter trees may be worth more than a larger per acre volume of smaller diameter trees.

Recommendations

My recommendations for thinning mixed oak stands in Virginia are as follows. Make the first thinning as early as possible, by mid-rotation or earlier, which would mean somewhere between age 30 and 40. However, the first thinning should be delayed until an operable volume can be removed. Thin heavily enough to encourage the development of large, healthy crowns. Thin a second time, and perhaps even a third time in some stands, to reduce stocking close to the number of crop trees desired at final harvest. Favor dominants and codominants for crop trees; they are more likely to remain dominant or codominant and are less likely to produce epicormic sprouts. Also favor trees with few or no epicormic sprouts because they are less likely to produce additional sprouts as a result of thinning. Most epicormic sprouts that are present before thinning, or that emerge as a result of thinning, should die and disappear well before harvest age, at least on the butt log. Where there is an opportunity to select among different species, my preferences are as follows:

1. Northern red oak - because of its faster growth rate, longevity, and relatively low tendency for epicormic sprouting. It also tends to produce sound, defect-free logs that are highly valued on today's market.

2. White oak - because of its longevity and tendency to produce sound logs that are highly valued and much in demand.

3. Black oak or yellow-poplar - black oak has a higher mortality rate and produces far more epicormic sprouts, but in recent years the demand for yellow-poplar has been weak and prices have been low. Also, height growth of yellow-poplar during the latter part of the rotation is less predictable.

4. Scarlet oak - my last choice, despite its low tendency to sprout. Scarlet oak does not prune well, and large, dead branches tend to persist on most trees. This gives it poor reputation among log buyers. It also is short-lived and has a high mortality rate.

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THE FIRST DECISION: TO REHABILITATE OR TO REGENERATE IMMATURE LOW-QUALITY HARDWOODS

Charles E. McGee

Principal Silviculturist
USDA Forest Service
Southern Forest Experiment Station
Sewanee, TN 37375

ABSTRACT

Low quality in immature hardwoods can be caused by a variety of reasons. After determining the cause of low quality, the first decision is to decide whether to regenerate the problem stand and start over or to attempt rehabilitation. Many factors affect the stand direction decision, some of the more important ones are landowner requirements, stand condition and the economic climate. These factors have never been organized to assist field foresters in stand direction decisionmaking. Consequently, foresters routinely making the first decision may make mistakes that have long-term financial and silvicultural repercussions. This paper suggests that more attention be given to the decisionmaking process in problem stands.

When initiating management in a low-quality immature hardwood stand the first question to be answered is "why the low quality?" The answer provides a basis for the first stand-direction decision: to rehabilitate or to regenerate. A stand prescription will then generally deal with how the stand is to be rehabilitated or regenerated.

The emphasis in this paper will be on stand direction decisionmaking. How do we decide to sacrifice an existing stand and start over? How do we decide to invest in an existing stand and commit the land for another period? Before discussing these questions about the first decision, let's consider the causes of low-quality in immature stands and very briefly discuss the role of prescription.

The Causes

When a physician is called to minister to a patient, his first act is to determine the cause of the patient's problem. A physician does not only treat symptoms but determines the cause of the malady and then takes corrective action. Foresters, occasionally, make serious blunders with low-quality stands because they often treat symptoms and do not determine the cause of the problem. Most of the time, the cause of low stand quality can be determined by observation and study.

However, on some occasions the forester, like the physician, may have to work hard to find the source of the problem and may, in some cases, have to make prescriptions without knowing all the answers. Let's consider the major causes of low-quality hardwood stands.

Site quality. Whenever low-quality stands are encountered, site quality should be considered a possible cause of the problem until proven otherwise. However, the forester should not assume that just because a stand is low-quality the site is low-quality, too. Often, low-quality stands mask great variations in site quality. It is important, particularly when dealing with immature hardwood stands, to know the range and variability of site quality. Without knowledge of site quality, it is difficult to prescribe corrective actions for low-quality stands.

Past cutting. On good sites, a primary cause of low quality in immature hardwood stands is past cutting. It is sad that most timber sales in upland hardwoods are made without guidance from a professional forester. It is even sadder that some of the sales marked by foresters produce low-quality stands. One can sympathize with the needs of landowners and loggers. It is understandable why some landowners and loggers cut the best timber and leave the rest. It is not easy to sympathize with foresters who continue to manufacture mediocre or low-quality stands from good stands. High grading, diameter-limit cutting, and loggers' choice sales are often masqueraded as some form of selective harvesting. But whatever the name used, harvest cuttings that consistently remove the best trees and leave poor ones inevitably produce low-quality stands.

The temptation for opportunistic cutting probably increases as the quality of the site and the quality of the stand increase. On good sites it is often possible to cut a high volume of timber and leave a number of residual trees that look reasonably good. I frequently see recently cut-over stands that can be classed as immature hardwood stands. Yet, in many cases, the so-called immature trees are immature only in size, not in age. While some of these residual trees may perform well, it has been my experience that epicormic sprouting and frustratingly slow height growth will be the norm.

Diseases and insects. Damage from insects and diseases has always been, and probably always will be, an important factor affecting the growth, survival, and quality of individual hardwood trees. Epidemics also occur; and, when they do, entire stands can be reduced in quality or killed outright. The investigating forester should be alert for widespread damage within the stand. However, the forester should not confuse secondary insect or disease damage with primary causes of quality loss.

Ice, drought, heat, and wind. Overnight an ice storm can convert a stand of high quality pole timber into a miserable collection of broken trees. Fortunately, significant ice damage usually is restricted to small areas.

In recent years, drought and heat have caused serious stress in hardwood stands of the East. However, drought and heat seem to take their toll mostly from very old and very young trees. Most stands of immature hardwoods seem to withstand the stress from weather reasonably well. There are, of course, notable exceptions. Similarly, winds seldom bother immature stands unless the winds are unusually severe.

Fire. Due to increased fire protection, damage from wildfire has been reduced. However, the forester should remember that a fire 10, 20, or even 40 years ago can be the major factor contributing to a low-quality stand.

The Prescription

Once the cause of low quality is determined and the stand-direction decision is made, most foresters have a good understanding of how to rehabilitate or regenerate a stand. For many organizations, the preparation of a stand prescription is a formal and often formidable operation. A prescription often goes into great detail about certain treatments and how they are to be applied. Yet, predating the preparation and implementation of a prescription is the first decision. While the prescription may be specific and voluminous, reference to the reasons for treating a stand in a certain way may be quite vague and indistinct. In recent discussions with field foresters, I found that almost without fail they could defend their prescriptions. However, these same professionals had great difficulty qualifying and quantifying their reasons for rehabilitating or regenerating a particular stand. As we take a look at this important point in the management of a low-quality stand, we will see why making the first decision is so tough.

The First Decision

In a study of low-quality woodlands Haymond and Zahner (1985) state, "In considering management of low-quality woodlands, many choices must be made. Some areas can be rehabilitated... Other areas should be regenerated... The first decision is the most difficult and requires expertise..."

In order to make a rational stand direction decision, i.e. the first decision, a forester must consider a number of qualitative and quantitative factors. These factors include economics, silviculture, ecology, biology, and sociology. In general, we foresters are more comfortable with the silvicultural and ecological factors, and our prescriptions usually show our appreciation for these values. However, actual stand direction decisions are often controlled by sociological or economic factors that are not directly related to the properties of the stand itself.

Landowner requirements. The most important factor in the stand direction decisionmaking process is the landowner's requirements. The

landowner's financial status and the need for revenue or the availability of cash often dictate stand-direction decisions. A landowner's reaction to cutting methods or perception of wildlife habitat needs may restrict regeneration activity. A need for mast and den trees tends to favor stand rehabilitation while a need for browse and diversity tends to favor regeneration. A landowner may also have an overriding objective of ownership that requires regeneration and conversion. In these situations, the actual silvicultural or ecological condition of the stand itself may be of minor importance. In these cases, the first decision is made almost ex situ.

Stand condition. The silvicultural condition of the stand is probably the next most important factor. Foresters take great comfort in silvicultural exercises and never miss a chance to amass great quantities of data that describes stand conditions. However, how the data collected in conjunction with stand management are used to reach a stand direction decision in low-quality stands is a puzzle. When, in an informal survey among foresters, I asked what stand information is needed prior to reaching a first decision in a low-quality immature hardwood stand, the foresters suggested age, site index, volume, species composition, stand structure, number of culls, stem quality, tree size, presence or absence of regeneration, etc. These factors are important, particularly in the prescription-writing phase, but that's later. However, when I asked how these stand factors specifically influenced their stand direction decisions, the foresters often could not answer. The general procedure is to gather the stand condition data, somehow integrate it and come out with a general impression as to the need for regeneration or rehabilitation. It becomes painfully obvious that we really do not know how individual stand factors affect our decisions.

Growing stock level. One important silvicultural key to making the first decision is the availability of desirable or acceptable growing stock. Theoretically, if the growing stock level falls below a certain point, the recommendation would be to regenerate; a growing stock level above a certain point would indicate stand rehabilitation and stand retention. Obviously, the theory is sound. Just as obviously, determining the appropriate levels of acceptable growing stock is the key.

The literature is very disappointing on the critical subject of making the first decision based on growing stock levels. Arend and Scholz (1969) refer to poorly stocked poletimber oak stands and suggest that "when poletimber oak stands are poorly stocked, about all that can be done is to wait until the trees can be harvested." McGee (1982) in referring to low-quality hardwood stands suggests that the number of stems and distribution of manageable trees is the key to prescribing regeneration, intermediate treatment, or postponement of action. Unfortunately, he does not quantitatively identify what these keys are. He skirts this point with the statement that "A simplistic rating system should not be substituted for common sense and experience." Sander (1977) also avoids the first decision problem when he concluded that "understocked stands or stands of poor quality should be

rehabilitated or regenerated." Kellison et al. (1982) said that the typical southern hardwood stand is dominated by low-quality trees. They suggest regeneration when basal areas of desirable trees are less than 20, 40, and 60 ft^2 at 20, 30, and 40 years of age, respectively. This guideline, if applied, would result in clearcutting the majority of cut-over upland stands. Maybe that's not such a bad idea. Roach and Gingrich (1968) give the following suggestions for prescribing for immature upland hardwoods. "When the amount of acceptable stock is below the C-level, seriously consider regenerating the stand. At this level, it will be better to start over than to waste growing space. However, no rigid rule can be set. The silviculturist will have to decide in each case how far below the C-level is too far, but there is some point of understocking where it pays to start over." While this approach is extremely helpful, we are left with several unknown points. Utz and Balmer (1970) address the effect of stand density and species composition on regeneration and rehabilitation decisions and offer reassuring and helpful advice. The effectiveness of their advice however is dependent upon recognizing and evaluating growing stock potential. So much for the silvicultural factors and guidelines.

Summary

Mistakes in decision-making for stand direction are made regularly. In spite of the lengthy foregoing discussion pointing up the complexity and importance of stand-direction decisions, we see many of these decisions made by landowners with little or no regard for stand parameters. We also see many stand-direction decisions made by novice foresters. In fact, for many foresters the first decision they make on the job may be whether to regenerate or rehabilitate a woodlot. For foresters who would take a more analytical approach to the problem there are few guidelines. The literature is almost bare on the subject of stand direction decisionmaking. However, once the stand direction decision is made, voluminous instructions are available on how to thin, clearcut, control culls, etc.

In view of the high stakes involved in decisionmaking for immature, low-quality stands, one might expect more attention to have been given to the subject by researchers and specialists. Perhaps the best explanation for lack of study involves the complexity of quantifying and integrating the broad array of factors that can impact a stand direction decision. As we have seen, the most compelling silvicultural or ecological consideration may be overriden by landowner needs and constraints. The other part of the explanation perhaps is the lack of perception of a problem. The same forester who might ponder lengthily over whether to mark a particular tree in a thinning might have made the decision to thin and rehabilitate the stand almost subconsciously with little or no forethought. The forester just did not perceive a problem. It is at this level that some stand direction mistakes are made.

We must recognize that some of the important factors affecting stand direction are beyond the control of the practicing forester. But we must admit that we researchers and practicing foresters can do a much

better job if the factors we do control are better understood. In particular, a better system of recognizing and classifying desirable, acceptable, and unacceptable growing stock would eliminate many errors. Our goal should be to eliminate the need to make the "First Decision" more than once.

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MANAGING IMMATURE APPALACHIAN HARDWOOD STANDS FOR FIBER

Bruce A. Schick

Technical Superintendent
West Virginia Woodlands
Westvaco Corporation
Rupert, WV 25984

ABSTRACT

Gingrich's yield data for thinned and unthinned stands of upland hardwoods provide the basis for discussion of biological and partial economic decision guides to maximize fiber production. Using maximum annual increment as a decision guide leads one to favor 50-year (SI 65) and 60-year (SI 75) fiber rotations in unthinned stands. Stands which are thinned every 10 years, beginning at age 20, should be grown on 50- to 60-year rotations also. A decision guide using marginal economic analysis would likely shorten the best rotation age for total fiber production in both thinned and unthinned stands. The argument in favor of thinning is strengthened if premiums are received for select species and large diameters, and if precommercially thinned stems are marketable.

Introduction

It is a pleasure to be with you today. My assignment is to discuss the management of immature Appalachian hardwood stands for fiber production, outlining differences in the rotation lengths and cultural practices that one might pursue to produce "fiber" as opposed to "quality sawtimber". The key question posed is, "How does one maximize fiber output in the shortest possible time?"

We will begin with (1) a brief literature review, (2) examine biological models which predict cubic foot (ft^3) and board foot (bf) volumes, and close by discussing several economic and technological constraints that may influence one's choice of fiber management strategies.

Literature Review

Nearly 50 years ago Schnur (1937) developed volume tables for fully-stocked even-aged upland oak stands. His data were derived from plots established upon the old clearcut "furnace" properties in Ohio and surrounding states, and still provide guidelines when forecasting

normal yields from unthinned upland oak properties that have been cleared. At 80 years Schnur (1937) predicted per acre yields of 3,700 ft^3 and 48.5 cords on oak site index (SI 65) land and 4,400 ft^3 and 58.0 cords on SI 75. Similarly, after 80 years Schnur (1937) found average volume yield to be 18,400 bf (International 1/8 inch) on SI 65 and 24,200 bf on SI 75.

Gingrich (1971) provided yield data for predominantly upland hardwood stands in the Central States. These data were developed from more than 200 plots established in stands ranging in age from 9 to 90 years. They not only provide indications of what yields might be expected from unthinned, or "normal" hardwood forests, but also provide guides for anticipated gains from thinned stands as well. Some biometricians feel that Gingrich's data provide a view of "real world" yields since many of the stands studied had been "high-graded" rather than clearcut for charcoal wood, as was the case with Schnur's data.

Gingrich (1971) forecasted 80-year yields of 35.6 cords and 8,200 bf (International 1/4-inch) for unthinned SI 65 and 46.5 cords and 12,500 bf for SI 75. Also, Gingrich found that considerable gains could be realized from thinnings made at 10-year intervals, began at various ages. For instance, cumulative per acre yields from such thinnings beginning at age 20 could rise from 33 to 42 cords and from 7,200 to 12,600 bf at 70 years for SI 65. Similarly, on SI 75 areas, 70-year total cumulative yields could increase from 43 to 57 cords and from 12,500 to 19,900 bf by thinning every 10 years when thinnings started at age 20.

Gingrich (1971) provided a set of silvicultural options depending upon stand age, period of management (20 or 40 years), and site index (55, 65, and 75). Options were either (1) leave stand alone, (2) start thinning, (3) regenerate without future thinnings, and (4) regenerate with thinnings. He provided thinning interval guides, as well as residual stocking levels (always 60%, unless the first thinning in a young stand), and comparative yields at age 60 depending upon stand age at the time of the first thinning. Gingrich (1971) recommended thinning from below and suggested that a single thinning would not have a great effect on final stand yield. He felt that the earlier a stand was thinned, the greater would be the accumulated yields over similar rotations.

Considerable additional research has reinforced the thesis that thinning is desirable if total fiber and sawtimber maximization is the objective of stand management. Dale (1972) concluded that, in general, at least 50% stocking is required to fully occupy the area with potential crop trees. Further, probably 60 to 70% is desirable to prevent increased stem taper, reduced height growth, delayed natural pruning, and the stimulation of epicormic branching of residual stems. Hilt (1979) concluded that thinning resulted in increased residual stem diameter, regardless of site or age, and that the heavier the thinning, the greater the response. Further, growth response after thinning was better in younger stands.

Considerable published research in the past 5 years has focused on crop tree release and/or thinning of young hardwood stands. Hilt and Dale (1982) applied precommercial thinnings to hardwood stands 8 years after clearcutting and found no statistically significant growth response. Thinnings were made to residual stocking levels of 30, 50 and 70%. Lamson (1983) found that significant diameter growth response resulted following the release of stump sprout origin stems 7 and 12 years following clearcutting. He recommended leaving the best one or two sprouts/clump, leaving dominants or codominants of good form which originate no more than 6 inches above groundline and are widely spaced on the trunk, and favoring sprouts on the uphill side of the stump. Smith and Lamson (1983) found that waiting until potential crop trees were 25 feet tall and thinning using a crown touching guide provided positive dbh increases. Among their recommendations were releasing no more than 50 to 75 crop trees/acre, removing all adjacent trees touching the crop tree crown, selecting crop trees from among the high-quality, vigorous, desirable species, and releasing only trees in the dominant or codominant crown class for intolerant species.

The apparent benefits of thinning young Appalachian hardwood stands are less obvious on SI 55 and lower forested land. In a study of the benefits of thinning and fertilization in a 25-year-old stand of predominant scarlet oak on a marginal Southern Appalachian site, Boyette and Brenneman (1981) reported that after 5 years the growth response was too small and the treatment cost too large to recommend either fertilization or thinning.

Although periodic thinnings increase per acre yields, does it "pay" to thin? Several studies suggest that thinning pays if sawtimber production is the objective on high site index land. McCauley and Marquis (1972) analyzed the return on investment in precommercial thinning of northern hardwoods. They concluded that the desirability of such investments in young northern hardwood stands depended on the product goals and time periods involved. Investments in pulpwood or low-value products grown on short rotations are seldom justified. However, they found returns to precommercial thinning of 6% or more on areas where sawtimber production was the major objective.

Worley (1970) provided insights concerning the economic payoffs of thinning hardwoods, and Utz and Sims (1981), using Gingrich's yield data, presented a comprehensive analysis of the anticipated rates of return from thinning both managed existing stands and regenerated stands of upland oak. In general, a 60-year rotation and thinnings beginning at age 20 produced the highest internal rates of return (IRR). These ranged from 6.3% on SI 55, 7.3% on SI 65, 9.2% on SI 75, and 10.3% on SI 85 areas. Forecasted IRR were higher on managed existing stands, but so were the required rotation lengths, rising to 80 years for SI 55 and SI 65 land. Yields and rotations to maximize IRR for SI 75 and SI 85, varied depending upon the year in which the first thinning began.

Biological Decision Models

Data adapted from Gingrich (1971) research appear in Tables 1 and 2. The left hand portion of Table 1 predicts cubic and board foot volume yields from unthinned upland oak stands if grown at 10-year intervals from age 40 through age 80 on oak SI 65 and SI 75 areas. Without management constraints and given a biological decision guide to maximize total fiber yield from the stand, the landowner should produce 3,950 ft^3/acre of fiber on an 80-year rotation on SI 65. Similarly, to maximize sawtimber yield he would produce 8,200 bf on the same 80-year rotation. Since SI 75 is more productive acreage, that land will produce 5,160 ft^3/acre of total fiber, including 12,500 bf of sawtimber, also on an 80-year rotation. Alternatively, since the land is more productive, the same 3,950 ft^3/acre of fiber produced on SI 65 acreage in 80 years may be grown in only 58 years on SI 75 land. However, maximization of total output is seldom used as a biological guideline for wood fiber decision-making, since rates of growth typically vary during stand rotation lengths. Forest stands tend to grow rapidly during their early years, and growth slows during later years.

The biological decision guide generally used to define the best stand rotation age is mean annual yield, since total yield at any given age, divided by the age of the stand balances the influence of changing stand growth rates, mortality, and ingrowth. Mean annual total ft^3 and board foot yields are shown at the right hand side of Table 1. Thus, if one chose mean annual yield as a biological decision guide for SI 65 land, he would grow wood fiber on a 50-year rotation (56 ft^3/acre/year) and sawtimber on a 70- or 80-year rotation (103 bf/acre/year). On SI 75 forest land, the 60-year fiber rotation and the 70-year sawtimber rotation would be chosen.

Two basic principles are thus far evident from our discussion. First, the lower the productivity of the land upon which timber is grown, the longer it takes to produce the same volume of fiber, whether total wood fiber or total sawtimber material. Second, maximum mean annual increment of total fiber tends to occur in a stand earlier than does maximum mean annual increment of sawtimber. Thus, if our objective is total fiber production, we will select a shorter rotation for final clearcut harvesting than if our objective is maximizing sawtimber output. For the moment, we will exclude discussion of the incremental gains data on Table 1.

Thinning and the Biological Decision Model

The data in Table 2 depict the significant gains in total output realized from thinning upland oak stands every 10 years, beginning at age 20. These gains assume that the stems removed from the young stand are used in some manner. Without economic, market or technological constraints, this assumption is valid. Through periodic

Table 1. Total annual and periodic yields for various rotation ages and sites for unthinned upland oak forests (Gingrich 1971).

Rotation age	Total yields and and incremental gains[a]				Mean annual yields and incremental gains			
	Ft^3		Board feet		Ft^3		Board feet	
			OAK SITE INDEX 65					
40	1,840		440		46		11	
		> 960		> 1,710		> 10		> 32
50	2,800		2,150		56		43	
		> 500		> 3,010		> -1		> 43
60	3,300		5,160		55		86	
		> 400		> 2,040		> -2		> 17
70	3,700		7,200		53		103	
		> 250		> 1,000		> -4		> 0
80	3,950		8,200		49		103	
			OAK SITE INDEX 75					
40	2,440		1,380		61		35	
		> 875		> 2,720		> 5		> 47
50	3,315		4,100		66		82	
		> 825		> 5,188		> 3		> 73
60	4,140		9,288		69		155	
		> 620		> 1,912		> -1		> 5
70	4,760		11,200		68		160	
		> 400		> 1,300		> -3		> -4
80	5,160		12,500		65		156	

[a]Incremental gains are merely the additional volume expected by postponing the harvest cut another 10 years.

thinnings, by age 70 on SI 65 land, total cumulative fiber yield rises from 3,700 ft^3/acre in the unthinned stand to 4,830 ft^3 in the thinned stand. Similarly, total sawtimber board foot yield increases by 5,400 bf, from 7,200 to 12,600 at 70 years. The gains are even larger from thinning on SI 75 areas.

While the gains from thinning are significant for cumulative ft^3 volume yields, the realizable gains in sawtimber output are phenomenal, and for good reason. By thinning from below, growth is placed on fewer stems, which, as a result, grow into sawtimber sized material sooner than they would in the unthinned stand.

Table 2. Cumulative, annual, and periodic yields for various rotation ages and sites for upland hardwood forests thinned every 10 years beginning at age 20 (Gingrich 1971).

Rotation age	Cumulative total yields and incremental gains[a]				Cumulative mean annual yields and incremental gains			
	Ft^3		Board feet		Ft^3		Board feet	
				SITE INDEX 65				
40	2,200		1,320		55		33	
		>1,015		>2,580		>9		>45
50	3,215		3,900		64		78	
		> 825		>3,780		>3		>50
60	4,040		7,680		67		128	
		> 790		>4,920		>2		>52
70	4,830		12,600		69		180	
				SITE INDEX 75				
40	3,200		2,400		80		60	
		>1,125		>5,450		>7		>97
50	4,325		7,850		87		157	
		>1,075		>6,250		>3		>78
60	5,400		14,100		90		235	
		>1,040		>5,780		>2		>49
70	6,440		19,880		92		284	

[a]Cumulative total yields include those volumes periodically thinned from the stand, as well as residual stand volumes.

If we focus upon the right hand side of Table 2, cumulative mean annual yields naturally increase, also, as a result of thinning. If maximization of this biological guide is the objective of management, with thinning one would extend the total fiber production rotation to 70 years on both SI 65 and SI 75 areas. Cumulative mean annual yield of sawtimber would still peak at 70 years in the thinned stands for both site indices, but with considerably higher mean annual board foot outputs--77 bf/acre/year more on SI 65, and 124 bf/acre/year more on SI 75 land.

To summarize, the biological decision guide of maximizing mean annual yield suggests that unthinned SI 65 stands should be grown on a 50-year rotation for fiber and on a 70- or 80-year rotation for sawtimber. Rotation ages for SI 75 land should be 60 years for total fiber and 70 years for sawtimber. In either case, the rotation at which total mean annual fiber maximization occurs is 10 to 20 years sooner than that at which total mean annual sawtimber production peaks.

If stands are thinned every 10 years, beginning at age 20, and if the thinned stems are used, the biological decision guide suggests growing the stands on a rotation age of 70 years, whether on SI 65 or SI 75. Since differences in mean annual ft^3 volume yields between ages of 50 and 70 years are small, one could argue that even the biological decision guide for thinned stands suggests a rotation age for total fiber of 50 to 60 years.

Economic Decision Guides

The most basic economic decision guide is the principle of the margin, i.e. rather than focusing on total yields, one looks at the additional, or incremental gains or losses. Most people govern their daily lives using this principle, although they usually balk at the thought of acting like economists. At the beginning of most activities, gains or benefits usually accrue--and typically at an increasing rate. Sooner or later the benefits subside, and finally, as a result of further inputs to the activity, total output begins to decline. Foresters are especially aware of this tilted S-shaped curve, as it depicts the total volume growth of a stand of timber, over time. When economic constraints are imposed upon our actions, we typically find that to maximize net profit or benefits we will continue to do something up to the point at which the additional gains from doing so peak. When these additional gains begin to fall off, we have probably begun to reach the point at which net profit or benefits are greatest. As rational economic decision makers, we will stop producing timber at that age at which the additional benefits of allowing the stand to grow are just equal to the additional costs of growing it.

This economic decision guide is partially outlined in Tables 1 and 2 as the differences between total cubic and board foot yields at various 10-year rotation ages. These data are the periodic or incremental gains realized by postponing harvest another 10 years. Data would not define precisely the age at which net profits from total fiber and total sawtimber production are maximized, since we have not attached specific cost and revenue data to them. What they provide is some insight into the difference between appropriate rotation ages as defined by a purely biological, as opposed to a partial economic, decision guide. The reader may apply their own revenue and cost assumptions to these yield data and quickly determine the internal rate of return or discounted present value of alternative timber growing investments.

When this partial economic decision guide is applied to the data in Tables 1 and 2, the rational manager would produce fiber in an unthinned SI 65 stand on a 50-year rotation, and sawtimber on a 60-year rotation. Similarly, on SI 75 land, the incremental gain guide selects a fiber rotation of 50 and a sawtimber rotation of 60 years, both 10 years before those rotations suggested using maximum mean annual yield as the decision guide. In a thinned stand, fiber would again be produced on a 50-year rotation and sawtimber on a

60-year rotation for both site indices. When locally prevailing market prices are attached to these yields, and when prevailing costs of managing and thinning are defined, it is likely that the spread between the best economic rotation for total fiber and total sawtimber will widen.

The Total Fiber Dilemma: To Thin or Not?

From a biological perspective, and assuming that precommercially thinned stems can be marketed, thinning obviously increases total fiber output at all rotation ages shown in Table 2. Whether the gains from thinning, when translated into dollars, are sufficient to "pay their way" is questionable. If one can afford to hold timber capital on the stump until age 60 or 70, and market the merchantable sawtimber, as sawtimber, Utz and Sims (1981) show internal rates of return on the investment of 10 to 12%. However, the shorter the rotation and the lower the site index, the smaller will be the return on investment using Gingrich (1971) yield data.

Based on residual stand data (Gingrich 1971), given thinnings every 10 years beginning at age 20, the investment in thinning is not justified if precommercially thinned stems are not marketed (Table 3). The biological gains to the residual stand, as predicted by Gingrich, are not adequate to offset the investment in thinning costs over a 30- to

Table 3. Comparison of volume yields from unthinned and thinned upland hardwood stands (Gingrich 1971).

Rotation age	Unthinned stand Total yields		Thinned stand[a] Residual yields following thinning[b]	
	Ft^3	Board feet	Ft^3	Board feet
		SITE INDEX 65		
40	1,840	440	1,760	1,320
50	2,800	2,150	2,150	3,500
60	3,300	5,160	2,460	6,120
70	3,700	7,200	2,730	9,030
80	3,950	8,200	-	-
		SITE INDEX 75		
40	2,440	1,380	2,140	2,160
50	3,515	4,100	2,600	6,450
60	4,140	9,288	3,060	10,680
70	4,760	11,200	3,465	13,720
80	5,160	12,500	-	-

[a]Thinnings every 10 years starting at age 20.
[b]Yields are those which exist 10 years following thinning.

50-year waiting period. Sawtimber gains to the residual stand from thinning average only about 1,000 bf at all rotation ages. On-going Forest Service and other studies may uncover additional information to dispell this notion.

Discussion

As a practitioner, I look forward to the guidelines suggested at this symposium by other authors. However, presently I am forced to lean upon the data provided by Gingrich (1971). If constrained by the inability to market precommercial thinnings, and if total fiber maximization is the goal, one should probably let the stand grow without thinning to age 50 on either SI 65 or 75 land and hope that the 2,800 to 3,300 ft^3 of fiber is marketable at that time. This "let it grow" approach views fiber in a rather traditional perspective as low value and small diameter material for fuel or pulp.

If one is optimistic about future markets for wood fiber, alternatively defined as a combination of market pulpwood, firewood, fiberboard furnish, and small sawtimber (that 20 years from now may be considered large diameter sawtimber), one might take the following approach. Define the age and site index of their immature Appalachian hardwood acres and follow Gingrich (1971) thinning prescriptions. To reduce uncertainty to a "manageable" level, thin the stand from below, favoring those species that grow quickly and those holding the greatest promise of retaining their currently high status in the present stumpage market. Or, if the objective were to produce primarily pulpwood or firewood, favor those species which yield the highest volume of oven-dried pulp or the highest BTU/green ton. Thin using the crown touching crop tree release guideline, and leave a residual stocking of between 60 and 70%. Skid the thinned material to roadside, cut to desired size and sell as firewood, pulpwood, small sawtimber, or fiber-board furnish (assuming no constraints exist). Continue to do so every 10 years. Clearcut the stand at age 50 (SI 65 or 75), sell the 2,200 to 2,600 ft^3 of residual fiber, including 3,500 to 6,500 bf of sawtimber, and start over.

The major advantages of thinning, the ability to select final crop trees by location and species, and the increased average diameter of the final stand, may be included in the calculation of internal rate of return on investment. If premiums exist, or are suspected to be realized on certain species or diameters in the future, this increased return could be reflected in the revenues used in the decision formula. If it is possible to realize such monetary gains, the argument in favor of thinning (even over short rotation periods) are improved.

Unless prices for traditional "small" diameter, "low" valued hardwood fiber climb markedly, short rotation (30 to 35 years) natural hardwood fiber silviculture is unlikely to become a reality. And, while I personally expect hardwood fiber to increase in value in the long-run, I doubt that one should totally ignore the role which sawtimber plays in carrying the lower diameter fiber, on any given acre, to market--regardless of the rotation over which it is grown!

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LOGGING DAMAGE DURING THINNING IN EVEN-AGED HARDWOOD STANDS

Ralph D. Nyland

Professor of Silviculture
SUNY College of Environmental Science and Forestry
Syracuse, NY 13210

ABSTRACT

Past studies of logging damage during thinning of even-aged hardwood stands indicate that most injuries result from skidding. Felling operations primarily affect trees of small sizes. The amount of damage from all sources will vary widely from stand to stand, likely because many factors influence the numbers and patterns of injuries. In few cases will the wounds lead to certain decay, but all wounds to the butt log will degrade the lumber and reduce the value of the tree. Careful logging practice, selection of appropriate machinery, and careful layout of skid trails will help minimize injuries. Conventional ground skidding, mechanized logging, and cable yarding all seem feasible if the contractor gives adequate attention to controlling logging damage.

Perspectives on Logging Injuries

Thinning implies long-term rotations to grow large-diameter and high-quality sawtimber and veneer products. For this, we favor fast-growing trees with the best lower-bole characteristics (straight, round, branch-free, and unblemished), and reduce crowding so the selected trees develop large crowns and grow rapidly in diameter. Most methods of thinning favor trees in upper canopy positions, with well-developed crowns. We also look carefully at the lower 16 feet of the trunk since that portion of the tree represents most of its value.

With sawtimber management goals, we protect the selected crop trees from future harm, and particularly against agents that would slow the growth or degrade the lower logs due to physical defects, discoloration, and decay. That means protecting against logging injuries as well as natural agents.

Injuries and Defect

Shigo's (1966) pioneering work has shown that an injury leads to discoloration of the wood present in the maples, beech, and the birches. The discoloration is less distinct in species like black cherry and black walnut that develop true heartwood, even in the absence of injuries. The extent of discoloration depends upon tree

vigor, the severity of an injury, the presence of old wounds in the tree, and on time (Shigo 1966). Discoloration reduces the value of lumber in the furniture market, and also may lead to possible development of rot in a tree. Injuries to the crown appear more consequential than ones to the trunk, especially with repeated crown injury (Shigo 1966; Shigo and Larson 1969).

Following discoloration rot may develop, given inoculum and proper conditions within the tree (Shigo 1966). Internal chemical processes compartmentalize the wounded tissues, zoning them off from the rest of the tree. This may reduce internal space for storage of energy and cause a stress (Shigo 1985). New wood laid down in subsequent growth will not discolor. Nor will the rot spread outward over time, given no later injury to the same tree (Shigo 1966; Shigo and Larson 1969).

Subsequent wounding of tissues close to any older internal defect may cause the discoloration and decay to spread (Shigo 1985). Thus, if periodic thinning throughout the rotation causes repeated damage to the same trees, their health and quality will decline. With some types of wounds, the repeated stress could result in an irreversible strain that leads to mortality. The more frequent the entry into a stand, the greater the probability of repeated injury to any one tree.

Wood-rotting fungi do not always develop. Yet Hesterberg (1957) reported at least an 80% chance of measurable decay within 10 years in sugar maple following injuries that break branches having a basal diameter of at least 4 inches. Stem injuries that remove bark from at least 150 in^2 of trunk surface have a 50% chance of developing decay within 10 years, and wounds of 130 to 200 in^2 have an 80% chance of decay within 20 years. Lavalle and Lortie (1968) observed similar effects with the removal of only 90 in^2 of bark from yellow birch trees. Silverborg (1954, 1959) also reported a high probability of rot developing in trees with broken branches at least 3 inches in diameter. Overall, available evidence indicates that injuries can lead to discoloration, with an increased chance that rot may develop in trees with large wounds.

Shigo (1966) pointed out that while wounds covering more than one-third of the tree trunk circumference are serious, the degree of decay and discoloration cannot be precisely predicted based upon external wound characteristics alone. Yet several reports like those cited do suggest that large wounds indicate a heightened probability of defect and decay developing (Hesterberg 1957; Ohman 1970). With that in mind, Nyland and Gabriel (1971) listed several types of wounds that appeared to have a better-than-even chance of eventually proving detrimental to sawtimber objectives (Table 1). These serve as useful indicators in judging the general importance of logging wounds from a silvicultural perspective.

Logging injuries may have other adverse effects. These may be either direct or indirect. For example, the felling of one tree may damage the crown of others, reducing the leaf surface area, and altering the growth rates. Some trees may also be broken off, bent over, or

knocked into leaning positions. Skidders can have similar effects by running over or pushing down trees of sapling sizes. In uneven-aged stands, Nyland and Gabriel (1971) found breaking off and bending over of residual trees primarily among saplings of shorter heights, and the frequency of crown injuries proportional to the number of trees present in a diameter class.

Table 1. Types of wounds and criteria for judging the importance of logging injuries to hardwood trees (Nyland and Gabriel 1971).

Type of injury	Wounds judged as major injuries
Bark abrasion	Bark removed, exposing 90 in^2 or more of sapwood for yellow birch, or 150 in^2 or more for other species.
Broken branches	Branches larger than 3 inches diameter broken from the tree.
Root damage	Roots exposed or severed over more than 25% of the area within the drip line of the tree crown.
Broken off	The main stem broken off, destroying the tree or most of the crown.
Bent over	The tree partly or entirely uprooted or tipped out of growing position.

The severing of roots around a tree also has important effects. When a skidder sinks into saturated soil, it leaves deep ruts in the skid trail and cuts the roots of the trail-side trees. In severe cases, the damage may remove sufficient root area to reduce moisture and nutrient up-take, as well as the energy storage capacity of the root system. Equally as important, cutting the roots around one side of a tree makes it more prone to windthrow. Fortunately, prohibiting logging over saturated soils controls the root cutting. Also, good skid trail design will keep the machines away from poorly drained areas where deep rutting would most likely occur.

Conventional Thinning

The effect of an intermediate stand treatment depends upon at least three factors: 1) the method of thinning used; 2) the intensity of the treatment; and 3) the logging system employed. Within the eastern hardwoods literature, different methods of thinning have not been compared to any great extent, particularly for damage to residual trees. Some reports compare effects from varying the intensity of

thinning. And recently, studies have included different logging systems. Historically, contractors have used chain saw felling, and tree-length or short-log skidding with articulated frame-steering, 4-wheel drive rubber-tired skidders. These conventionally operated stands provide a standard to compare other logging systems.

Lamson et al. (1984) assessed harvesting injuries in a 60-year-old West Virginia cherry-maple stand marked for thinning to remove 33, 48, and 60% of the initial basal area. They found crown injuries infrequent among trees <5 inches dbh at all intensities of thinning. In contrast, as the intensity of thinning increased, a greater proportion of the residual stand suffered an injury that exposed sapwood (Table 2). Considerable numbers of trees were destroyed or bent over, but almost exclusively among trees <5 inches dbh. Between 30 and 55% of the unmarked trees were bent over, broken off, or otherwise destroyed. Though most destroyed trees had small diameters, their loss reduced the projected relative density by 5 to 8% below that marked.

Table 2. Bark and crown damage in a 60-year-old West Virginia hardwood stand subjected to different intensities of thinning (Lamson et al. 1984).

Residual relative density		Residual stand[a]					
		Basal area			Number trees/acre		
Marked	Actual	Total	Damaged	Percent	Total	Damaged	Percent
-----Percent----		---Ft^2/acre---			---No./acre---		
74	69	99	25	25	177	44	25
61	53	76	34	45	136	63	46
45	37	56	34	60	85	50	59

[a]Trees 5.0 inches dbh and larger.

The 53% plot had only 73 trees/acre 5.0 inches or larger not damaged during the harvesting, and the 37% plot only 35 trees/acre. In neither case will this provide full site occupancy with undamaged trees by the end of the rotation. Also, in the 69, 53, and 37% plots a total of 7, 13, and 22%, respectively, of the residual dominant and codominant trees received skidding injuries that covered at least 100 in^2 of the trunk, leading Lamson and Miller (1983) to suggest that "most sapwood wounds on potential crop trees are small enough to heal with little danger of sapwood decay".

Miller et al. (1984) evaluated logging damage to a 53-year-old mixed oak-cove hardwood stand thinned during spring to different levels of relative density. Among the plots, located between the skid trails, logging destroyed and bent over sufficient trees to reduce the target relative density by about 5%. Most of these trees had diameters <5 inches dbh. One-half of the skidding wounds and 9 of 10 crown

injuries were among trees <5 inches dbh, and damage was greatest with the heaviest thinning (Table 3). The two highest levels of relative density had sufficient numbers of undamaged trees for full site utilization. About 10% of the dominant and codominant trees suffered a wound, with only about 4% of them at least 100 in^2 in size.

Table 3. Logging damage to a 53-year-old mixed oak-cove hardwood residual stand thinned to different levels of relative density (Miller et al. 1984).

Relative density	Basal area	Number trees	Trees damaged	
			Exposed sapwood	Broken top
	Ft^2/ac	No./ac	----------Percent----------	
69	79	265	5	11
56	65	180	9	12
40	46	142	18	21

[a]Trees 1.0 inches dbh and larger.

I recently assessed logging injuries following crown thinning of three separate commercially harvested 3.6-acre research plots. On two we cut 36% of the basal area and on the third 27% (Table 4). Felling and skidding together destroyed about 6 to 9% of the designated residual trees on each plot, almost entirely among trees <6 inches dbh. These losses reduced the relative density by 3 to 5%. Among the residuals, about two-thirds of all injured trees had diameters <6 inches. Few of any size class received a major injury (criteria in Table 1), including not more than 8% of the trees >5 inches dbh. Overall, skidding caused about twice as many injuries as felling. Though both procedures inflicted few major wounds, 15 to 20% of the residual stand has a basal injury. The undamaged trees and ones with only small wounds will suffice for full site utilization by the end of the rotation. The least dense plot had the smallest amount of basal area cut and the fewest injuries to trees >5 inches dbh.

These three studies indicate that felling and skidding during thinning mostly damages saplings (<6 inches), particularly in cases where logging breaks off, bends over, or otherwise destroys a tree. These losses can reduce the target relative density by up to 10%, even though they do not importantly alter the residual basal area or volume. Neither Lamson et al. (1984), Lamson and Miller (1983), nor Miller et al. (1984) recommend making adjustments to the marking guide to anticipate losses. Whether undamaged trees will ensure full site utilization varies from stand to stand, and in some cases, basal injuries have left too few undamaged trees of upper crown positions to provide full site occupancy by the end of the rotation. The incidence of damage seems to increase with the intensity of thinning rather than the level of residual relative density. In general, the importance must be judged for each case. However, even when only limited

proportions of the larger residual trees have injuries that would lead to important decay and discoloration, small wounds will degrade the lumber and reduce the value of the tree.

Table 4. Logging damage to residual trees during commercial thinning of a 74-year-old northern hardwood stand in the Adirondack Mountains of New York.[a]

Relative density	Basal area	Number trees	Basal area removed	Residual trees injured			
				Major	Other	Major	Other
	Ft^2/ac	No./ac	Percent	--------Percent----------			
ALL TREES 1.0 INCHES DBH AND LARGER							
56	84	236	27	2	6	2	12
75	95	268	36	3	5	1	14
72	98	246	36	2	8	<1	20
TREES <5 INCHES DBH							
56	78	94	-	4	1	4	10
75	88	99	-	1	2	3	17
73	91	105	-	4	3	1	18

[a]Major injuries defined in Table 1.

Whole Tree Skidding

Recently, some logging contractors have found markets for fuel chips. While many chipwood operations employ clearcutting with whole-tree skidding, fuel chips could come from otherwise unmerchantable stems and the tops and low value parts of other trees removed in thinning. These operations can fit into any method of thinning, and even include chain saw felling and conventional machines for skidding. However, the contractor would skid out entire trees rather than just the main stem, perhaps using wider trails and a larger tractor.

Hannah et al. (1981) investigated logging injuries following one whole-tree skidding operation in a 65-year-old northern hardwood stand in Vermont. The partial cutting left only a lightly-stocked stand by reducing the initial basal area of 120 ft^2/acre by one-half. In all, 27% of the residual trees examined had logging wounds, with multiple injuries on most. For about 9 of 10 injuries, the skidding had skinned bark off the tree. This included 68% of the trees within 2 feet of a skidder track, but the frequency of injury declined with distance from the skid trails. Similarly, Shigo (1966) and Nyland and Gabriel (1971) had reported a high incidence of skidding damage to trees along the main skidding trails with tree-length skidding, though the numbers and severity of wounds varied from job to job. Hannah et al. (1981) felt that giving attention to skid trail alignment and

straightness, limiting machine size, and cutting off large strong side branches would help control skidding injuries.

Kelly (1983) also investigated logging damages from whole-tree skidding in Vermont northern hardwood stands thinned to either 60 or 80 ft^2 of residual basal area. In the former, the contractor used a feller-buncher and a grapple skidder, and for the other job chain saws and a conventional rubber-tired skidder. In both cases about 45% of the residual trees 2 inches dbh and larger sustained injuries, with multiple wounds on most. Yet only 12 to 13% of the injuries were considered severe. Skidding caused 70 to 90% of the damage, and basal wounds from skidded trees rubbing against residual ones were more prevalent than injuries inflicted directly by the machines (Table 5). Limiting the contractor to a conventional skidder offered no advantage.

Results indicate that trees at least 2 inches in dbh without a wound or having only a small one will suffice for full site occupancy by the end of the rotation. However, logging damaged a high proportion of trees in upper crown positions, and left basal defects on about 40% of the residual trees.

Table 5. Logging injuries to residual trees using whole-tree skidding methods in Vermont northern hardwood stands (Kelley 1983).

	Trees >5 inches dbh				Trees 2 inches dbh+	
Logging job[a]	Basal area/ acre	Number trees/ acre	Total injured	Severely injured	Number/ acre	Percent injured
	Ft^2		------Percent------			
FB/G	80	196	42	13	110	34
CS/CS	60	184	47	12	110	52

[a]FB/G--feller-buncher and grapple skidder.
CS/CS--chain saws and conventional skidder.

I recently looked at several thinned stands operated by whole-tree skidding and generally observed a pattern of damage similar to conventional tree-length jobs. Of several different stands inspected by walking the skid trails and traversing the area in between, I observed considerable variation in the frequency and severity of injuries from one site to another. The worst case had been cut in spring and skidded using large tractors. Some cull trees cut from the stand had large side branches that did not bend upon impact with residual trees. In that case, basal wounds were widespread and large, especially along the skid trails. In contrast, the best cases with actually little skidding damage had been cut in another season by contractors who used smaller machines. The trees in those stands seemed to have smaller side branches more typical of second-growth

hardwoods. Here I found few skidding injuries, either along the trails or between them.

In all cases examined the area between the main skid trails had relatively few basal injuries on the residual trees, with the most severe wounds at curves of the skidding corridors or where the operator used a trail-side tree to turn a load when entering onto a main skid trail. In the best of the whole-tree jobs, the operator tended to drive in the center of the wide skidding corridors. The branches on the skidded trees seemed to cushion the impact with residual ones, just as reported by Hanna et al. (1981), protecting the lower trunks in many cases.

These three reports indicate that whole-tree skidding could prove acceptable if done properly. Most available evidence, though, shows a high incidence of skidding injuries, perhaps reflecting a tendency for the chipwood operators to use large-size machines to speed the skidding and optimize production of the chipper. Time of year, equipment size, skid trail layout, crown configuration, and care of operation seem important in determining the numbers and severity of basal wounds. Given the proper mix of these, whole-tree skidding should not cause damage much different from conventional tree-length operations. Yet, the worst-case stand that I inspected had so many severe injuries that I would recommend against whole-tree skidding unless I had assurance of adequate attention to the conduct of the skidding operation.

Mechanized Thinning Operations

Advances in harvesting equipment design have opened new opportunities for mechanized logging in many regions, and particularly at sites lacking severe slopes and difficult surface features. New logging systems include mechanized felling and bunching, grapple skidding, and conversion of trees into logs, bolts, and chips without traditional inputs of labor. These systems offer potentials for more efficient and less costly operations, and contractors can often succeed with less cordwood volumes by utilizing materials bypassed during conventional logging (Biltonen et al. 1976).

Biltonen et al. (1976) evaluated several systems for use in thinning second-growth hardwood stands in the upper Lake States. The scheme that offered the best compromise between silvicultural benefits and efficient operation incorporated a felling device that held the trees upright before dropping them to the ground at selected places. They laid out a series of straight skid trails of sufficient width for the grapple skidder, and added short branching trails that departed from the main skidding corridors in a herringbone pattern. The feller operator could move off of the main corridors along the spur trails, cut the marked trees, back up to the main skidding corridor, and lay each cut tree along the skidway in a position ready for pick-up by the grapple skidder.

In their experiments, Biltonen et al. (1976) had the contractor fell one plot using chain saws, but removed no products from this stand. For the plot harvested with the feller-buncher and grapple skidder they could assess both felling and skidding damage (Table 6). In that case, wounds to the bole and exposed roots were the most prevalent, with multiple injuries on many trees. About 125 trees/acre remained undamaged. That should suffice for full site utilization by the end of the rotation. Both methods left about 9 trees/acre (5% of the residual trees) with crown injuries, indicating that the mechanization did not increase the felling injuries. In Vermont, Kelley (1983) also had observed felling injuries on only 6% of the residual trees in a stand thinned with a feller-buncher, and the skidding and machine operations caused 87% of all injuries.

Table 6. Injuries to residual trees from thinning second-growth northern hardwoods using chain saw felling or mechanical logging (Biltonen et al. 1976).

Felling treatment	Total number trees/acre	Trees injured		Type tree injury		
		No./acre	Percent	Bole	Roots	Crown
				----No./acre------		
Chain saw	155	16	10	6	-	9
Mechanized	156	31	20	22	14	9

Johnson et al. (1979) tested a similar approach to thinning, but have used a tracked, long-reach feller-buncher that could cut and retrieve trees up to 20 feet away. They harvested all trees from 15-feet wide skidding corridors spaced at 40-feet intervals. The operator removed trees from between the strips without driving the feller-buncher out of the corridors, and bunched the felled trees along edges of the strips but among the residual trees. They used a grapple skidder to pick up the loads, move them into the skidding corridors, and pull the bunches to a landing.

Most residual stand damage resulted from skidding. All together 32% of the residual trees were injured, and 19% had large wounds (Table 7). The thinning left only 55 ft^2 of basal area in a lightly stocked residual stand of 109 trees/acre. Only 95 trees did not have a wound covering more than 50 in^2. That number will not suffice for full site utilization by trees lacking large wounds.

Johnson et al. (1979) attributed the prevalent skidding damage to the wide tops of some trees and the piling of cut trees between standing residual ones. As the operator picked up the loads and turned into the skidding corridor, the loads unavoidably hit some residual trees. This tendency had also been reported by Shigo (1966) and Nyland and Gabriel (1971) in stands skidded tree-length with conventional skidders. Johnson et al. (1979) concluded that bunching within the

skidding corridors would have reduced the damage by at least 10%. That would provide a more tolerable level of damage in the residual stand. Biltonen et al. (1976) also suggested that using wide skid trails matched to the equipment would decrease the numbers of skidding injuries. Skid trail layout, the placement of spur trails, and care in machine operation also appear critical in controlling stand damage and making mechanized harvesting acceptable in thinning immature hardwood stands.

Table 7. Damage to residual trees from thinning northern hardwoods using a tracked, long-reach feller buncher and grapple skidder (Johnson et al. 1979).

	No./acre	Percent trees injured
Total residual trees	109	--
Injured trees	35	32
Stem damage	16	46
Root damage	6	17
Stem and root damage	13	37
Trees by severity of wound		
Wound >50 in^2	14	40
Wound <50 in^2	21	60

Cable Yarding

During the last decade, the logging industry has reevaluated cable yarding in eastern hardwood stands. Engineering improvements made available smaller and highly mobile equipment better fitted to the sizes of timber available and more suitable for efficiently harvesting on steep slopes. The equipment has proven economically attractive, both with clearcutting and partial cutting.

Gibson and Biller (1975) examined logging injuries in one partially cut West Virginia hardwood stand where they yarded the tree-length pieces using a skyline system. They did not describe residual stand conditions except to report an average of 9 trees/acre damaged in logging. About one-fifth of the injured trees were broken off or bent over. The remainder had stem wounds. Though general in nature, their findings do not suggest major problems with cable yarding.

Wendel and Kochenderfer (1978) studied another partially cut and cable yarded West Virginia hardwood stand. They set out 15-foot wide yarding corridors spaced 150 to 200 feet apart, cut all trees from these pathways, and laterally yarded the logs up to 100 feet into the main corridors. The yarding operation destroyed only 3% of the residual trees (1.0 inches dbh+) and another 3% had injuries to the main stem (Table 8). About two-thirds of the trees with stem injuries

and almost all destroyed in yarding were <6 inches dbh. They did not assess felling damage. Results indicated that cable yarding compared favorably to other systems of skidding in controlling logging injuries, and left sufficient numbers of undamaged residuals for full site utilization.

Table 8. Residual stand damage from cable yarding in a West Virginia hardwood stand (Wendel and Kochenderfer 1978).

Residual stand[a]	Number trees/acre	Percent of residual
All trees	521	100
Trees >5 inches dbh	102	20
Injured trees	34	7
Bark abraded	18	3
Root damage	1	<1
Destroyed	15	3
Injured trees >5 inches dbh	7	7

[a]Trees 1.0 inch dbh and larger.

In another test, Kochenderfer and Wendel (1980) used a truck-mounted crane for yarding on steep slopes in West Virginia. Of 513 residual trees/acre (1.0 inch dbh and larger) yarding destroyed 1% while 10% of the stems were damaged. Most stem wounds covered <25 in^2 of surface. Two-thirds of all damaged trees had diameters of <6 inches dbh, again indicating a favorable effect of cable yarding compared to conventional skidding. Lamson and Miller (1983) also observed low levels of yarding damage, with not more than 5% of the residual dominant and codominant trees classified as high risk due to logging injuries on plots cut to three levels of relative density. The frequency of injuries did not seem related to residual relative density. In both studies, cable yarding did less stand damage than expected with conventional ground skidding.

Fox (1985) and Koten (1985) evaluated two partially cut New York northern hardwood stands yarded tree-length, including lateral yarding to pre-cut corridors (Table 9). The Ticonderoga stand was treated in spring with an inexperienced crew. Yarding inflicted major wounds to 9% of the residual trees. At the Ischua site, only 4% received major damage. Both cases compared favorably to the 5% damage that Nyland and Gabriel (1971) observed with conventional tree-length skidding among uneven-aged northern hardwoods in New York. Differences between the two yarded sites appeared related to time of logging, differences in tree crown size, and crew experience. Their findings support Carvell's (1984) conclusion that injuries associated with a well-planned cable yarding operation would compare favorably with or be fewer than tree injuries from conventional ground skidding.

Table 9. Residual tree injuries from cable yarding in two northern hardwood stands in New York (Fox 1985; Koten 1985).

Residual stand	Stand locations		Nyland and Gabriel (1971
	Ischua	Ticonderoga	
Total Number trees/acre	155	140	151
Injured trees			
Number trees/acre	50	44	41
Percent	32	31	21
Square feet/acre	26	12	19
Percent	36	29	28
Major injuries (felling)	8	4	5
Percent	5	3	10
Major injuries (yarding/ skidding)	4	12	8
Percent	3	9	5

Consequences of Selection Thinning

While timber harvesting during most types of intermediate stand treatment does not necessarily cause excessive damage, the selection method of thinning may have intolerable effects. This method has gained fairly widespread use among the vast acreages of second-growth hardwood forests reaching sawtimber status in eastern United States. In these stands, the available timber comes largely from the biggest trees that occupy dominant and upper codominant crown positions. These often include the shade-tolerant, fast-growing species like black cherry, white ash, yellow-poplar, and red oak. By definition, selection thinning removes these "dominants that have exceeded the diameter-limit prescribed, in favor of thinner trees of at least as good growth form and condition" (Ford-Robertson 1971). This implies that the residual stems have the potential for good future growth and quality.

Published reports do not describe injuries associated with selection thinning, per se. Yet the findings of Nyland and Gabriel (1971) from partially cut uneven-age stands appear relevant, since both even- and uneven-aged hardwood stands with a component of shade-tolerant species have inverse-J diameter distributions with more small than large trees. Both uneven-age management and selection thinning include the harvesting of large-crowned trees of the tallest heights and greatest sizes to enhance the quality and growth of the smaller residuals. Selection system differs by cutting throughout the dbh size classes to properly tend the immature trees and maintain a specified diameter distribution.

For uneven-aged stands, Nyland and Gabriel (1971) observed a frequency of injury proportional to the numbers in a size class. They reported

an average of about 20% of the residual basal area in trees with important logging injuries (Table 1). Unlike crown, free, or mechanical thinning in even-aged stands, felling wounds to the crown were twice as prevalent as basal injuries from skidding. Basal damage occurred throughout the stand, but about 70% of trees along the major skid trails had skidding wounds.

Based upon these reports, I recommend against the selection method of thinning in emerging second-growth hardwood stands, particularly since Nyland and Gabriel (1971) observed that changes in logging practices seem only to transfer the injuries from one tree to others rather than to reduce the numbers damaged. I also dislike the financial aspects of removing the fast-growing and most valuable elements of the stand before those trees attain optimal grade as would happen with the selection method of thinning.

Conclusions and Recommendations

When we use crown, free, mechanical, or ordinary thinning (Ford-Robertson 1971), we do not have important probems with felling damage in any of the logging systems used today. Destruction of many understory trees usually has little economic impact. In fact, Carvell (1984) commented that in even-aged stands these small low-vigor stems of poor crown positions often pose a management problem at the end of a rotation, so their loss during thinning could prove beneficial. I feel that we can likely anticipate losing 10% of the saplings and could adjust the marking guide accordingly to arrive at a prescribed level of residual relative density. Other researchers consider this unnecessary.

The cases that I have examined, and the information I gleaned from pertinent literature, suggest that conventional skidding can be managed to control basal injuries within tolerable limits. Time of year, size of machinery, skid trail design, directional felling, and operator attitude all play an important role in determining the extent and severity of injuries to the residual stand. I also feel that whole-tree skidding, mechanized logging, and cable yarding have a place in thinning, given an appropriate mix of machinery and a skid trail system fitted to the machines used. I see real potential for whole-tree skidding if done properly. In fact, the fuel chip market often makes a commercial venture possible with less volume/acre and may allow earlier entry to a stand for the first thinning. That would have an economic advantage in shortening rotations and providing earlier financial pay-off to the landowner.

Nyland and Gabriel (1971) pointed out that repeated entry to a stand at frequent intervals (i.e. 10 to 15 years) would result in repeated injury to the growing stock, including probable reinjury to some trees over several cutting cycles. This would cause repeated physical degrade, continued discoloration, and a heightened probability of developing internal cull. In short, repeated logging in the same stand could reduce the potentials for long-term development of quality sawlog products. Careful planning and appropriate control over

stocking will minimize the numbers of thinnings needed. Balancing stocking between 60 and 80% relative density as recommended by Roach (1977), Roach and Gingrich (1968), and Marquis et al. (1984) will help in this regard.

Based upon my studies, I recommend the following as part of the damage control procedures for every commercial thinning operation:

1. Retain large-crowned trees and free them by cutting shorter trees with smaller crowns.

2. Use directional felling to divert falling trees away from high-quality residuals, and to help align the boles for efficient skidding with minimum turning.

3. Use well-organized skidding corridors sufficient to accommodate machine operations and to minimize turning.

4. Cut out forks and remove large branches from the felled trees so they track well and fit the skidding corridors.

5. Use machinery as small as you can and still efficiently move the pieces.

6. Schedule logging for times of year when the soil is well drained or frozen, and avoid springtime operations when the bark is easily skinned off the tree trunks.

7. Communicate with the logging contractor to share concerns and work out ways to instill careful work practices among the machine operators.

8. Avoid short thinning cycles to minimize the number of entries into a stand during the rotation.

I can give no assurance that these safeguards will work effectively. The tendency for logging damage to vary in extent and severity from stand to stand suggests that many factors influence the outcome. When Nyland and Gabriel (1971) used measures like directional felling, logging crew training and supervision, and special skid trail design, they saw no significant reduction in numbers or kinds of injuries following partial cutting in uneven-aged stands. The control practices simply seemed to transfer the damage from one tree to another without reducing the overall effect. Still I am convinced that operator attitude importantly influences the numbers and kinds of wounds to basal portions of the residual stand in conventional and whole-tree skidding, and in completely mechanized logging or cable yarding.

Most studies show that felling has little effect on the residual stand in thinning, particularly among trees in the main crown canopy. Instead most injuries result from skidding. Even when these wounds have only small dimensions and may not result in measurable rot, all affect tree quality. Even a small wound may potentially cause a grading defect and will reduce the value of lumber cut from a tree. Ohman (1970) pointed out that injuries within 8 feet of the ground are the most consequential economically, since the butt log has the greatest value of any in a tree. Large wounds may lead to discoloration and decay, and repeated injury to trail-side trees will compound the problem. Periodic salvage of damaged trees offers no sure solution. It could entail prematurely cutting some trees of the best crown positions, repeatedly widening the skidding corridors, and possible reducing stand relative density below desired levels. To prove tolerable, logging damage must be minimized, leaving sufficient unblemished trees of good crown positions to ensure full site occupancy by the end of a rotation.

I am convinced that the relationship we develop with the logging contractor and the way we attempt to communicate our concerns and interests will importantly influence the success to all parties. By working together to select appropriate methods for thinning, mixes of machines, and logging practices, we probably have the best chance to influence the numbers and patterns of injuries and the long-term effect on the stand. Though most reports voice little concern about logging damage leading to measurable decay, each wound to the butt log will affect wood quality. Consequently, I urge you to give logging damage serious attention. Do not ignore logging injuries and pretend that they do not happen. Rather actively think about ways to control injuries when planning silvicultural treatments, and look for ways to keep the damages within tolerable levels for the management objectives.

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COORDINATING TIMBER AND WILDLIFE MANAGEMENT PRACTICES IN IMMATURE APPALACHIAN HARDWOOD STANDS

E. D. Michael and J. M. Dickson

Professor of Wildlife Management;
Graduate Research Assistant
Division of Forestry
West Virginia University
Morgantown, WV 26506

ABSTRACT

This paper reviews the current literature regarding impacts of management of immature Appalachian hardwood stands upon wildlife populations. The literature review summarizes impacts of the following silvicultural practices: partial cutting, clearcutting, prescribed burning, and herbicide application. Timber management recommendations for four age classes (seedling, sapling, pole, and small sawtimber) are presented for six wildlife species groups. Wildlife species groups are: big game (black bear and white-tailed deer), game birds (turkey and ruffed grouse), small game mammals (cottontail rabbits and gray squirrels), furbearers (racoon and fox), small nongame mammals (shrews, mice, and chipmunks), and songbirds.

Introduction

Silvicultural practices influence wildlife management in several ways, but primarily through habitat alteration. Implementation of these practices determines their impact on wildlife. An understanding of the relationships between plant and wildlife species present in immature hardwood stands is essential for the coordination of timber management with wildlife management.

Appalachian mixed hardwoods are found in coves, on lower slopes, on northern and eastern aspects, and on gentle terrain (Trimble et al. 1974). Dominant tree species include: yellow-poplar, northern red oak, white oak, black cherry, sugar maple, red maple, cucumbertree, black locust, and to a lesser extent, black birch, white ash, basswood, elm, and beech.

The avoidance of population fluctuations in wildlife species requires the continuous provision of diversity of habitat. Optimum yields of wildlife require adjusting and regulating timber age classes and management techniques on smaller units of land than is needed for sustained yield of timber alone (Roach 1974). Appalachian mixed hardwoods are well suited to management for habitat diversity.

Trimble et al. (1974) outlined the following reasons for the adaptability of Appalachian hardwood stands: (1) soil fertility and moisture conditions make these stands capable of supporting a lush and varied understory; (2) a large number of tree species exist in these stands; and (3) increased variety of total habitat exists prior to any management of the stands.

Openings created through timber stand improvement (TSI) practices help to increase the structural diversity, as well as the species diversity of hardwood stands. This greatly benefits "edge" species of wildlife: those associated with shrub cover, diverse understories, and openings. Species associated with forest edges include white-tailed deer, ruffed grouse, various small mammals and their predators, rabbits, and a variety of songbirds.

Management aimed primarily at the rotation age of a stand can benefit "interior" species of wildlife; those species requiring larger amounts of undisturbed forest habitat. Some of the species common to this type of habitat include: fox and grey squirrels, wild turkey, and black bear.

The "best" silvicultural practice for wildlife depends on the species of wildlife desired. Frequent small cuttings benefit ruffed grouse (Sharp 1963), deer, wild turkey (McComb 1982), birds (Crawford et al. 1981), and small mammals (Geier and Best 1980). In general, hardwood management for a low proportion of sawtimber will favor edge species such as most songbirds, white-tailed deer, and ruffed grouse. Management for a high proportion of sawtimber will favor interior species such as black bear, grey squirrel, and wild turkey (Trimble et al. 1974).

Objectives

Several concepts have been developed for timber/wildlife management. The two most common are "featured-species" management and "diversity". Featured-species management involves direct habitat improvements only to supply those wildlife needs that cannot be supplied through "judicious use of the axe" (Zeedyk and Hazel 1974). Management is aimed at supplying food and cover without waste or without compromising other multiple-use objectives. This practice is the basis for the Wildlife Habitat Management Handbook compiled by the Southern Region USDA Forest Service (1981). Management practices recommended in the handbook apply mainly to southern pine stands.

"Diversity" focuses on ecosystem richness and implements management practices that benefit the wildlife community, not an individual species (Siderits and Radtke 1977). This technique has been applied to management in eastern hardwood stands. The goal is to obtain as many species of wildlife as possible, regardless of the number of any one species.

Management of immature Appalachian hardwood stands requires management practices that are a hybrid form of the two preceding philosophies.

This hybridization of techniques is the goal of the present paper. Through a review of current silvicultural techniques and their impacts on wildlife management, recommendations will be made for managing Appalachian mixed hardwood stands for timber and wildlife.

Literature Review by Silvicultural Technique

Partial cutting. The effects of silvicultural cutting techniques have been related to wildlife management only in a broad sense. The focus of research has been the understory development resulting from thinnings, improvement cuts, cleanings, and liberation cuts. Canopy openings created by these intermediate cuts allow sunlight to reach herbaceous vegetation. Abundance and nutritional value of these plant species are increased and the composition of the understory is improved, thus benefiting the entire wildlife food chain (Resler 1972). Through habitat improvement, partial cutting increases forest-edge wildlife and species able to tolerate smaller units of habitat (Pengelly 1972). Various types of thinnings are useful in enhancing the development and controlling the composition of understory vegetation that may provide browse, forage, and seeds for wildlife (Smith 1962). To best integrate the practices of silviculture with wildlife management, it is important in any improvement cutting or thinning to encourage mast-producing species, thus providing a food source for squirrels, turkey, deer, and a variety of small mammals (McComb 1982). Little forage will be available to wildlife species until intensive intermediate cuttings, such as cleanings or thinnings, open the stand (Crawford 1984).

To gain a diversity of wildlife species, silviculture must also be aimed at creating structural diversity in forest stands. Precommercial and commercial thinning operations create vertical and horizontal diversity; crown thinning promotes increased growth in the forest understory and on the forest floor (Crawford 1984).

Clearcutting. Clearcutting is a management practice seldom used in immature hardwood stands. It is used most often in stands that have reached the end of their rotation. However, it may be used in immature stands harvested for pulpwood or as part of a sanitation cutting. The results of a clearcutting operation, in terms of wildlife impact, depend on the size and shape of the clearcut. Clearcutting even-aged stands in small patches, and likewise group selection in uneven-aged stands, are good methods for maintaining a variety of wildlife species in the stand (Trimble et al. 1974). This is due, in part, to the ability of clearcuts to supply necessary habitat for a greater number of species (Resler 1972). The early successional stage areas created by clearcuttings are commonly used by deer, cottontails, small mammals, and a variety of songbirds (Perkins 1974).

The benefits of clearcutting to various wildlife species depend to a great extent on the size and shape of the cut. In general, narrow cuts of varying sizes are the most beneficial. For deer, strip cuts provide excellent cover adjacent to abundant browse (Krefting 1962).

Small clearcut areas are the best for ruffed grouse because extensive amounts of edge are created (Madson 1969). Newly created habitat will usually be occupied within 1 to 3 years by songbirds that otherwise might not have been able to locate a suitable habitat for breeding or nesting (Gill et al. 1974). Clearcutting indirectly benefits furbearer populations by increasing the populations of many prey species. Clearcutting is followed by increases in small mammal abundance and diversity that persist until succession returns the area to forest (Kirkland 1977). This increase is especially common in species of white-footed mice which are present in greater densities in openings than in uncut forest stands (Buckner and Shure 1985). As a multiple-use silvicultural technique, clearcutting is the most satisfactory method for maintaining an abundance of many forest wildlife species (Gullion 1982).

Prescribed burning. Prescribed burning in hardwood stands is a controversial subject. Its application to wildlife management usually takes the form of increasing wildlife food and ground cover. Late winter burns can be used to prune basic annual growth (Komarek 1963) and increase revegetation. The general benefits of prescribed burning have been identified by Givens (1962) as: (1) increasing desirable wildlife food plants; (2) increasing accessibility to seeds; (3) improving nesting conditions and mobility; (4) improving hunting conditions and hunter success; (5) reducing wildlife hazard, (6) aiding forest regeneration; (7) reducing undesirable vegetative trends.

The effects of prescribed burning operations on a variety of species have been studied. Fire is commonly used to improve big game habitat. If used following harvesting, it assists regeneration, regenerates food plants, and induces vigorous sprouting of browse shrubs (Miller 1963). Pruning of these browse species by fire results in more succulent sprout growth (Goodrum and Reid 1958), thus providing a higher quality food source for both big game and small game species. Burning often reduces the number of herbivorous small mammals for two growing seasons, yet simultaneously increases the number of insectivorous species almost immediately (Fala 1975). The increase in light and temperature resulting from a burn may favor certain small game mammals and game birds (USDA 1978). The response of songbirds to prescribed burning is variable. It can be attributable in part to an individual home range attachment by resident birds (Emlen 1970), as well as to general habitat requirements. Increases of food and protective cover following prescribed burning have been indicated by studies of the increase in the number of bird species observed during the post-burning time period (Michael and Thornburgh 1971).

Herbicide Application. The most frequent use of herbicides in wildlife management is to control algae blooms in water supplies or to prevent woody sprouts from developing in grassy areas (K. L. Carvell, personal communication 1985). Neither of these uses directly involve timber management. However, modification of a few basic silvicultural practices through the use of herbicides can benefit wildlife. Herbicide application can be used to enhance natural regeneration on

intermediate sites (Crawford 1984). Undesirable trees may be killed by herbiciding, rather than cutting, to provide potential nesting and feeding for cavity using species of wildlife (Conner 1978). The use of herbicides for wildlife/timber management purposes is part of the forefront for current multiple-use research.

Management Recommendations

Management recommendations based on broad species groups and timber stand classes have been derived from personal research and a review of available literature. These recommendations originate from general wildlife management techniques. More special guidelines would apply if management was concentrated on a single species rather than on a diversity of species. The following recommendations by no means encompass all wildlife species; however, most of the silvicultural techniques prescribed will also benefit birds of prey, reptiles, and amphibians. Endangered species represent a special case that is much too detailed for inclusion in the present summary.

I. Big game (white-tailed deer, black bear)

Seedling or open stands

Prescribed burning is a good way to prepare the site and to increase palatability and nutrition of forage and browse species.

Minimize the distance to cover, protecting rhododendron and mountain laurel thickets and vine mats whenever possible.

Keep these areas irregularly shaped to maximize the amount of forest edge available.

Limit the size of these areas to approximately one-third the total management area.

Ensure that maximum regeneration is available to prevent over-browsing.

Protect and maintain water supplies and possible den locations.

Encourage seedlings of mast-producing species and berry-producing species.

Sapling stands

To provide a source of food as forage declines and browse begins to grow out of reach, favor dogwoods, honeysuckles, and viburnums.

Young trees lack a thick protective bark and could be severely damaged by burning. Wounds make these trees susceptible to insect, disease, and fungal infestation.

Cover, den sites, and water supplies should continue to be emphasized.

Precommercial thinnings may be utilized to encourage mast-producing species.

Pole-size stands

Thinning will increase the amount of light reaching the understory and consequently, the amount of food available.

A variety of tree species should be maintained to establish a diverse habitat.

Mast-producers should be favored. Due to its superior crop production, the red oak group should be emphasized over the white oak group. The white oak group should not be completely excluded as it is a yearly acorn producer.

Small sawtimber stands

Intermediate cuts, including frequent thinnings (at 10-year intervals) will continue to provide a diverse understory and winter browse. Thinning will also help to stimulate seed and mast production.

Snags should be retained for denning, nesting, and feeding. Herbicide applications during intermediate treatments can be utilized to create additional snags.

Coniferous species should be retained to provide winter cover.

II. Game Birds (wild turkey, ruffed grouse)

Seedling or open stands

Protect broods and nests in open areas. Open areas provide insects for brood feeding. Prescribed burning can be used to create more nutritious vegetation, however, it should not be done from March through June. Increased nutrition will benefit game birds prior to the breeding season as well as during the breeding season.

Maintain irregular configurations of open or young seedling areas with a minimum distance to cover.

Encourage establishment of mast-producing species. Aspen, if present, should be maintained.

Cover should be preserved.

Sapling stands

Precommercial thinning should be utilized to create a diverse understory. Mast-producing species should be favored.

Dogwoods and other fruit-producing shrubs and vines should be emphasized.

A water supply and escape cover still remain important.

Pole-size stands

Frequent thinnings will encourage a diverse understory and promote mast production.

Species that produce fruit or soft mast should be favored.

Small sawtimber stands

Frequent thinnings should be continued as should emphasis on mast-producers and a diverse understory. Thinnings will also help to increase crown growth and subsequently mast production.

III. Small game mammals (rabbits, grey squirrels, fox squirrels)

Seedling or open stands

A dense cover of grasses and herbaceous material should be encouraged to provide food and cover for rabbits. These areas are of little benefit to grey or fox squirrels. Hardwood reproduction is required to maintain a squirrel population. Any den trees present should be protected for squirrels.

Sapling stands

Precommercial thinning or cleanings should favor mast-producers and will also help to maintain a diverse and well-developed understory. In stands <8 inches dbh, a canopy cover of 50% will yield good understory reproduction.

Pole-size stands

Frequent thinning will promote good crown development and ultimately improve mast production.

Low thinnings may be utilized to remove poorly growing or suppressed trees and increase total productivity.

Advanced reproduction of hardwood species should be encouraged.

A diverse understory with some crown openings is essential to the existence of a rabbit population.

Fruit producing trees and shrubs are a favored food source in these stands.

The red oak group should be slightly favored over the white oak group, but a variety of mast-producing species must be maintained to prevent a mast failure during any given year.

Small sawtimber stands

Den trees should be protected. Herbicides may be utilized to help create a greater density of dens. A minimum of three den trees/acre should be present.

A low, diverse understory must be maintained to provide food and cover for rabbits. Without sufficient understory vegetation, these stands are of little value to rabbits.

Mast-producers should be maintained. Hickory and beech provide preferred squirrel food.

Slash from thinning operations could be utilized in the creation of brush piles to increase the amount of cover available to rabbits.

IV. Furbearers (racoon, red and grey fox, bobcat, opossum, weasel)

Seedling or open stands

Open areas and regenerating stands provide a diverse habitat good for many furbearers. The fruits and berries produced supply food for omnivorous furbearers. The attraction of small mammals, rabbits, and ground-dwelling birds provide food for larger predators. Limited cover on these sites helps to increase predator hunting success.

Edge ratios should be maximized.

Water supplies should be protected.

Sapling stands

Grapevines should be left for omnivorous species. In addition to nut producers, black cherry, yellow-poplar, and cucumber trees should be favored.

Some openings should be maintained to provide habitat diversity.

Pole-size stands

Thinnings should be made to maintain a good understory and to encourage good crown development for future mast production.

Rock piles and brush thickets yield essential cover and den locations.

Small sawtimber stands

Habitat diversity is very important.

Large den trees should be left standing.

Rock piles, brush piles, stumps, and hollow logs are other important denning locations and should be maintained.

Herbicide applications could be used to create potential dens in some of the larger diameter trees.

In general, any management practice that increases small mammals, songbirds, or small game will be of benefit to furbearers.

A diverse habitat is essential to accommodate a variety of these predators.

V. Small non-game mammals (mice, shrews, voles, chipmunks, flying squirrels)

Seedling or open stands

Distance to the forest edge should be minimized.

Escape cover is very important on these areas: small mammals are exposed to predation in young, open stands.

Grasses and other low, seed or fruit-producing species should be encouraged.

Prescribed burning may be utilized for site preparation. This will also provide an increase in nutrients to help stimulate good development of ground and understory vegetation.

A slight drop in the mouse population may be apparent at the end of this stage; however, other small mammals should remain constant.

Sapling stands

Ground vegetation is still important; dogwoods, honeysuckles, and viburnums should be favored.

Good understory development will encourage insect populations and provide a greater food supply.

Cleanings and precommercial thinnings will aid understory development.

Pole-size stands

Thinnings are important to maintain the understory. Slash may be left scattered to provide runways or piled to provide additional cover.

As the understory declines, mast-producers should be favored to maintain a continuing food supply.

Small sawtimber stands

Intermediate cuts should be continued for understory development: slash remains useful.

Snags are important for use as den sites and day-refuges for some small mammal species.

Soft and hard mast sources and seed supplies should be emphasized.

Rock and brush piles should remain undisturbed whenever possible.

Diverse understory vegetation in a forest stand will promote a diverse small mammal population which in turn will help to support a diversity of predatory species.

VI. Songbirds (songbirds, woodpeckers)

Seedling or open stands

Open areas provide good development of grasses and small fruit-producing species. These areas also provide an abundant supply of insects which are very important during the breeding season and for raising young.

Vertical diversity should be encouraged to provide the abundant food supply required to maintain a songbird population.

Sapling stands

Initial TSI practices should be implemented to develop the species composition of the stand. For maximum songbird benefit, cherry, dogwood, beech, and oak are the favored tree species. Grapes, raspberries, blueberries, viburnums, and greenbrier should be favored in the understory.

Establishment of brush piles will provide cover and nesting and roosting habitat.

The sapling stage commonly has the highest density of songbirds and the greatest number of species.

Pole-size stands

Vertical density should be maintained.

To provide adequate cover, conifers and thickets of greenbrier, mountain laurel, rhododendron, and multiflora rose should be favored.

The density and species diversity of songbirds will decrease as this stage advances.

Small sawtimber stands

Diversity should be maintained through frequent thinnings.

Snags provide an important supply of food, nest cavities and perches and should be favored.

A minimum of three snags per acre should be present for a given songbird species.

Herbicides may be used to create snags in areas that have a low density of "natural" snags.

All TSI practices should be undertaken with consideration given to protection of songbird habitat during the breeding and nesting seasons.

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MANAGING APPALACHIAN HARDWOOD STANDS TO MINIMIZE GYPSY MOTH IMPACTS

Kurt W. Gottschalk

Research Forester
USDA Forest Service
Northeastern Forest Experiment Station
Morgantown, WV 26505

ABSTRACT

Intermediate stand treatments that may minimize gypsy moth impacts on Appalachian hardwood stands are recommended based on ecological and silvicultural background information on the interaction of the insects and their hosts. Decision tables and charts are presented that match the proper prescription to existing stand and insect population conditions. Pre-outbreak prescriptions focus on increasing stand vigor, removing trees most likely to die, reducing gypsy moth habitat, and reducing preferred gypsy moth food sources. Outbreak prescriptions prioritize stands for possible control actions, while post-outbreak prescriptions center on efficient salvage of dead trees.

Introduction

As the gypsy moth has moved south and west from New England into larger areas of commercial forests in the Appalachians, its impact has been felt by many sectors of the forestry community. Gypsy moth defoliation has affected recreation, hunting, wildlife habitat, water yield and quality, and, through mortality of trees, has impacted local timber supplies and prices within heavily affected areas making forest management impossible on thousands of acres (Donley and Feicht 1985). Early silvicultural treatments for gypsy moth infested stands recommended reducing the amount of preferred food for gypsy moths in the stand or changing the species composition to nonpreferred host trees. In many mixed-oak forest stands, it is not feasible to eliminate preferred food species. The guidelines for intermediate stand treatments presented here synthesize current knowledge for managing forests under the influence of gypsy moth infestation and are to be used to supplement existing forest management guidelines for the forest types involved. These recommendations are not prescribed to directly control the gypsy moth in forest stands or across the infested area, but are designed to minimize gypsy moth impacts before, during, and following the occurrence of defoliation.

Silvical Background

Despite a long interest in the use of silvicultural treatments to control gypsy moth populations (Fiske 1913; Clement and Munro 1917), few guidelines were available until very recently (Houston 1981; Gottschalk 1982). More recently, this interest has been heightened due to increased ecological and health restrictions on chemical control methods, increased area of gypsy moth impact, and increased popularity of integrated pest management approaches. The three forest types being addressed in this workshop--mixed oaks, Allegheny hardwoods (cherry-maple), and cove or mixed hardwoods--are all potential gypsy moth targets; however, they do differ in their susceptibility and vulnerability in response to gypsy moth.

Susceptibility

Susceptibility to defoliation is defined as the likelihood of a forest being defoliated if a gypsy moth population is present (Smith 1962). The susceptibility of stands is determined by a combination of species composition, site factors, and stand history characteristics that together contribute to favorable habitat for the gypsy moth and less favorable habitat for its predators and parasites, as first described by Bess et al. (1947). Susceptible stands are defoliated more frequently than resistant stands and in many years are the only stands supporting a gypsy moth population large enough to cause defoliation. Stands that are resistant to defoliation are either not defoliated or defoliated only in years of outbreak conditions, especially when they are located adjacent to susceptible stands (Houston and Valentine 1977).

Stand Composition

The single most important factor determining the susceptibility of a stand is its species composition. Mosher (1915) established that gypsy moth larvae favored certain trees and plants over others (Table 1). He showed that some species were favored by all instars, other species would not be eaten by young instars (first and second) but could be eaten by later instars (third and higher); that some species are not particularly favored, but may be eaten when favored food is scarce, and some species are not eaten under any circumstances. An instar is a stage in the development of a caterpillar that is determined by the time interval between successive moltings of the exoskeleton as it grows. Gypsy moths go through five or six instars before pupating into a moth. Behaviorial changes in the third instar are significant in their interactions with hosts, predators, and parasites (Doane and McManus 1981). Table 1 classifies some of the more common tree and shrub species into four groups or food preference classes. Oaks are some of the species that are most highly favored by the gypsy moth. Since first instar gypsy moths must feed on Class I species in order to survive, stands with little or no Class I species present presumably will not support populations of young larvae and are resistant to defoliation. Conversely, stands with large numbers of Class I species have the potential to support large gypsy moth

populations. For this reason, the mixed-oak forest type, which encompasses 45% of the 248 million acre eastern hardwood forest, is prime habitat for the gypsy moth.

Table 1. Breakdown of woody plant species into four gypsy moth food preference (susceptibility) classes.

Class I. Species that are favored food for gypsy moth larvae during larval stages.
Overstory: Apple, basswood, bigtooth and quaking aspen, gray, paper (white), and river birch, boxelder, larch (tamrack), American mountain-ash, all oak species, Lombardy poplar, sweetgum, willow.
Understory: Alder, hawthorn, hazelnut, eastern hophornbeam, serviceberry, all sumac species, witch-hazel.
Class II. Species that are favored food for gypsy moth larvae, after the earlier larval stages.
Overstory: American chestnut, eastern hemlock, all pine species, all spruce species.
Class III. Non-preferred species fed upon by later larval stages when preferred foliage is not available.
Overstory: American beech, black (sweet) and yellow birch, blackgum (tupelo), Ohio and yellow buckeye, butternut, sweet and black cherry, eastern cottonwood, cucumbertree, American and slippery elm, hackberry, all hickory species, Norway, red, silver, and sugar maple, pear, silver poplar, sassafras, black walnut.
Understory: Blueberries, pin and choke cherry, American hornbeam, paw paw, persimmon, redbud, sourwood, sweetfern.
Class IV. Unfavored species that are rarely fed upon.
Overstory: All ash species, baldcypress, northern catalpa, eastern redcedar, balsam and Fraser fir, American holly, horsechestnut, Kentucky coffee-tree, black and honey locust, mulberry, sycamore, tulip-tree (yellow-poplar).
Understory: All azeala species, dogwood, elderberry, grape, greenbrier, juniper, mountain and striped maple, rhododendron, all Rubus species, sheep and mountain laurel, spicebush, sarsaparilla, all viburnum species.

The Allegheny hardwood type is composed primarily of Class III species and so is relatively resistant to defoliation. These cherry-maple stands are at greatest risk of defoliation when they occur in the oak-northern hardwood transition zone. There, they are intermixed with mixed oak stands or have a sizeable percentage of oak (usually northern red oak) and other preferred species present in the stand that allows development of the young larvae to the stage where they can feed on the black cherry and red and sugar maples. Most Allegheny hardwood stands would be rated low susceptibility and would only rarely be defoliated by the gypsy moth.

The cove or mixed hardwood type is characterized by a large diversity of species. The susceptibility of any one stand would depend primarily on the percentage of preferred food species present in the stand. A stand that had 60% preferred food species would have medium susceptibility, while one that had 40% would have low susceptibility, and one that had 20% would be resistant to most gypsy moth defoliation.

The location of a cove hardwood stand to mixed-oak stands may influence its susceptibility because larvae can disperse from one stand to other nearby stands. Cove hardwood stands are highly variable in their susceptibility.

Other Factors

In addition to species composition, susceptible sites are characterized by slow growth, frequent drought stresses, low amounts of litter, and low foliage biomass. Dry, rocky ridgetops with shallow soils or outwash plains with dry, sandy soils are prime examples. Early successional status and disturbances are also common in susceptible stands. Frequent fire, heavy cutting, slash disposal, grazing, windthrow, and ice storm damage are just a few of the disturbances that tend to create susceptible stands. Slow growth and disturbances create abundant hiding places or refuges for gypsy moth larvae, who usually seek shelter during the day while in the last three instars. Larvae seek shelter on rock outcroppings, in the litter, or in suitable locations on the tree, such as bark flaps, large dead branches, wounds or holes in the bole, dead sprout stubs, deep bark fissures, and lower sides of branches and trees with crook or sweep. Man-made refuges such as signs, fences, buildings, and trash are also used. In low gypsy moth populations, survival of late-instar larvae and pupae was high when they found refuges off the ground. This difference was attributed to predation by small mammals and other predators and parasites (Bess et al. 1947; Smith 1985). Removal of these "structural features" is one technique for reducing favorable gypsy moth habitat in a stand. Providing favorable predator and parasite habitat would also reduce the susceptibility of the stand. However, many refuges for gypsy moth also are good predator habitat. The goal should be to reduce gypsy moth refuges that are high in the trees and leave refuges that are low in the trees or on the ground where they also provide predator habitat. This situation will force the larvae out into the open, down where the predators can find them.

Stands that are more mesophytic (wet bottoms, moist slopes, and ridges with favorable moisture regimes) generally have deep soil and litter layers. The straight, fast-growing trees in these stands have few refuges. These mesophytic stands are rarely disturbed and are generally more resistant to defoliation.

The susceptibility of a stand can be increased temporarily by forest management activities (Smith 1962). Stress and disturbance from thinnings, soil compaction, increased light and moisture levels, and logging damage all require time for the stand to recover. Strips of susceptible forests often occur adjacent to housing developments, recreational facilities, roads, rights-of-way, and other areas due to intensive human activity causing disturbances that create refuges and stress the trees. Periodic environmental stresses, such as a 2- to 3-year drought or frost damage, can often make a stand more susceptible. Succession tends to make stands less susceptible, while

disturbances that set back the successional stage make them more susceptible (Bess et al. 1947).

Vulnerability

The vulnerability of a stand is defined as its likelihood of suffering mortality after a defoliation period (Smith 1962). The distinction between susceptibility and vulnerability is important; stands that are highly susceptible to gypsy moth defoliation may not suffer much mortality (low vulnerability) when they are frequently, heavily, defoliated, whereas stands that are not very susceptible (resistant stands) to defoliation may suffer high mortality on the rare occasion when they are defoliated (Bess et al. 1947).

Defoliation

Severity. Gypsy moth defoliation has traditionally been described in three classes: light (0 to 30%), moderate (30 to 60%), and heavy (60 to 100%). Light defoliation is usually not noticeable from aerial surveys and causes little to no visible damage to the tree, but may result in small losses in radial growth. The greater the amount of foliage eaten by the insect, the greater are the adverse effects. When a tree is defoliated to the point that it refoliates, the tree is significantly altered (Wargo 1978). Refoliation occurs in the range of 50 to 75% defoliation and results in the mobilization of food (starch) reserves in the roots to keep the tree alive and produce new leaves. These trees are usually more vulnerable to other stresses the following season due to these reduced or depleted food reserves. Gypsy moths defoliate trees at the most adverse time; when the leaves are just about fully expanded and the tree has maximum energy demands and lowest reserve food levels.

Frequency. Increasing the frequency of defoliation increases vulnerability. One year of heavy defoliation resulted in 7 to 35% oak mortality in New England, while 2 years resulted in 22 to 55% mortality (Campbell and Sloan 1977; Campbell 1979). Quimby (1982) in nine stands in central Pennsylvania, found the following mortality percentages for oaks and all species: 18 and 17% after one defoliation, 89 and 35% after two defoliations, and 98 and 65% after three defoliations, respectively.

Distribution. The distribution of defoliation among individual trees is probably more important for determining vulnerability than stand defoliation levels, because it relates directly to the refoliation status, stress level, and physiological condition of that tree. Stands that contain homogeneous compositions of preferred species would be expected to have uniform defoliation among trees of similar crown class and condition. For these stands, an average stand-level defoliation of 30% usually means that approximately 30% of the foliage was removed from all of the trees and their stress levels would be similar and minor. On the other hand, for stands with mixtures of

preferred and non-preferred species, an average 30% stand-level defoliation may occur when preferred trees have 75 to 80% defoliation and non-preferred trees have little or no defoliation. This situation could result in high stress and mortality of preferred species such as oaks and little effect on other species.

Tree Responses

When a tree undergoes refoliation, its entire physiological balance changes and it often becomes out of phase with the season.

Canopy. Defoliation reduces the primary leaf area by direct consumption. Secondary leaves produced by the refoliation are smaller, there are fewer of them, and they remain on the tree much later in the fall where they are exposed to frosts. The primary leaves produced the following season are also smaller and fewer in number. Along with this reduction in number of leaves is a reduction in terminal growth and the dieback of twigs and branches due to starvation because secondary leaves do not have time to replenish starch reserves, or winter injury because new buds do not have time to harden off before cold winter temperatures arrive (Wargo 1981a, b). With the death of terminal buds, lateral buds begin to grow, which results in clumped foliage. When crown dieback is heavy, epicormic sprouting occurs on the bole and larger branches (Staley 1965). Crown condition can recover, but it my take as long as 5 to 10 years to do so (Campbell and Sloan 1977).

Stem radial growth. Reductions in stem growth that are generally proportional to defoliation severity have been reported by a number of people; light to complete defoliations resulted in reduction from 4 to 8% with 25 to 70% reduction being most common. Recovery of stem growth rates generally had a lag phase that corresponds to recovery of crown condition (Nichols 1968).

Roots. Many small feeder roots die after defoliation, probably from lack of food (Staley 1965). This loss of roots results in reduced water and mineral uptake that slows the recovery of the crown. It also results in a weakening of tree health, allowing for colonization by the shoestring root rot fungus (Wargo 1978).

Tree Health

Tree vigor has been defined as the overall physiological condition, or "health" of a tree in a given environment. Tree health has traditionally been measured using general indicators, such as crown class and condition since its leaves are a tree's source of energy (Wargo 1978a). Diameter growth rate has also been used as a general indicator, but is influenced by many other factors as well. The crown changes due to stress are long-term and may not represent a tree's immediate physiological condition due to stresses that have occurred recently and weakened the tree. Root starch content and cambial electrical resistance have been used as short-term indicators of tree health or physiological condition (Wargo 1981c).

Crown Condition and Class. Crown condition before defoliation has been shown to be one of the most important variables that determines mortality (or vulnerability) (Campbell and Sloan 1977; Herrick 1982; Campbell and Valentine 1972). Poor crown trees have 50% or more of their branches dead; foliage density, size, and coloration that is definitely subnormal; or heavy epicormic sprouting. Fair crown trees have more than 25 or less than 50% dead branches; foliage density, size, or coloration that is subnormal; or some epicormic sprouting evident. Good crown trees have healthy foliage, less than 25% dead branches, and little or no epicormic sprouting (Herrick 1982). Vulnerability is highest for poor crown trees, intermediate for fair crown trees and good crown trees rarely die unless several years of heavy defoliation reduce their crown condition.

Crown class and tree size are not as strongly correlated with mortality. As a general rule intermediate and suppressed trees are more likely to die than dominant and codominant trees and either smaller diameter trees or very large, over mature trees are more likely to die than larger trees (Campbell and Sloan 1977). These rules-of-thumb do not always hold true. As severity and frequency of defoliation increase, more dominant and codominant trees die (Campbell and Valentine 1972). The addition of other stresses, such as drought, result in more sawtimber-sized trees dying (Quimby 1985). A dominant tree of poor crown condition will usually die before a tree in the intermediate class with good crown condition.

Environmental Conditions

Adverse environmental conditions, such as drought, late spring frosts, and excessively moist conditions, can all stress trees before, during, and after defoliation resulting in higher vulnerability than either stress alone (Staley 1965; Nichols 1968; Quimby 1985). Temperature and moisture conditions during the defoliation and refoliation periods affect the amount of defoliation, development of leaf diseases, the production and expansion of refoliated leaves, overall tree health, and development of secondary organisms (Wargo 1978, 1981b).

Site and Stand Factors

It is difficult to make generalities about site and stand factors because mortality can be found in almost every possible situation. However, a few observations can be made. Mortality tends to be higher on moister, mesic sites with higher stand indices (especially on benches and flats) than on drier, poorer quality sites, although exceptions can be found. Elevation, aspect, and other variables have occasionally been found to be correlated with mortality, but not with any consistency.

Mortality is usually highest among preferred food species, especially oaks, although some Class II and III species can be greatly affected. There are a number of reports of oak mortality ranging from 5 to 100%, but most commonly in the 20 to 60% range. Mortality of all species ranges from 5 to 80%, most commonly between 5 and 50%.

With such a wide variety of physiographic areas, sites, stand compositions and conditions, and defoliation frequencies and intensities, it is no wonder that gypsy moth-related mortality is hard to predict and confuses many people when they see contradictory reports in the literature. A good rule-of-thumb is that managers can expect on the average 15 to 35% mortality the first time gypsy moth defoliates a mixed-oak stand. Some stands will be less and some will be more--up to 60 to 80% or even higher in a very few stands. If drought or other stresses are present at the same time, then these figures will increase.

Secondary Organisms

Defoliation by the gypsy moth rarely kills hardwood trees directly. Most trees that die following defoliation by gypsy moth are attacked by secondary or "opportunistic" organisms such as shoestring root rot (Armillaria mellea), a fungus that attacks the roots, and twolined chestnut borer (Agrilus bilineatus), an insect that attacks the phloem and cambium layers. It is often the actions of these secondary organisms that kill the tree (Dunbar and Stephens 1975; Wargo 1977). Healthy trees are able to resist or tolerate attacks from these organisms and when these organisms are excluded, trees can tolerate several years of defoliation without dying (Cote and Allen 1980). In many cases, both organisms are active on a tree, though either one alone is sufficient to cause death. One possible reason for higher mortality levels in disturbed stands is the potential for increased populations of secondary organisms in these areas (Houston 1981; Haack 1985).

Gypsy Moth Population Monitoring

Gypsy moth populations need to be monitored in order to use these guidelines for two reasons. The first is to decide which of three decision tables or charts to use based on imminence or potential occurrence of defoliation and the second is to determine the need to apply control treatments to meet landowner and manager objectives.

Imminence of Defoliation

It is very important to determine the stand's potential for defoliation in order to know what treatments are possible and appropriate. The potential for defoliation can be determined from information on the location and spread of gypsy moth populations. This data is collected by APHIS (USDA Animal and Plant Health Inspection Service) in areas that are not presently infested, by the forest pest management staff of your state agency (either Agriculture, Natural Resources or Forestry), or by the Forest Pest Management staff, USDA Forest Service on federally owned land. These specialists can provide information on extent of the currently infested area, population levels and expected trends, direction and rate of movement, and when the infestation would be expected to affect your lands.

Once an area has been infested, then gypsy moth populations will rise and fall on a cyclic basis. The periodicity of this cycle has been in the range of 8 to 10 years (Wallner 1982) and it may be decreasing to 5 years. At any rate, very few stands with gypsy moth populations will be in the longer than 3- to 5-year potential defoliation category. Conversely, mortality of preferred food species may decrease the susceptibility of a stand sufficiently that it is no longer likely to be defoliated or its cycle is lengthened beyond 8 to 10 years.

Population Control

When defoliation is imminent, gypsy moth populations need to be monitored, control thresholds determined, and decisions made on the need to do population control treatments. Once gypsy moth populations have been established in an area, the most useful measure for determining thresholds has been egg masses/acre. Egg masses are evident in infested areas for 7 to 8 months providing the lead time managers-landowners need to make decisions and arrange treatments. The number of egg masses/acre in a stand can be used to predict the ultimate defoliation potential. A method for predicting gypsy moth defoliation percentage from the number of egg masses/acre has been developed (Gansner et al. 1985).

Many state aerial spraying programs are based on preventing tree defoliation as well as the nuisance that is caused by gypsy moth caterpillars. Most of these programs use thresholds of 250 to 500 egg masses/acre or less than 20% defoliation. Foliage protection thresholds to prevent mortality and minimize growth loss in forest stands would be much higher, up to 50 to 60% defoliation might be considered acceptable (Wargo 1978). Foliage protection thresholds for aesthetics might use 30% defoliation; for wildlife mast production, 20% defoliation, and recreational activities might use the same threshold guidelines as nuisance spray programs.

Silvicultural Guidelines for Immature Appalachian Hardwood Stands

This section provides guidelines and instructions for determining silvicultural prescriptions that may be applied to reduce losses caused by gypsy moth defoliation in mixed oak, oak-pine, Allegheny hardwood, and cove or mixed hardwood stands of the Appalachians that are threatened by the gypsy moth. Existing guidelines to be used in conjunction with these guidelines include the Upland Central Hardwoods (Roach and Gingrich 1968), the oaks in the North Central States (Sander 1977), the oak in New England (Hibbs and Bentley 1983), and the hardwood stands of the Alleghenies (Marquis et al. 1984).

Stand prescription involves deciding which silvicultural treatment should be applied in a stand to achieve the manager-landowner objectives and preparing detailed instructions for implementing the treatment.

Determining Appropriate Treatment

Guidelines for minimizing gypsy moth impacts have been prepared two ways--decision charts (Figure 1) and decision tables (Table 2). These decision-making aids have been divided into three sets based on stand defoliation potential. Forest managers should use the decision chart or table that corresponds to the condition of their forest stand as related to defoliation. Once potential for defoliation has been determined, it is also necessary to have completed a stand examination involving an inventory of both overstory and regeneration conditions. This information will allow calculation of the stand characteristics needed for the decision points in the charts and tables.

Decision Charts

To use the charts, start at the top box and then follow the arrow to the box that contains the criteria that match your stand's characteristic. From that box, follow the arrow down to the next characteristic. Again, find the box below it that matches your stand's value for the characteristic. Continue down the chart, matching criteria on the chart to stand characteristics until you arrive at a prescription in a dashed box at the bottom of the chart. This prescription is the recommended one for the conditions present in your stand. Specific instructions for that prescription are in the following section.

Decision Tables

The same prescription can be obtained by using the decision tables instead of the charts. The tables have the prescriptions across the top row and the stand characteristics down the first column. You simply match the criteria in a column of the table with your stand characteristics. Starting at the first row and working down will provide a process similar to the decision charts. Any row element with dashes in it does not apply to that column. When a stands' characteristics match all the criteria in a column, the recommended prescription is the one at the top of the column.

Stand Prescriptions

Many of the prescriptions presented here had a conceptual beginning in a paper on forest management considerations of dieback and decline diseases by Houston (1981) as well as some of the older literature on

Table 2.--Decision tables for intermediate stand treatment prescriptions based on the imminence of defoliation, stand, and insect conditions. When all of the conditions in a column are met, then the proper prescription is the one at the top of the column (in caps).

A. Defoliation not imminent for 3 to 5 years or longer.

Stand Characteristics	REGENERATE STAND	REGENERATE STAND	DEFER CUTTING 6 TO 15 YEARS OR REEXAMINE	DEFER CUTTING 10 - 15 YEARS OR REEXAMINE	SANITATION THINNING	PRESALVAGE THINNING
Density of Acceptable Growing Stock	less than C-level (35%)	C-level (35%) or more	C-level (35%) or more	C-level (35%) or more	C-level (35%) or more	C-level (35%) or more
Stand Maturity	--	0 to 5 years	6 to 15 years	16 years or more	16 years or more	16 years or more
Relative Stand Density	--	--	--	less than 80%	80% or more	80% or more
Percent BA in Preferred Food Species	--	--	--	--	less than 50%	50% or more

B. Defoliation imminent within 3 to 5 years or now occurring.

Stand Characteristics	REGENERATE STAND	REEXAMINE STAND	SPRAY PRIORITY THREE	SPRAY PRIORITY 4 OR REEXAMINE	SPRAY PRIORITY TWO
Stand Maturity	0 to 10 years	11 years or more	11 years or more	11 years or more	11 years or more
Stand Condition	--	no stress in last 5 years	no stress in last 5 years	stress is present in last 5 years	stress is present in last 5 years
Stand Value	--	low	high	low	high

C. Defoliation has occurred, wait 1 to 3 years for mortality to occur.

Stand Characteristics	REGENERATE STAND	REGENERATE STAND	DEFER CUTTING	SALVAGE CUTTING	SALVAGE THINNING
Density of Acceptable Growing Stock	less than C-level (35%)	C-level (35%) or more	C-level (35%) or more	C-level (35%) or more	C-level (35%) or more
Stand Maturity	--	0 to 10 years	11 years or more	11 years or more	11 years or more
Relative Stand Density	--	--	less than 60%	less than 60%	60% or more
Percent Mortality (in stand density)	--	--	less than 30%	30% or more	--

A. Defoliation not imminent for 3 to 5 years or longer.

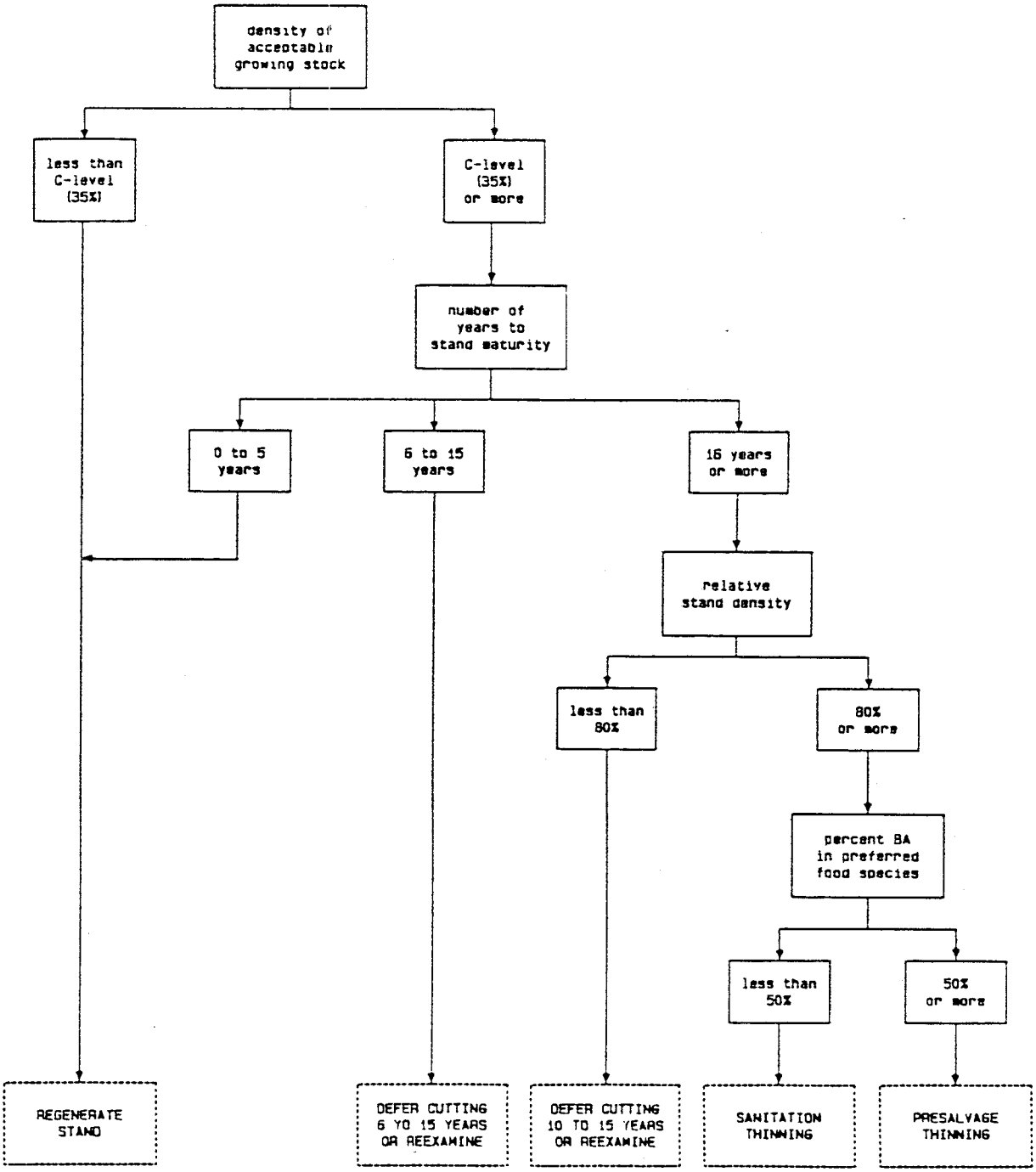


Figure 1.--Decision charts for intermediate stand treatment prescriptions based on the imminence of defoliation, stand, and insect conditions.

B. Defoliation imminent within 3 to 5 years or now occurring.

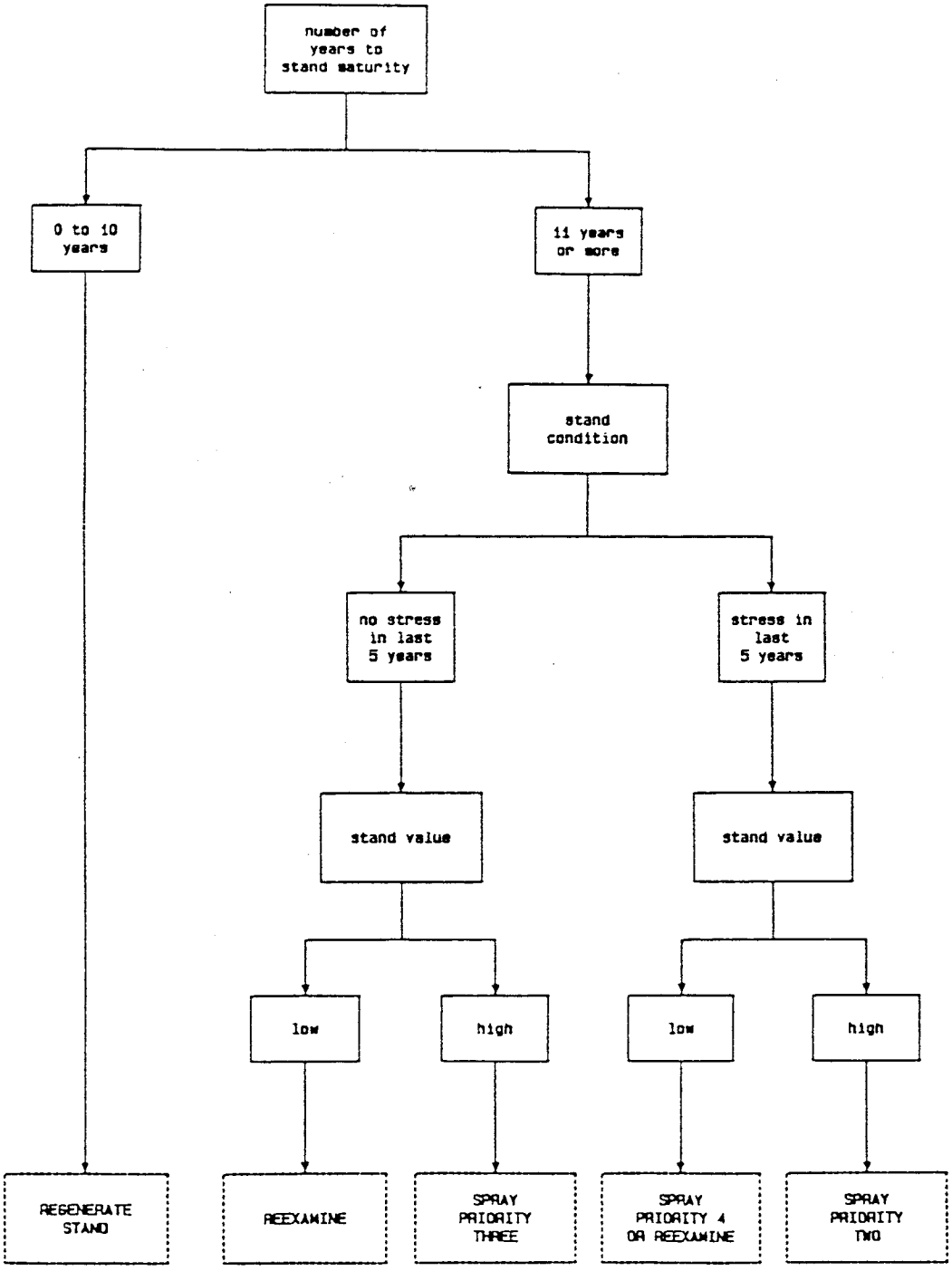


Figure 1 con't.

C. Defoliation has occurred, wait 1 to 3 years for mortality to occur.

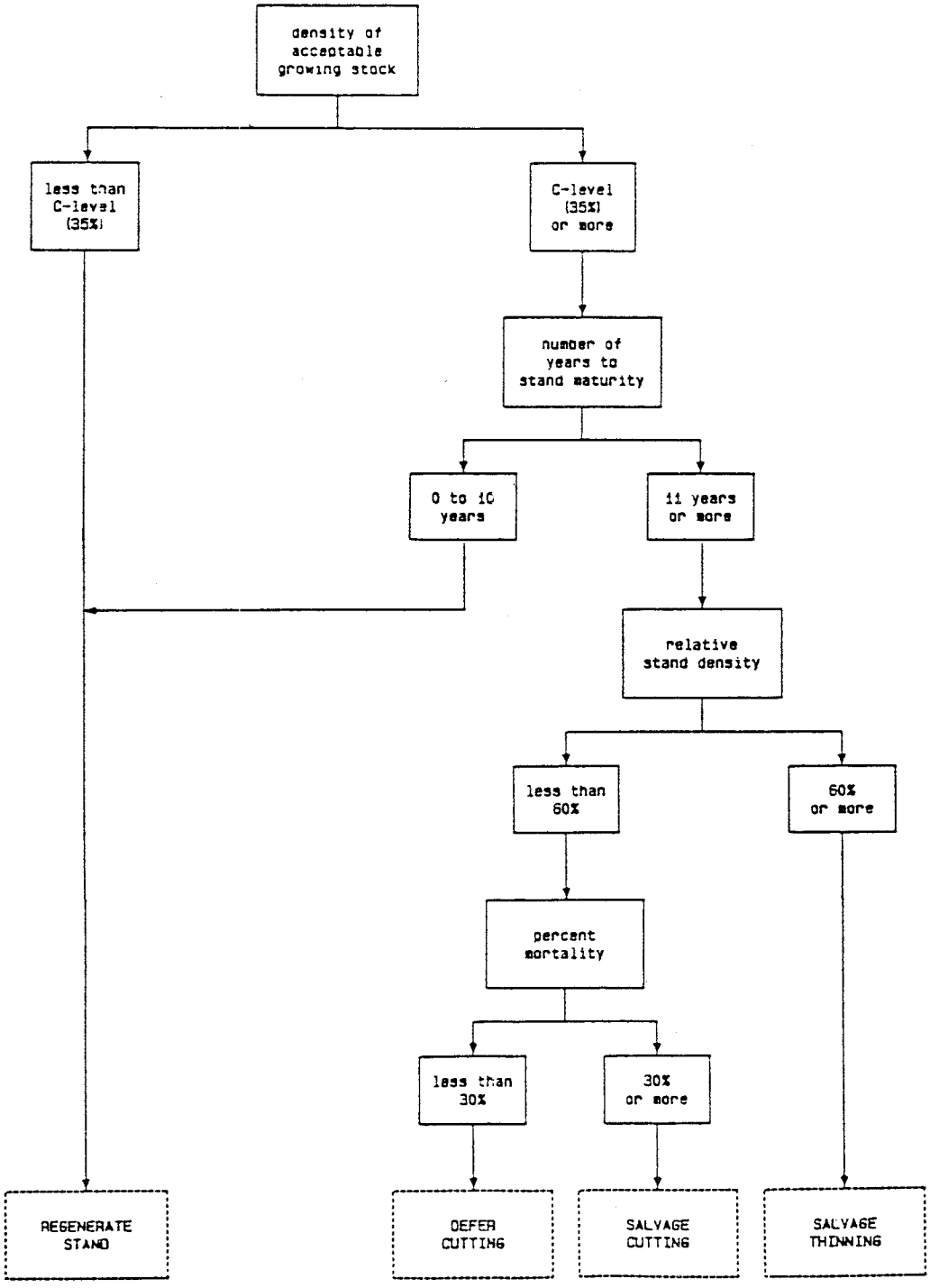


Figure 1 con't.

silvicultural treatments to control the gypsy moth, were presented at a conference in 1982 (Gottschalk 1982), and have since been expanded and refined.[1]

Defoliation Not Imminent for 3 to 5 Years or Longer

In stands where defoliation is not expected for 3 to 5 years or longer, the primary objectives of these guidelines are to reduce stand susceptibility and vulnerability and to regenerate understocked stands and stands near maturity before they are defoliated. Stand susceptibility is reduced by: reducing preferred food species, refuges, promoting predator and parasite habitat, and increasing forest diversity. Stand vulnerability may be reduced by: removing high hazard trees, increasing stand and tree vigor, and reducing secondary organisms.

Presalvage Thinning

Presalvage thinning is designed to reduce damage by removing highly vulnerable (high hazard) trees before they are defoliated and die; its major objective is to reduce stand vulnerability (Smith 1962). Secondary objectives of the treatment are: to increase stand and tree vigor (and crown condition), to remove refuges for gypsy moth larvae and pupae, and to promote predator and parasite habitat.

Stands to be considered for presalvage thinning are those with greater than C-level density of acceptable growing stock, are more than 15 years from maturity and have more than 80% relative density. Under normal management, they would receive a commercial thinning from below. The thinning would reduce relative stand density to 60%, but not remove more than 35% in any one cut. It should also remove unacceptable growing stock, improve spacing, and concentrate cutting in smaller trees to mold stand structure into a more pronounced bell-shaped diameter distribution. The result is an increase in stand diameter, a reduction in rotation length, and an improvement in stand quality and value. However, under management taking potential gypsy moth defoliation into account, the normal prescription must be altered slightly. Stands with more than 50% of their basal area in gypsy moth-preferred food species cannot have this percentage reduced enough to significantly change the stand's susceptibility, so the thinning concentrates on reducing vulnerability instead.

The necessity of having 3 to 5 years before defoliation for implementing this prescription is caused by the time the stand needs to recover from the stress and disturbance caused by the thinning.

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[1]Gottschalk, Kurt W. Silvicultural guidelines for forest stands threatened by gypsy moth. USDA For. Serv. Gen. Tech. Rep. In Press.

Recovery periods can be anywhere from 1 to 5 years (Graney 1983). If gypsy moth infestation should occur before this recovery is completed, the stand is then at a higher risk and will need to be protected (see spray priority two prescription). Thinning may allow stands to be more vulnerable to attack by certain damaging agents through stress and disturbance, while the trees gradually build up the resistance through increased growth and vigor, to reduce the harmful effects of these agents (Smith 1962). Another potential disadvantage of presalvage thinning is that it may provide favorable stand conditions for increasing populations of shoestring root rot and twolined chestnut borer which ensures that infectious sources of these secondary invaders will be plentiful (Houston 1981).

Priorities for marking trees to be removed are (highest to lowest): poor crown condition oaks, poor crown condition other species, trees with abundant refuges, and fair crown condition trees. These priorities should integrate well with the normal marking priorities such as maintaining the desired residual stand density, removing undesirable species, and achieving the desired stand structure. Additional measures could be taken to enhance predator and parasite habitat, such as leaving snags, leaving cavity or den trees, and creating brush piles for small mammals.

Sanitation Thinning

Sanitation thinning is designed to prevent the spread and establishment of damaging organisms to the stand (Smith 1962); its major objective is to reduce stand susceptibility. Sanitation thinning is accomplished by eliminating trees that are current or prospective sources of infestation. In the case of gypsy moth, this process involves removing preferred food species, removing refuges, and promoting predator and parasite habitat. Secondary objectives are to increase stand and tree vigor, and to remove high hazard trees. The same precautions on timing and secondary organisms given in the presalvage thinning description are appropriate here, although to a lesser degree due to the lower stand susceptibility.

Stands that may be considered for sanitation thinning are very similar to those prescribed for presalvage thinning. The major difference is that these stands have less than 50% of their basal area in preferred food species, so it is possible to reduce this percentage enough to change the stand susceptibility. There is some evidence to support the theory that a minimum of 15 to 20% basal area of preferred food species is required in order for a sufficiently large gypsy moth population to develop to the stage that they can survive on non-preferred hosts. Reduction of the percentage of preferred food

species to 15 to 20% or less, should make the stand less suceptible to defoliation[2]. The landowner or manager should realize that this treatment may reduce the stand value considerably, since the white and red oaks that would be removed are often the most valuable species in the stand. Of course, some oaks and other preferred species can be retained, but there is still a risk that they will be heavily defoliated even though the stand as a whole is only lightly defoliated.

Priorities for marking trees to be removed are (highest to lowest); preferred food species, then trees with abundant structural features or refuges, poor crown condition trees, and fair crown condition trees. In addition, snags and cavity or den trees should be left and brush piles created for small mammals.

Defer cutting 10 to 15 years or re-examine. Gypsy moth management would re-examine these stands for potential control actions if defoliation became apparent, for salvage if defoliation occurred, or for thinning once stand density increased without defoliation. These stands also have greater than C-level density of acceptable growing stock and are more than 15 years from maturity. However, they have less than 80% relative stand density, so they do not need to be thinned at this time. Normal management would defer cutting for 10 to 15 years or until the stand density was more than 80%.

Defer Cutting 6 to 15 years or re-examine. As in the preceding prescription, the only gypsy moth modification would be to re-examine these stands for potential control actions or regeneration cuttings if defoliation became imminent. These stands are adequately stocked with acceptable growing stock but are within 6 to 15 years of being mature. It is not desirable to thin them now and then harvest them a few years later, so the proper prescription is to defer cutting until the stands are mature and then harvest them.

Regenerate stand. Stands that qualify for regeneration have either an unacceptable (less than C-level) density of acceptable growing stock or are within 5 years of maturity. The proper prescription is to regenerate these stands to bring them back into production in the former case or to regenerate them before defoliation and retain stump sprouting potential in the latter case.

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[2]Gansner, David A.; Herrick, Owen W. Rating forest stands for gypsy moth defoliation. USDA For. Serv. Res. Note, In Press.

Defoliation Imminent Within 3 to 5 Years or Now Occurring

In stands where defoliation is imminent or now occurring, the primary objective is to protect stands that are at high risk and have high value and to regenerate stands that are close to maturity before they are defoliated. Stand value and condition are used to select stands for aerial spraying, since it will not be economically feasible to treat all stands.

These spraying prescriptions only need to be carried out if the egg mass population exceeds the threshold level for the management objectives of the stands. If this level is never exceeded, then the stands should not be defoliated heavily enough to cause any problems. The only possible exception would be if a low egg mass population was supplemented by a large number of larvae blowing in from adjacent stands. If surrounding stands have large egg mass levels, then it would be important to schedule spraying of these stands. An excellent example would be a lower slope stand with only 500 egg masses/acre but with a ridgetop stand above it that has 10,000 egg masses/acre. Additional information on aerial spraying options and costs is provided in a later section.

Spray priority two. Under certain circumstances of high value and high vulnerability, the proper prescription is to aerial spray these stands with an insecticide to protect their foliage. Stands that qualify are more than 10 years from maturity, have had some type of stress or disturbance in the last 5 years, and have a high stand value for meeting the landowner's or manager's objectives. These stands are too far from maturity to liquidate them by harvesting, but the stress or disturbance has temporarily made them more vulnerable. The high stand value means that there is a high risk in allowing these stands to be defoliated. When selecting stands to spray, these stands rank second in importance only behind stands that have been shelterwood cut within 5 years of defoliation.

Spray priority three. Stands that meet the criteria for this prescription should be sprayed with third level priority after all priority 1 and 2 stands have been treated and provided egg mass threshold levels have been reached. Should the landowner run out of funds for treatment before spraying these areas, the stands should be re-examined after defoliation for salvage potential. Stands in priority 3 are more than 10 years from maturity, have not had any stress or disturbance in the last 5 years, and have high stand value for meeting the landowner-manager objectives. While being too far from maturity to liquidate, these stands have not been made more vulnerable by stress or disturbance. Along with their high value, these stands have considerable risk but less than that of spray priority two stands.

Spray priority four or re-examine. Stands meeting these criteria would be sprayed only after all the priority 1, 2, and 3 stands were sprayed, there were still sufficient funds available, and the egg mass

threshold levels were reached. If the stands could not be sprayed, then they should be re-examined after defoliation for potential salvage of dead trees. These stands are similar to the stands in the preceding prescription in their maturity and stand condition. In these cases, however, the stand values for meeting management objectives are low. Because of these low values, the aerial spray priority of these stands is fourth in line.

Re-examine stand. For the following reasons, the proper prescription for these stands is to re-examine the stands after defoliation to determine salvage potential. These stands are similar in maturity and condition to the ones in the preceding prescription, but their stand values for meeting management objectives are low, so this stand is at very low risk and probably should not be treated. If the landowner has unlimited funds, these stands could also be sprayed, if desired.

Regenerate stand. Since these stands are within 10 years of maturity and defoliation is imminent, they should be harvested before defoliation or as soon as possible if defoliation is already underway. The landowner is facing a tradeoff between liquidating the stands a few years early, allowing retention of the stump sprouting potential needed to regenerate oaks on the site versus allowing defoliation and subsequent mortality to occur resulting in loss of value and stump sprouting.

Defoliation Has Occurred, Wait 1 to 3 Years for Mortality to Occur

In stands where defoliation has occurred, the primary objectives are to salvage mortality and to regenerate stands that are understocked due to excessive mortality and stands that are near maturity. It is necessary to wait for the bulk of the mortality to occur before deciding on the appropriate treatment for the stand. Mortality is spread out over several years, but the majority of it will occur in 1 year. That year is generally within 2 to 3 years of defoliation. Since there can be anywhere from 1 to 3 years of defoliation, most mortality should be present within 1 to 3 years after defoliation stops. It will take careful monitoring to determine the year. Because of the loss of timber quality and value (Donley and Feicht 1985), it is important for salvage to be as prompt as possible after the majority of the mortality has occurred. Some mortality will probably occur later than 3 years, but it should be minor and not seriously affect the prescription.

Salvage thinning. Salvage thinning will salvage economic value from all of the dead trees and thin the remaining live trees in order to reduce susceptibility and vulnerability. Stands that qualify for salvage thinning have greater than C-level density of acceptable growing stock, are more than 10 years from maturity, and have greater than 60% stand density in live trees. They are sufficiently

well-stocked to be managed to maturity. These thinnings will improve stand vigor, growth, quality, and may make the salvage cut economically feasible by supplementing the volume of dead trees with green trees. They should remove no more than 35% stocking of live trees in any one cut, while reducing relative stand density to 60%. If following the salvage thinning, defoliation is then imminent within 3 to 5 years, the stands will have been stressed by the cutting and may need to be sprayed. On the other hand, the occurrence of mortality has probably resulted in less susceptible and less vulnerable stands than were present before the previous defoliation.

Priorities for marking trees to be removed are (highest to lowest): dead trees, poor crown condition oaks that are likely to die, poor crown condition other species that are likely to die, trees with structural features or refuges, and fair crown condition trees. These priorities are to be integrated into the normal ones of maintaining the desired residual stand density, removing unacceptable growing stock trees before better quality trees, and achieving the desired stand structure. It may also be desirable to leave several of the more highly deteriorated, low value dead trees as snags, in addition to cavity or den trees and creation of brush piles for small animals.

Salvage cutting. The objective in stands that qualify for this treatment is to economically salvage dead and dying trees. These stands are similar in acceptable growing stock density and stand maturity to the stands in the preceding prescription, but have less than 60% stand density in live trees. This situation means that no thinning of live trees is necessary since their density is already below the optimum residual density. They also have greater than 30% mortality which means that there is sufficient volume and value of dead trees to have a salvage cut. Marking priorities are simple--only dead trees should be cut and removed because all of the live trees (with the possible exception of very poor crown condition trees that are not going to recover) are needed to carry the stand to maturity (or to the next thinning). If desired, several dead trees could be left as snags. Due to the mortality that has occurred, the residual stand is probably less susceptible and less vulnerable than before the previous defoliation.

Defer cutting. Stands that qualify for this treatment probably do not have sufficient volume and value of dead trees to have an economically feasible salvage cut since live trees cannot be cut, so the proper prescription is to defer cutting until the stands can be thinned or re-examined if defoliation is imminent. These stands are similar to the stands in the preceding prescription in all of their characteristics except that percent mortality is less than 30%. If they have good access, it may be possible to personally salvage the dead trees for firewood or even to have a firewood salvage sale in them. This situation would be an alternative to just letting the

trees decay. The residual stands are probably less susceptible and less vulnerable than before the previous defoliation due to the mortality that has occurred.

Regenerate stand. Since these stands have either an unacceptable density of acceptable growing stock or are within 10 years of maturity, the proper prescription is to regenerate them to bring them back into production and salvage mortality in the former case or to salvage mortality and minimize their value loss rather than waiting for stand maturity in the latter case.

Utilization of Dead Trees.

In order for dead trees to be salvaged economically, it is necessary to know how efficiently they can be utilized for various end products. Once a tree dies, it is attacked by a variety of insects, fungi, and bacteria that gradually decay the tree and make it less utilizable with increasing time after death[3] (Donley and Feicht 1985). The faster a tree can be utilized after it dies, the more volume and value it will produce. Under the provisions of the Gypsy Moth Quarantine administered by APHIS, an inspection and permit is required to move logs, trees, or firewood from the infested area to uninfested areas. This quarantine is intended to slow down and prevent the spread of gypsy moth.

Sawtimber and Veneer

These products are generally the highest value ones produced by the stand, so salvage operations should try to minimize their losses. Red and white oak trees that were dead 1 year or less, 2 to 4 years, or 5 years or more were examined for their lumber utilization potential (Garges et al. 1984; Labosky et al. 1984). Lumber recovery from these trees decreased 4 to 8% for trees dead 1 year and 20% for trees dead 2 years or more. Most of this loss was from sapwood decay and drying checks. In addition to less volume recovery, there was a substantial shift in lumber grades recovered; 1 Common and better grades decreased and 2 and 3 Common grades increased with increasing time after death due to decay, checks, and insect borer holes, producing substantial value loss. Lumber from trees dead 5 years or more also suffered grade reduction due to checking during kiln drying. These losses could be minimized by using a mild kiln schedule (Labosky et al. 1984). Decreases in stumpage value with time after death reflects these volume and value losses (Laubach 1982; Donley and Feicht 1985).

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[3]Merrill, W.; Karasevicz D. Biodeterioration of oaks killed by gypsy moth defoliation. 1984 and 1985. Progress Reports for USDA For. Serv. Coop. Agreements 23-811 and 23-908.

Veneer users will generally not buy a tree once it is dead due to staining, drying, and checking, so death of a veneer tree will result in its being downgraded to sawtimber status (Laubach 1982). The best salvage period for sawtimber is within the first year after death which results in neglible losses. Trees can still be salvaged successfully up to 4 to 5 years after death, but with increasing volume and value loss and decreasing stumpage value.

Pulpwood and firewood

Dead trees that do not qualify for sawtimber can be salvaged for pulpwood or firewood. Pulping characteristics have been examined for trees dead 1 year or less, 2 to 4 years, or 5 years or more in two studies (Labosky and Baldwin 1984; DeCrease et al. 1985). Pulp yields were constant and similar to green trees for trees dead up to 5 years. Pulp quality decreased slightly after 3 to 4 years and fiber strength declined slightly after 5 years. There was a decrease in debarking losses and fines and an increase in chip solids up to 3 to 4 years. In many respects, trees that were dead 1 to 4 years were actually as good or better than green trees. This situation makes sense when you consider that in the 1950's, pulp and paper companies were actually killing trees with sodium arsenate and letting them stand dead for a year or two so that the bark would fall off before harvesting them. Firewood value is also enhanced some by the debarking and drying process that occurs in dead trees. However, this is offset somewhat by the increased danger in felling dead trees. For pulpwood and firewood use, salvage does not have to be as prompt as for sawtimber; any time from death to 5 years after is suitable.

Aerial Spraying Options and Costs

The information provided in this section is by no means exhaustive. Further information and, in some instances, assistance on aerial spraying can be obtained by contacting your state forest pest management specialist, county extension agent, or, in the case of federal lands, Forest Pest Management staff, USDA Forest Service.

In preparing an aerial spraying operation, adequate advance planning is necessary. A map showing the areas to be treated and their priorities should be prepared as soon as possible. One thing to remember--as the size of the treatment area increases (within limits), the cost/acre decreases, so the same total dollar figure could perhaps spray 500 acres or 700 acres due to this economy of scale. It might be more cost effective and easier to include some lower priority stands in a spray block if that would make a large contiguous treatment area, rather than spraying four small, dispersed high priority stands. Neighboring landowners could also join forces and have their land sprayed as one block resulting in substantial cost savings over several individual spraying operations. Total costs of insecticide and application range from $4 to $11/acre for large areas. All cost information in this section is based on 1984 costs of six states spraying large areas for gypsy moth. Other activities and concerns of a spray operation include minimizing drift to nontarget

areas and having well-marked boundaries on the spray block for the pilot.

Aircraft

There are two major types of aircraft used in spray operations: fixed-wing and helicopters. Airplanes are generally less expensive to operate, fly at faster treatment speeds, and carry greater payloads than helicopters. These factors usually result in a lower total cost. Airplanes also work best over relatively gentle terrain. Application costs for fixed-wing aircraft are in the range of $2 to $3/acre.

Helicopters generally have higher operating costs, fly at slower treatment speeds, and carry smaller payloads than fixed-wing aircraft. These factors usually result in a higher total cost. Helicopters may be able to treat very small and scattered blocks more efficiently than fixed-wing aircraft; especially where airports are not close by. Application costs for helicopters are in the range of $4 to $7/acre. For many small landowners, helicopters are probably the better choice, although costs for small areas may exceed these rates considerably.

Insecticide

There are several insecticides registered by the Environmental Protection Agency (EPA) for use in aerial spraying treatments on gypsy moth populations. Two products that are still in the development and testing phase are not available for general use: nucleopolyhedrosis virus (NPV, Gypcheck), a natural virus that kills gypsy moth; and disparlure, a sex pheromone that disrupts normal mating. Three chemical insecticides are available, all of which kill on contact or through ingestion. They are acephate (Orthene), carbaryl (Sevin), and trichlorfon (Dylox). A fourth chemical insecticide, diflubenzuron (Dimilin), is an insect growth regulator that prevents molting. It needs to be ingested and takes 2 to 7 days to act. One microbial (biological) product, a bacteria Bacillus thuringiensis or Bt for short (Dipel, Thuricide, or Bactospeine), also needs to be ingested; the bacteria cause gut paralysis and cessation of feeding. Death occurs by starvation usually within 7 days. The first four available products all give 90 to 98% population reduction when used properly. Depending upon initial population levels and health, Bt gives 70 to 90% population reduction. All of the materials should be applied when larvae are in early second to third instar and leaves are about one-third expanded. Insecticide costs vary from a low of $2 to $2.50/acre for Dimilin; and $3 to $5/acre for Orthene, Dylox, and Sevin; to $3.50 to $5/acre for Bt. In 1984, six states sprayed approximately equal areas of Dimilin (249,000 acres), and Bt (222,000) with significantly less acreage of Sevin (37,000 acres) and minor use of Dylox (4,100 acres). Additional information on advantages, disadvantages, toxicities, and environmental and health effects of these products are discussed by Nichols (1982) and U.S. Department of Agriculture (1985).

Conclusions

While these guidelines have not been tested, they do represent the current state-of-knowledge of the impacts of gypsy moth defoliation on forest stands. There do seem to be many opportunities for managers to manage gypsy moth in an economical manner without sacrificing management objectives or allowing the insect to dominate management actions as has happened in many areas of Pennsylvania, New York, and other infested areas. Eventually the forest, forest managers, and this exotic insect pest may slowly come to a level of natural coexistence.

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FERTILIZING APPALACHIAN HARDWOODS

L. R. Auchmoody

Principal Forest Soil Scientist
USDA Forest Service
Northeastern Forest Experiment Station
Warren, PA 16365

Abstract

The use of fertilizers to improve hardwood growth rates has been of interest for more than 50 years. Responses to nitrogen suggest that many, if not most, forest sites in the central Appalachians are nitrogen deficient to some degree. Nitrogen responses may last for 5 years or more. Phosphorus deficiencies may also become important in some areas after nitrogen requirements have been satisfied. Neither research studies nor general experience are adequate to recommend fertilizer use in the region, except for young black cherry in northwestern Pennsylvania.

Introduction

In the broad field of intensive culture, probably few other techniques have stimulated more interest than using fertilizers to increase forest growth rates. In the United States, the first fertilization research began more than 50 years ago, but it was really not until the mid-1950's that experiments and interest in improving forest productivity by fertilization began to increase (Doolittle 1959). Since then, operational forest fertilization programs have been developed for southern pines in the Southeast, and for Douglas-fir in the Pacific Northwest (Bengtson 1979; Ballard 1979; Gessel et al. 1979). Presently large acreages are fertilized in each of these regions annually. With Appalachian hardwoods in the Northeast, the limited amount of research completed suggests that widespread responses are possible for many species. However, forest fertilization programs are not active. The exception is in northwestern Pennsylvania, where fertilizers are used operationally to stimulate the growth of young seedling stands that are in jeopardy from intense deer browsing (Auchmoody 1983).

The objectives of this paper are to provide a current summary of the forest fertilization research that applies to Appalachian hardwoods, and to address some of the practical and commonly asked questions about using fertilizers to increase growth rates.

Completed Research

The use of inorganic fertilizers to increase productivity of Appalachian hardwoods has long been of interest. Perhaps the first attempt to improve growth rates began in the 1930's with the application of nitrogen to pin oak shade trees in south-central New York (Wyman 1936). Other early fertilization experiments, also begun in the 1930's, included such species as red oak, yellow-poplar, and white ash, and were conducted over a wide range of conditions, from seedlings planted on strip mines to large shade trees situated along roadsides (Chapman 1933; Pridham 1937; Cummings 1941; Pridham 1941). Generally these experiments showed that hardwoods would respond to nitrogen when growing on a variety of soils and under a variety of environmental conditions.

The first bona fide forest fertilization experiments with hardwoods were started between 1935 and 1937 in typical young stands of central and southeastern New York (Mitchell and Chandler 1939). These experiments showed that diameter growth of several hardwood species could be increased by the application of nitrogen fertilizer; that nitrogen requirements and the degree of response obtainable from applied fertilizers varied substantially among different species; and that the level of nitrogen contained in the foliage was closely related to growth rates and to the supply of nitrogen in the soil. This study also estimated that nitrogen deficiencies were serious on 20% of the sites in the Northeast, that 65% of the sites had moderate nitrogen deficiencies, and that only 15% of the sites were not nitrogen deficient.

Following the Mitchell and Chandler experiments in 1938, Finn and Tryon (1942) began additional fertilization trials in mixed oak and red maple stands, also located in southeastern New York. Their results further confirmed that nitrogen availability was a major factor limiting forest production, and that improved growth rates were indeed obtainable by increasing soil nitrogen supplies through fertilization.

Although little fertilization research was conducted during World War II, in the late 1940's and throughout the 1950's there was greatly renewed interest in mineral nutrition of trees and forest fertilization. As a result, reports documenting hardwood responses to fertilization began to appear with increasing frequency, prompting a national symposium on mineral nutrition of trees in 1959 (Ralston et al. 1959) as well as several major reviews (White and Leaf 1957; Mustanoja and Leaf 1965).

Further interest in hardwood fertilization during the late 1960's and 1970's can be attributed largely to two major symposia which provided up-to-date references on the topic (Bengtson et al. 1967; Leaf and Leonard 1973). Interest also was stimulated by significant studies completed in the Tennessee Valley and in central Pennsylvania that reported major responses of oak to nitrogen and phosphorus (Farmer et al. 1970a), and to nitrogen and lime (Ward and Bowersox 1970). By the

early 1970's, a survey in the Northeast showed that there were at least 95 hardwood fertilization studies in progress that included many important species (Auchmoody and Filip 1973). Unfortunately, many of these experiments were never completed or published.

Published results covering the last 15 years suggest that nitrogen deficiencies for certain hardwoods are likely widespread throughout the Appalachian region; that phosphorus deficiencies may also become important once nitrogen requirements have been satisfied; and that growth rates of several important timber species can be increased by fertilization. For example, yellow-poplar, red oak, and black cherry sawtimber growing on medium to good sites in West Virginia have responded with increased diameter growth rates to nitrogen fertilization (Auchmoody and Smith 1977; Lamson 1978; Lamson 1980). Yellow-poplar seedlings within the region also have responded to fertilization with increased height growth (Farmer et al. 1970b; Auchmoody and Wendel 1973; Buckner and Maki 1977). On the glaciated Allegheny Plateau of south-central New York, young sawtimber-size black cherry and white ash were the most responsive species to nitrogen fertilization (Stanturf and Stone 1985), though growth rates were stimulated less than previous studies might suggest (Mitchell and Chandler 1939).

Black cherry in northwestern Pennsylvania has consistently shown large responses in both height and diameter growth to nitrogen and phosphorus, the result of widespread deficiencies on the unglaciated Allegheny Plateau, (Auchmoody 1982; Auchmoody 1985a). These studies further suggest that nitrogen responses are temporary and generally last only about 4 years, indicating that a single application of nitrogen to these ecosystems will not permanently affect their capacity to supply future nitrogen (Auchmoody 1985b).

Oak stands, both within and surrounding the Appalachians, have also responded to fertilization, though these responses generally have been less than those obtainable with yellow-poplar or black cherry (Karnig 1972; Graney and Pope 1978a, b; Boyette and Brenneman 1981; Graney 1983).

State of the Art

Despite more than 50 years since the first attempts to use fertilizers for increasing growth rates, and the completion of several important studies within the Appalachian Region, many questions remain unanswered. The fact is that neither studies nor general experience are yet adequate to recommend fertilizer use anywhere in the region, except for young black cherry stands in northwestern Pennsylvania.

To the best of my knowledge, except for the black cherry experiments, virtually all other reported studies in the Appalachian Region have been screening-type experiments. These experiments generally are well designed but utilize small plots and a limited number of test trees to determine those nutrients that produce a response and the degree that growth can be increased. Responses are expressed in individual-tree

diameter or basal-area growth, and usually are based on a limited number of dominants and codominants. No published studies have determined the volume increases per acre that might be obtained by fertilization, the kinds of studies that are essential for economic evaluations. And few tests have evaluated nutrients other than nitrogen and phosphorus, optimum application rates remain mostly unexplored, and diagnostic guides for determining responsive sites are mostly undeveloped. It is with these limitations that I have attempted to answer the following practical questions dealing with fertilization of Appalachian hardwoods.

Q: Which nutrients may be limiting Appalachian hardwood productivity?

Nitrogen and phosphorus are the only two nutrients that have resulted in significant growth responses to date, though lime in combination with nitrogen was found beneficial in one study with oaks. Experiments clearly indicate that nitrogen is the primary growth-limiting nutrient in the Appalachian Region, and when soil phosphorus also is in short supply it becomes growth-limiting only after nitrogen requirements have been satisfied. On deficient sites, this means that a response often will be obtained to nitrogen applied by itself; that a larger response will result when both nitrogen and phosphorus are supplied; and that little or no response should be forthcoming if phosphorus is supplied without nitrogen.

There are no reports of growth responses to potassium, even where it has been applied in combination with nitrogen and phosphorus. Furthermore, because most soils supporting Appalachian hardwoods have formed from sedimentary rocks that usually are well supplied with basic cations, responses to potassium, calcium, magnesium, and the micronutrients by deep rooted forest trees generally would not be expected.

Q: What portion of the Appalachian area might be nutrient deficient?

Nitrogen is likely in short supply for certain species on nearly all forest sites throughout the Region. However, the importance of phosphorus within the area is less clear. We do know that there are strong phosphorus deficiencies throughout the Allegheny National Forest in northwestern Pennsylvania, and that these may extend south and east, where soils are similar and have formed from the same geologic parent materials. I would not expect strong phosphorus deficiencies on glacial soils in northern Pennsylvania and southern New York, or elsewhere on good forest soils that have a pH of 5 or more. Strong responses to phosphorus have not occurred in the Appalachians of West Virginia, but have been reported in the Tennessee Valley.

Q: Where might the best responses to fertilization occur?

The best responses to fertilization can be expected on sites where growth-limiting factors other than nutrient availability are absent. These generally are good sites where soil moisture remains plentiful

during the growing season, where there are responsive species, and where stands are relatively young. Minimum responses are likely on hot and dry southern exposures that support unresponsive or mildly responsive species such as blackgum, chestnut oak, and the hickories, on sites characterized by shallow or very stony soils, on sites that are excessively wet, and where there is an adverse climate and short growing season. Also, old stands are likely less responsive than young stands.

Regionally, the largest fertilizer responses have been obtained with young black cherry on the unglaciated Allegheny Plateau of northwestern Pennsylvania. This is an area characterized by soils that are strongly nitrogen and phosphorus deficient, but otherwise have excellent physical properties, adequate soil moisture throughout the summer, and support a species that is nutrient demanding and capable of very rapid growth when its nutrient requirements are satisfied.

Q: About how much can growth be increased by fertilization?

Responses to applied fertilizers are affected by many factors, so they likely will be quite variable. For example, responses are influenced by species composition, stand stocking and structure, stand age, crown class, site quality, genetics, pretreatment growth rates, and degree of nutrient deficiency. Generally, uncrowded or thinned stands will be most responsive because there is room for crown development and expansion. However, thinned stands that are already growing rapidly may not be capable of growing much faster when fertilized.

Some of the most spectacular responses within the Appalachian Region have been with black cherry on the Allegheny Plateau, as previously mentioned. In young seedling stands located on the Allegheny National Forest, it has been possible to nearly triple height and diameter growth for a few years after fertilization. For example, annual height growth of 4 to 6 feet is common and up to 8 feet has been measured on a few trees in the same season that fertilizers were applied. Diameter increases have been of similar magnitude. Let me hasten to add, however, that responses of this size do not continue for more than a year or two after fertilization. In older sawtimber stands, it has been possible to increase basal area growth of dominant and codominant black cherry only by about 20%.

Elsewhere in the Region, yellow-poplar basal area growth has been increased by roughly 50% on good sites in the central Appalachians and by nearly 150% on poor to medium sites in the Tennessee Valley. Basal-area growth of oaks after fertilization has ranged from about 30% on good sites in the central Appalachians to 75% elsewhere on less productive sites. We have no estimates of stand volume responses from fertilization anywhere in the Region.

Q: How long does a single application of fertilizer usually increase growth?

Diameter responses of Appalachian hardwoods to nitrogen or nitrogen plus phosphorus usually are characterized by a large surge in growth during the first season or two, followed by a progressive decline thereafter. Growth rates of fertilized trees growing under crowded conditions actually may decline to levels less than for those of unfertilized trees when nitrogen availability returns to pretreatment levels because of increased competition brought on by the fertilizers. In other situations, fertilizers may promote dominance differentiation and cause a shift in stand structure, resulting in indirect basal area fertilizer responses by the dominant and codominant trees for as long as they remain larger than their unfertilized comparison trees.

Though few studies have measured the complete response period from a single fertilizer application, improved diameter growth rates can easily last for 5 years or more. In young black cherry stands on the Allegheny Plateau, height and diameter responses usually are complete in less than 5 years.

Q: Why aren't responses maintained for a longer time?

Most fertilizer responses ultimately depend upon increased nitrogen availability over and above those levels that can be supplied naturally. In most Appalachian hardwood stands, there is little evidence to suggest that a one-shot application of nitrogen will permanently improve a site's future capacity to supply nitrogen. Indeed, the common misunderstanding that a continuing long-term response can be stimulated from a single application of nitrogen should be laid to rest. After several years, the supply of applied nitrogen simply returns to original levels and the response disappears.

Q: By what mechanism does fertilization increase growth rates?

When fertilizers are applied, nutrients in short supply (i.e. nitrogen, phosphorus, or both) are absorbed and act to increase the photosynthetic area of the stand by stimulating leaf size and the number of leaves/tree. Changes in photosynthetic efficiency also may occur. It is this buildup in crown area and change in photosynthetic efficiency that ultimately translates into extra growth. In situations where noticeable differences in leaf size, color, and number do not occur after fertilization, growth responses usually will not be forthcoming.

When fertilizers are applied at the proper time in the spring, responses usually can be detected very soon thereafter. With young black cherry, for example, appreciable height growth gains as well as major increases in leaf size, number, and color (greenness) are readily apparent within a month.

Increased tree growth occurs both from an accelerated growth rate during the normal growing season and from continuation of growth into autumn. Nitrogen fertilization also seems to allow continued growth during periods of mild moisture stress. In addition, it tends to stimulate dominance in crowded stands, and growth rates of dominants and codominants increase at the expense of intermediate and overtopped trees which eventually die.

Q: Which important Appalachian species are responsive to fertilizers?

Black cherry and yellow-poplar are the two species that have shown consistent and large increases in diameter and height growth to fertilization. Oaks, particularly northern red oak, are also responsive, but generally less so than either black cherry or yellow-poplar. And there are large differences in responsiveness among oak species. Sugar maple appears to be quite unresponsive based on tests conducted in the Lake States and on the glaciated Allegheny Plateau.

In general, there seems to be a relationship between shade tolerance and ability to respond to fertilization. Fast-growing intolerants, such as yellow-poplar, white ash, and black cherry, are highly responsive to nitrogen fertilizers and often to phosphorus as well. These are nutrient-demanding species that also have the genetic capacity for very rapid growth when nitrogen and phosphorus are supplied at unlimiting levels. At the opposite end of the scale are the tolerant blackgum, beech, sugar maple, chestnut oak, and hickories that are least responsive to fertilizers. Species that are intermediate in tolerance, like most of the oaks, are likely to show some response to increased nitrogen, but less than the intolerants. Black locust, which is nodulated, would not be expected to respond to nitrogenous fertilizers since this species is capable of fixing its own nitrogen. Also important is the fact that seedlings, saplings, and young stands of responsive species tend to respond more dramatically than older stands.

Q: Are fertilizers used operationally anywhere in the Appalachian Region?

Fertilization is a technique that has been used routinely since 1977 to establish black cherry regeneration following clearcutting on the Allegheny National Forest in northwestern Pennsylvania. There, growth and development of young seedling stands are strongly limited by a combination of severe deer browsing and severe soil nitrogen and phosphorus deficiencies. Without corrective action, these can halt development of young stands for 6 to 8 years, and can result in partial or complete regeneration failures.

Fertilization is used solely to establish thrifty, fully stocked stands of desirable species. Fertilizers greatly stimulate growth of seedlings and herbaceous plants, resulting in more palatable deer browse than can be consumed; this allows many seedlings to escape browsing and grow out of reach of deer in a season or two. In the 10

years that fertilizers have been used for this purpose, nearly 8,000 acres have been treated successfully.

Q: Where fertilizers are used in northwestern Pennsylvania, what are some of the requirements that can influence success?

Achieving consistent responses to applied fertilizers is contingent upon using the proper fertilizer carriers, and applying them uniformly to the stand at the correct rates and at the proper time. It is, of course, also essential to be able to delineate deficient areas.

What to use. The choice of nitrogen and phosphorus fertilizers is limited to high analysis carriers that are available locally in large quantities. Urea (46% nitrogen) and ammonium nitrate (33% nitrogen) are the most readily available and most commonly used nitrogen sources. For black cherry, we have obtained superior responses with ammonium nitrate and it is now used exclusively to supply nitrogen. Triple superphosphate (20% phosphorus) is the only phosphorus carrier we have tried. In soils common to the Allegheny Plateau, a single application will supply adequate phosphorus for at least 5 years, and probably longer. I believe these materials also would be suitable for use throughout the central Appalachians.

Application rates. The application of nitrogen and phosphorus to young black cherry stands is essential to get seedlings off to a fast start and above the reach of deer in a season or two. Tests of fertilizer rates have shown that 200 pounds/acre of nitrogen is sufficient to produce maximum height and diameter growth rates. Similarly, 43 pounds/acre of phosphorus is ample to meet phosphorus requirements. In practice, 150 pounds of nitrogen (450 pounds of ammonium nitrate) and 40 pounds of phosphorus (200 pounds of triple superphosphate) per acre are applied. While these rates are less than optimum for nitrogen, they are sufficient to produce responses that enable most young stands to become established.

Time of application. Fertilizer applications that are made in the spring at about the time of leafout when the vegetation is capable of rapid nutrient uptake will produce the best results. Nitrogen applications made earlier when stands are dormant risk loss from leaching (nitrate moves freely with soil water), and those made later in the growing season reduce the time for growth when nutrient supplies are unlimiting. The time of phosphorus fertilization is less critical than for nitrogen, because phosphorus is not subject to loss from leaching. Therefore, phosphorus can be applied before or at the same time as nitrogen.

Method of application. When fertilizers are applied by helicopter, it is essential that a uniform distribution be obtained. This is crucial for phosphorus, since only a small quantity is applied, and because phosphorus moves little from where it initially reaches the ground. Even distribution of nitrogen fertilizer is important, but because nitrogen is mobile in the soil and is applied in much larger quantities, its initial distribution is less critical than for

phosphorus. Adequate distribution is achievable by double coverage of the area, by accurate calibration of the application equipment (though much will remain a function of pilot skill), and by application of blends that contain both nitrogen and phosphorus rather than individual carriers. If ammonium nitrate and triple superphosphate are used, bulk blending is possible if storage does not exceed several days.

Delineating responsive areas. On the Allegheny Plateau, this is relatively simple because nearly all areas appear to be deficient in both nitrogen and phosphorus. However, fertilizers are not applied to young clearcuts until after the seedlings have adapted to the new exposure and developed a strong root system. This usually is achieved by the second growing season, and fertilizers are applied then or in the third year. Fertilizers applied sooner than this will be wasted because very small seedlings are unable to respond with the height growth necessary to move the stand out of the reach of deer. Also, small seedlings can be killed by fertilizers if they are not well rooted in the mineral soil.

Q: What is the cost of aerial fertilization?

At the rates that fertilizers are applied on the Allegheny National Forest, current costs are about $135/acre. Over the past 10 years, prices have ranged from a low of about $80/acre when the program was first started to a high of about $200/acre several years ago when costs of fuel and nitrogenous fertilizers were at a maximum. These figures include the fertilizers, delivery to the site, and acceptable application. Economically, costs can be justified only where regeneration success is not certain, and where satisfactory regeneration cannot be obtained by other less expensive means.

Q: Is forest fertilization likely to increase within the Region?

I do not foresee widespread use of fertilizers anywhere in the Appalachian Region, except where they are now used and are essential for establishing young cherry stands on the Allegheny Plateau that are in danger of failure from severe deer browsing. Use elsewhere in established stands probably will be limited by the high cost of treatment that improves productivity only temporarily.

Summary

Published results, together with results from studies in progress, indicate that: (1) many hardwoods in the Appalachians have potential for responding to fertilization; (2) nitrogen and phosphorus are the two nutrients that have effectively increased growth rates; (3) response may be large and last 5 years or more; (4) response is affected not only by the degree of nutrient deficiency, but also by species, age, stand structure and stocking, and other site limiting factors; and (5) within the region, forest fertilization is operational in northwestern Pennsylvania, but further widespread use with Appalachian hardwoods is not anticipated.

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PRUNING APPALACHIAN HARDWOODS

Richard C. Schlesinger

Research Forester
USDA Forest Service
North Central Forest Experiment Station
Carbondale, IL 62901

ABSTRACT

Hardwood pruning has been much discussed but rarely done. Although most Appalachian hardwoods shed branches well, oaks and such valuable species as black cherry and black walnut do not. Because branch defects are a primary cause of degrade, pruning has the potential for increasing tree quality of those species that do not shed well and can be a cost effective silvicultural treatment.

Introduction

Pruning hardwoods has been discussed for more than 40 years in the American forestry literature and for many more in the European literature. Some information is conflicting, but a large body of knowledge is available for those choosing to prune. Nevertheless, pruning has not become a common silvicultural tool in our hardwood forests.

The eastern United States appears to have an abundance of hardwoods and the supply is expected to remain high in the near future (Anonymous 1978). However, questions exist about the portion of the resource actually available and about the apparent decrease in the number of high-quality hardwood trees of many species, a decrease reflected in the premium prices paid for such trees.

Several factors determine log grades, including size, sweep, crook, and decay, but branch defect is one of the most important (Hoffard et al. 1977). Several studies have shown that branch defects are frequently the reason an otherwise grade 1 log is a grade 2 or 3 log (Miller et al. 1978; Ward 1964). The veneer grades allow few or no such defects. Therefore, pruning could have an important role in developing high-quality hardwood trees for the future.

In this paper, I will analyze the principal Appalachian hardwood species in terms of three factors. The first is whether a species tends to shed branches naturally. The second is whether a sufficient price differential exists between tree grades for a species to make pruning economical. The third is whether epicormic branching will probably be a problem. Finally, I will attempt to summarize the available information on how to prune for those species for which pruning appears to be worthwhile.

Determining Whether to Prune

The first consideration in deciding to prune is how well a species sheds branches naturally. Of the 27 species most common to the Appalachian forest (Table 1), 8 are known to shed live branches by forming an abscission-like layer, but generally only small branches are involved (Millington and Chaney 1973). Generally, natural shedding involves three steps. First, the branch dies, normally as the result of shading. Next, it weakens because of invasion by wood decay fungi and/or insects. Last, the branch breaks from the stem because of wind, snow, ice, or other mechanical mechanism.

Eighteen of the species may not need to be pruned because they shed their branches well under conditions of side shade (Table 1, categories A and B). However, scarlet oak, sugar maple, and black walnut are considered poor shedders (categories D and E), while blackgum, chestnut oak, white oak, black oak, butternut, and black cherry are considered only moderately good shedders (category C). These nine species warrant further consideration as candidates for pruning.

The second point to consider is whether a large enough price differential exists between tree grades to justify the expense of pruning. That is, if pruning can reduce branch defects, so that an otherwise grade 2 tree becomes a grade 1, is it worth it? Several economic projections have been made to determine whether pruning is worthwhile (Allen 1964; Burns and Nichols 1952; Stern 1971). It appears that a price differential of $40 to $50/M bf would yield a 4% to 5% return on investment 60 years after pruning. Of the nine species that are not good natural shedders, six show large enough price differentials to justify the expense of pruning (Table 1, price categories C to F). Only blackgum, chestnut oak, and sugar maple do not. In the case of sugar maple, the existence of a veneer market would provide the price differential necessary to justify pruning.

Several of these same species are known to produce epicormic branches, especially white oak (Roth 1948). The probability that a tree will produce epicormic branches after pruning depends as much on its relative crown size and vigor as on the species' inherent tendency to sprout. If a tree's crown is in relative balance with its size, there is less chance that light pruning will stimulate the production of epicormic branches. White oak is the one species for which epicormic branching potential may argue against pruning.

Table 1. Species characteristics important to pruning.[a]

Species	Shedding[b]	Price[c]	Sprouting[d]	Prune
Aspen	A	A	-	No
Beech	B	A	-	No
Sweet birch	B	A	-	No
Cucumbertree	B	(A)	-	No
Elm	B	A	-	No
Shagbark hickory	B	A	C	No
Pignut hickory	B	A	C	No
Mockernut hickory	B	A	C	No
Bitternut hickory	B	A	C	No
Sassafras	B	(A)	-	No
Basswood	B	B	-	No
Black locust	B	(B)	-	No
Red maple	B	B	C	No
Sycamore	B	(B)	-	No
Yellow-poplar	B	B	-	No
Yellow-birch	B	C	-	?
Northern red oak	B	E	B	?
White ash	B	E	D	?
Blackgum	(C)	A	-	No
Chestnut oak	C	(B)	B	No
Butternut	C	C	-	Yes
White oak	C	D	A	Yes
Black oak	C	D	-	Yes
Black cherry	C	E	B	Yes
Scarlet oak	D	(D)	-	Yes
Sugar maple	D	B	C	?
Black walnut	E	F	B	Yes

[a]Information obtained from the following: Hoover and Park 1985; Millington and Chaney 1973; Peterson 1985; Smith 1966; and Trimble 1974. If no specific information was found in the literature, the author's judgment was used, e.g. (A).

[b]Natural shedding categories: A=excellent; B=good under side shade; C=moderately good; D=poor; E=very poor.

[c]Price differential categories (average between prime - #1 sawlogs and #1-#2 sawlogs): A=$0-$25; B=$25-$50; C=$50-75; D=$75-$100; E=$100-125; F=$125-$150.

[d]Potential for producing epicormic sprouts: A=very high; B=high; C=moderate; D=low; -=unknown.

An additional consideration is the role that stocking control plays in both natural shedding and pruning (Grisez 1978). Most Appalachian hardwoods require side shade for natural shedding to proceed effectively. In understocked stands, generally those with less than B level or 100 crown competition factor (CCF) stocking, pruning will be needed to produce quality trees. Even those species classified as good natural shedders, e.g. yellow birch, northern red oak, and white ash, should be considered for pruning because the log grade price structure for each makes pruning a sound investment.

How to Prune

Some conflicting advice is present in the literature on how best to prune, but recent work especially by Shigo provides a sound foundation upon which to formulate pruning strategies for producing high-quality trees (Shigo 1984; 1985). It is particularly important to recognize that the tree is a biological organism that responds to the loss of branches, and that the individual tree is part of a larger unit, i.e., the stand in which it is growing. Pruning cannot be considered in isolation from other silvicultural practices, especially those that affect stocking.

To be most effective, pruning should be done in two or more steps, beginning when trees are 4 to 6 inches dbh and continuing until at least the first 17 feet of the bole are clear (Grisez 1978). If the stand was at full stocking (B-level or 100 CCF) before the first pruning, most of the branches will be small (less than 2 inches in diameter) and many will be dead. Generally only dominant and codominant trees, and no more than 100 to 150 trees per acre, should be selected for pruning.

Pruning times depend upon several factors, among which numbers and sizes of branches removed are the most important. Estimates of pruning times vary from 1.5 minutes/tree (Stoeckeler and Arbogast 1948) to 8.8 minutes (Clark 1953). Using a time of 6 minutes for pruning to a height of 17 feet (Burns and Nichols 1952) and a labor rate of $5.00/hour, the estimated cost/tree would be $0.50.

Pruning is best done in the late dormant season to minimize wound "healing" problems (Shigo 1980; Smith 1980); leaf flush is the worst time to prune. Shigo's (1983) concept of "target pruning", which recognizes the branch collar as part of the stem, focuses on the branch/bark ridge, the junction between the branch and the stem. Pruning on the branch side of this ridge will also minimize "healing" problems.

Pruning can reduce growth when applied to live branches (MacDaniels 1973). Thus, care must be taken not to remove too much of the live crown during any one operation. The general "rule-of-thumb" is to remove no more than 25% of the live crown during pruning and to leave a tree with a 50% crown ratio.

Vigorous, rapidly growing trees will generally "heal" better and have fewer defects than slowly growing trees. Thus, the stocking level before pruning should be high enough to promote natural shedding and to minimize the size of the lower branches, yet low enough to maintain vigorous growth. Also, trees that have been too crowded so that their crowns are much reduced are more likely to produce epicormic branches as a response to pruning, because this is one way to rebuild their crowns (Clark and Seidel 1961).

Pruning is the proverbial "two-edged sword" in that it can significantly increase tree quality (and value), but also can reduce quality if done carelessly or incorrectly. Thus, it should be done by well-trained people who understand fully the principles of good pruning.

Conclusions

An investment in pruning will always carry an element of risk because the price differential needed to cover the cost of pruning now must still exist at the time of harvest. Likewise, a decision not to prune now, because the current price differential is insufficient to cover the costs, could be a mistake if a larger price differential develops in the future. However, these types of risks are involved in all forestry management decisions that depend upon future markets.

Based on natural shedding ability, most Appalachian hardwood species do not have to be pruned. Yet among the few that do not naturally shed branches well are the oak species, black cherry, and black walnut, potentially some of the most valuable species in the forests. It is probably unrealistic, and perhaps unnecessary, to expect all trees in a stand to produce high-quality prime veneer and sawlogs. But if pruning can add to the value of 25 percent or more of the final crop trees, it may be one of the most cost-effective silvicultural investments available.

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WILD GRAPEVINES--A SPECIAL PROBLEM IN IMMATURE APPALACHIAN HARDWOOD STANDS

H. Clay Smith and Neil I. Lamson

Principal Silviculturist; Research Forester
USDA Forest Service
Northeastern Forest Experiment Station
Parsons, WV 26287

ABSTRACT

Wild grapevines are highly desirable to wildlife but often are detrimental to timber production. Information is available on controlling the growth of grapevines in immature Appalachian hardwood stands. Overstory shading and cutting of grapevines near groundline are the keys to control. Suggestions are provided that allow the forest manager and landowner to make decisions on grapevine management to satisfy objectives ranging from maximum wildlife interest to maximum production of quality timber.

Wild grapevines are important sources of food and cover for wildlife (Martin et al. 1951). However, grapevines can cause severe crown and bole damage to trees, reduce tree quality, and in some instances, kill trees. Many timber managers view the uncontrolled growth of wild grapevines as a serious threat to the management of quality timber products. Throughout the Appalachians, there are many areas where grapevines dominate the overstory forest canopy. Yet, some wildlife managers regard the controlled growth as a threat to wildlife populations. We believe that a compromise is possible between advocates of wildlife and timber interests.

In this paper we provide information for forest managers who want to control the growth of grapevines in immature Appalachian hardwood stands--sapling stands where dominant-codominant trees average less than 5 inches dbh and pole-small sawtimber stands. The degree of control depends on forest management objectives. However, there is no feasible way to completely eliminate or control grapevines for all situations. For example, it is extremely difficult to eliminate grapevine arbors. We define a grapevine arbor as an entanglement or matting of vines where the vines dominate the vegetation to the point that trees are bent over and/or uprooted, creating an opening in the stand.

The key to controlling grapevines in immature stands is shading from overstory canopy. Herbicides, though efficient, are not

necessary. However, before we discuss methods and situations for controlling the growth of grapevines, we need to review the general silvical characteristics of grape.

Silvical Characteristics of Grape

Grapes are intolerant of shade, prolific stump sprouters, layer or root easily, and ring porous (Trimble and Tryon 1979). These vines grow on a wide range of soil and site conditions, but usually are more concentrated on the good growing sites--red oak site index 70 and above.

Usually, male and female plants flower on separate vines from mid-May to early July, but some vines produce both male and female flowers on the same plant. Flower pollen is disseminated by wind, rain, insects, and animals. Frost does not seem to have an effect on flowering.

During development, the grape fruit (berry) is susceptible to a fungal disease, black rot, and curculio beetles. Rain or high humidity can lead to the development of fungal disease. In fact, it has been reported that black rot and beetle damage were responsible for 90% loss of grape fruit in one year (Della-Bianca 1978; 1979). Grape berries ripen in September and October. Each berry produces two to six seeds; there is an average of 42 berries per grape cluster (Figure 1). It has been estimated that a female vine could produce 2,655 seeds/acre/year if three seeds/berry were present. Grapevines can produce seed 3 years after germination. Generally, a moderate seed crop is produced each year, but overhead shading also reduces the production of berries. Seed remains viable in the soil duff for several years (Wendel 1981); when the overstory is removed such as after clearcutting or heavy partial cutting, newly germinated grape seedlings can easily exceed 100,000/acre. Most of these seedlings do not live long.

Grapes are supported on branches by tendrils that enable the vines to climb. Shoot growth starts slowly in the spring, followed by periods of rapid growth. Stump sprouts grow faster than seedlings during early growth; a stump sprout growing 15 feet a year is not uncommon. From early spring to about mid-September, grapevines bleed sap when cut or injured. This is important for grapevine control measures involving the use of herbicides.



Figure 1. Cluster of grape berries.

Controlling Wild Grapevines

Controlling the growth and development of grapevines in immature stands is not difficult. If the objective is to manage solely for wildlife purposes, then the forest manager may want to stimulate the reproduction and growth of grapevines by making clearcut openings in areas where vines are present. Conversely, landowners who want to grow high-quality timber products could try to eliminate all vines; however, it is highly unlikely that all vines could be eliminated as some grape arbors usually are present in most stands.

Usually, landowners want to have both wildlife benefits and quality timber products simultaneously. This would mean having some grapevines in the stand but not a stand dominated by the vines. Allowing grapevines to develop in arbors and applying grapevine control treatments in the stand is a feasible compromise. If there are no arbors in the stand, you can develop arbors by simply felling small groups of trees that have vines in the crowns. Generally, if no control treatments are applied to a portion of the area where vines are present, arbors will eventually develop.

Grapevine Arbors (Clumps)

Arbors or tangles of vines (Figure 2) in the woods are the key for wildlife for even if the forest manager wanted to eliminate all grapevines in the stand, including those in the arbor, it would not be possible. Our information and experience indicate there is no practical way to eliminate vines in arbors. Herbicides can be used repeatedly in the openings and the vines (seed origin) still will dominate the arbor. We do know that where small arbors exist, the encroachment of tree crowns around the edge of the arbor opening may eventually close. Thus, shading would occur and the vines in the arbor would die. Grapevines dominate arbors and it is not possible to grow quality hardwood timber or mast-producing trees for many years.

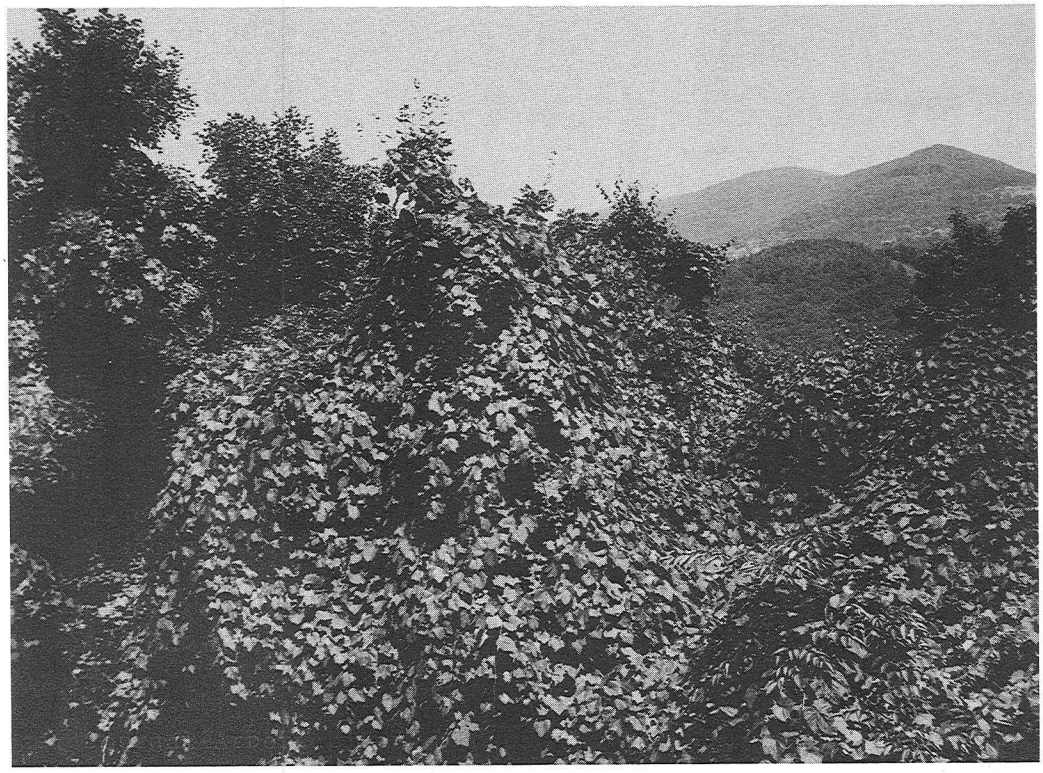


Figure 2. Grapevine arbor or entanglement.

Sapling Stands

In young, even-age sapling stands, forest managers have two choices for controlling wild grapevines after the trees have developed a closed crown canopy: cut the grapevines or use herbicides. We suggest waiting until the crown canopy provides shade and then cutting the vines near the ground. At this time, 8 to 10 years after cutting, crown closure is well developed in a fully stocked stand. And you can easily walk under the crowns. Grapevines attached to the tree bole-tree crown are cut near groundline. There is no need to cut layered

vines or vine loops. The cut vine stumps will sprout but if overstory shading is present, sprouts will die within 2 to 3 years after cutting.

Grapevines are susceptible to herbicides. However, herbicides are not necessary in sapling stands as the forest shade canopy will control stump sprouting. If a stand has a high number of grapevines/acre, a second vine control treatment maybe necessary in 4 to 5 years. This second treatment is for vines missed by the crew during the initial treatment, not for vine stump sprouting. We have found in monitored areas that 90 to 95% of vines are cut when applying a single control treatment. Still, a follow-up treatment may be required depending on the situation.

Thus, for sapling stands, herbicides are effective and can be used as a basal spray where crown shading is lacking, though the use of herbicides is more expensive and risky than cutting. Zedaker (this proceedings) discusses herbicide use in more detail. Cutting vines near groundline with blade-type equipment such as a Woodsman's Pal or brush axe is quick and efficient. Loppers also work well in young stands as the diameter of the vines usually is not larger than the lopper can cut. Do not plan a crop tree release thinning or any other practice that opens up the stand. Do the grapevine control treatment first. Then wait 4 to 5 years before doing any other cultural practice.

Pole and Small Sawlog Stands

In older stands, use methods to control grapevines similar to those used in sapling stands. In a well-developed overstory, cut the vines near groundline. The vine stumps will sprout but these sprouts will die within 2 to 3 years. We recommend treating grapevines along with commercial thinnings as crown canopies will shade the forest floor.

If a clearcut is not anticipated within 4 to 5 years, then herbicides are not necessary; this is usually the situation. However, if a clearcut or heavy understory removal is planned within 3 to 4 years after a grapevine control treatment, then a herbicide basal spray treatment is desirable and the vine layers or loops need to be treated, too (Smith 1984). A herbicide treatment is necessary because cut vines will sprout for 2 to 3 years and clearcutting would cause these sprouting vines to persist.

Treatment Costs

Estimates of manhours/acre required to cut grapevines in sapling stands are summarized in Table 1. About 1.2 manhours are required to cut stands averaging 100 vines/acre; cutting 500 vines/acre requires 3.2 manhours. We do not recommend using herbicides in sapling stands. If herbicides were used, the treatment cost would be higher than cutting as the vines usually are small and there is a considerable waste of herbicides when trying to spray small stems. Also, two men cutting vines are more efficient than one man basal spraying and a second member of the crew supplying the herbicide mixture.

Table 1. Estimated number of manhours per acre required to cut grapevines in sapling stands.[a]

Grapevines/acre	Manhours/acre
----------Number----------	
10	0.7
25	0.8
50	0.9
100	1.2
150	1.4
200	1.6
250	1.9
300	2.2
400	2.7
500	3.2
600	3.7
700	4.2
800	4.7
900	5.2
1,000	5.7
1,100	6.2
1,200	6.7

[a]Stand averages 1,900 trees/acre 1.0 inches in dbh and larger.

Estimating costs to treat pole and small sawlogs is difficult, and specific data are not available. However, data are available for mature stands where vines were treated before a clearcut is planned. Many of the vines in older stands are larger than 4 inches in diameter. Thus, costs for cutting vines (Table 2) are greater than those for herbiciding, but

there is a problem with the cost data. The herbicide data were collected from small areas (<2 acres) and the distance to carry the herbicide to the sprayer was not great. Mixing, hauling, and supplying the herbicide could not be evaluated adequately. In large areas where access is limited, it would be much more difficult to supply herbicide for the sprayer, so the cost of basal spraying would increase.

Table 2. Number of manhours per acre to cut or basal spray grapevines--sawtimber stands.

Treated vines (no.)	Cut vines[a]	Basal spray vines[b]	Herbicide-oil mixture
	------Manhours/acre-----		Gallons
10	0.7	0.5	0.02
25	0.9	0.5	0.18
50	1.3	0.7	0.46
100	2.2	0.9	1.01
150	3.0	1.2	1.56
200	3.8	1.4	2.11
300	-	1.9	3.21
500	-	2.9	5.41

[a]Estimates include a 10 minute/manhour allowance for periodic crew breaks--each crew member cut vines.

[b]Estimates include a 10 minute/manhour allowance for periodic breaks--two-man basal spray crew.

In the older stands, 2.2 manhours were required to cut 100 grapevines/acre (Table 2). A Woodsman's Pal or small hatchet-axe was used to cut the vines. By contrast, about 0.9 manhours was needed to treat 100 vines with herbicides. One gallon of herbicide-oil mixture (WEEDONE 170) was used. To obtain more comparable data, herbicide the same area and record all data. Then, when conditions are similar, revisit the area and cut all grapevines previously treated with herbicides.

When Grapevines Are A Problem

Periodically, we are asked: how many vines/acre constitute a problem? We have some information for sapling stands that will help you decide when vines become a problem. In Table 3, the number of vines/acre is related to number of trees/acre with grapevines in the crown and the percentage of the stand that has trees with grapevines. Once a tree gets grapevines in its crown or tree bole, the vines are beginning to dominate the tree. When this occurs, the use of that tree for future production of timber products is low, and there is a degree of risk for mast-producing trees too.

Table 3. Estimate of grapevines in tree crowns (sapling stands).

Grapevines/ acre (No.)	Trees with grapevines	
	No./acre	Percent of stand[a]
10	60	3
25	80	4
50	115	6
100	190	10
150	262	14
200	335	18
250	405	21
300	480	25
400	625	33
500	765	40
600	910	48
700	1,055	56
800	1,200	63
900	1,345	71
1,000	1,490	78
1,100	1,635	86
1,200	1,780	94

[a]Stand averages 1,900 trees/acre 1.0 inch in dbh and larger.

For sapling stands (Table 3), 100 grapevines/acre relate to 190 trees with grapevines in the crowns; and this would account for about 10% of the stand area. This does not include an estimate of grapevines in arbor areas. Arbors are excluded from control treatments. If a stand has 500 grapevines/acre, we estimate that 765 trees have grapevines in the crowns; this represents 40% of the stand area.

It is not our intention to determine the number of grapevines per acre that forest managers or landowners can accept. That is their decision. To us, the key is the percentage of the stand lost to grapevines. In some cases on a good quality, high-value hardwood site, the owner may want ot eliminate all grapevines. For other situations and owner objectives, 1,000 grapevines/acre may be appropriate. Because we are oriented toward timber production, we believe that 50 grapevines/acre are about the most we would want. If arbors were present, we would want few grapevines in the remaining stand. Also, when we set aside 10% of the stand area for roads and decks and another 5 to 6% for grapevines (not counting arbors), the area lost to timber production approaches 15 to 20%.

Cutting Vines

Our main recommendation for controlling grapevines in immature stands is to cut the vines near groundline. We use at least a 2-man crew but larger crews can be used. We suggest working across the slope contour. Crew members should be certain to overlap each other. This allows for a much better job, though some vines still will be missed. The best time to cut vines is during the dormant season when a light snow is on the ground--the vines are easy to see and crew members can tell where they have been.

Partial cuts such as improvement cuts and thinnings usually result in residual stands with considerable shading of the overstory. Grapevines do not grow well under dense shading. Grapevines can be controlled by cutting the vines that grow in trees. Vines are cut near groundline before, during, or after logging with blades, hatchets, loppers, or chain saws. The cut vine stump will sprout, but the sprouts will die within a few years. Barring drastic overstory removal or a natural disaster, the vines will not become a problem until the overstory canopy is removed (harvest cut). When the overstory is removed, the grape seed stored in the soil will germinate. However, there is no need to control grapevines in the new stand until this stand develops an overstory canopy 8 to 10 years after the harvest cut.

To some, large vines are hard to cut, so it may be easier and cheaper to basal spray large vines with a herbicide-oil solution (according to the label directions). However, in partial cuts, logging crew fellers can cut the vines with chain saws and still keep up with the normal logging operations. If this is not possible, make a special trip into the stand before logging to treat the vines. At this time, it is much easier to cut or herbicide the vines than walking through the tops from felled trees.

Controlling grapevines in more mature stands where partial cuts such as thinnings or crop tree release are planned should not present major control problems for the forest manager. In fact, in some of these stands, there may not be enough grapevines to satisfy wildlife management objectives. Depending on forest management objectives, grapevine arbors may need to be established. Also, seedling-origin grapevines are not a problem under the shade of partially cut stands unless the stands are suddenly opened up due to factors such as heavy logging, windstorms, ice, and snow.

Other Vines

At high elevations, Dutchman's pipe, also commonly called camphor vine, or pipe-vine can cause problems in hardwood stands. Vines have little food value for wildlife, and little

is known about controlling their growth. The vines sprout prolifically and occur on moist productive sites in association with Allegheny hardwoods but rarely occur on the drier oak sites. On the basis of our observation in a cooperative study on the Monongahela National Forest in Marlinton, WV, with Bob Acciavatti (Northeastern Area State & Private Forestry) and Bob Burt (MNF Marlinton Ranger District), camphor vines are more tolerant than grapevines. In sapling stands, these vines sprout prolifically following a control treatment such as cutting or basal spraying with herbicides. These sprouts can easily climb into tree crowns. Camphor vines do not seem to translocate the herbicide well, so the vine layers do not die unless they are herbicided directly.

We suggest treating camphor vines as you would treat grapevines. However, for camphor vines, a second treatment within a few years after the initial one is necessary in areas where the camphor vine is a major problem. After the second treatment (cutting preferred), we think sprouting probably will not be a problem and the stand should improve drastically. Camphor vines are softer than grapevines and much easier to cut.

Recommendations

Grapevines are highly desirable to wildlife, but often the vines are detrimental to timber production. A majority of the vines occur on good hardwood sites. If forest managers want to control the growth of wild grapes, it is possible to do this in hardwood (immature) stands as soon as the overstory canopy closes. Shading is the key as the vines are shade intolerant. Thus, for immature stands, we recommend controlling the growth of the vines by cutting. Vines in tree crowns are cut near groundline (couple feet above ground) using blade-type equipment, a hatchet or small axe. The vines will sprout but in 2 to 3 years, the vine stump sprouts will die due to overstory shading. Do not cut vines in grapevine arbors or clump areas. When desired, cut vines in trees along the border of the arbors to keep the arbors from enlarging. However, where wildlife interests are the main objective, we suggest not cutting grapevines in trees bordering the arbors. This should help retain the arbor or even make it larger.

Use of herbicides in young sapling stands is not necessary. However, older small sawlog stands may have several large vines of more than 3 inches in dbh. Basal spraying could be considered but we still recommend cutting. Also, in sapling stands where grapevines are a problem, control the growth of the grapevines first. Then, if desirable, consider a crop tree release type cultural treatment 4 to 5 years or later.

When possible, we prefer applying grapevine control early in stand development at the sapling stage. If we delay a control treatment until the stand is old enough to apply an improvement

cut or commercial thinning, many of the potentially best crop trees have been damaged or destroyed.

In pole and small sawtimber size stands, a grapevine control and crop tree release or thinning can be done at the same time. Also, remember grape seeds remain viable in the soil for a long period. Areas that have serious grapevine problems requiring a control treatment have the potential to produce wild grapevines whenever the overstory is removed--clearcut. Usually, the new regenerated sapling stand will need a vine control treatment.

Until more information is available, we suggest using the same techniques to control camphor vines as those used to control grapevines.

We believe the grapevine arbor concept allows a good compromise between wildlife and timber interest. No grapevine control measures should be attempted in arbors. If you want to keep the arbors from expanding, cut the vines in trees bordering the arbors. If arbors are not present or more arbors are needed, do not apply control treatment to areas where grapevines are concentrated. The arbors will eventually develop. If arbors are desired, cut small groups of trees that have grapevines in their crowns.

Basically, if landowners or forest managers want to control the growth of the grapevines, we have given you ways to do it. Deciding when the grapevines are a problem is a decision forest managers and or landowners make together. A few grapevines are of little concern to forest managers interested in multiple-use; however, depending on objectives, too many or too few grapevines can make a major impact on wildlife and timber resources. We know that both wildlife and timber interests can benefit if landowners and forest managers are willing to compromise.

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HERBICIDES AND APPLICATION TECHNIQUES FOR MANAGING IMMATURE HARDWOODS

Shepard M. Zedaker

Department of Forestry
Virginia Polytechnic Institute and State University
Blacksburg, VA 24061

ABSTRACT

The current availability of herbicides and application techniques for vegetation management in immature hardwood stands is discussed. Use guidelines for specific stand conditions are provided as well as treatment costs, application safety, and environmental protection information.

Introduction

Undesirable plants, or weeds, are as much a detriment to yield in immature hardwood stands (average dbh <12 inches) as in any forest managed for a specific crop. The tree size, stem density, and species composition of such stands present unique vegetation management problems which are not easily nor cheaply solved. At the same time, vegetation management treatments in immature stands can help eliminate weed problems that may be more difficult to solve at other times during the rotation or in subsequent rotations. For this reason, the process of vegetation management for hardwood production should be treated as a continuum in which short-term gains from weed control are not as important as long-term changes in species composition and dominance. Site resources usurped by weed trees, shrubs, and vines are not available to crop trees. The distribution of those resources between desirable and undesirable plants is likely to get worse in subsequent rotations unless vegetation management treatments are carried out at the most opportune times. The best biological time for herbicidal treatment of woody perennials is when they are small and less vigorous; when they are still in the understory of maturing stands.

The structural characteristics of immature hardwood stands are also advantageous for vegetation management with herbicides. Unfortunately, there are no herbicides currently labeled that, when applied as a broadcast treatment, are selective enough to eliminate weedy broadleaved perennials without substantial damage to crop hardwoods. Selectivity is therefore dependent on herbicide placement where crop trees will not have an opportunity for significant uptake. In immature hardwood stands, individual stems of weed trees and shrubs have reached sufficient size to allow single stem treatment. Vine and shrub canopies have often differentiated themselves into separate canopy layers allowing broadcast treatment with foliar applied

herbicides directed to the understory. Residual weed "wolf" trees left from earlier high-grading can be felled and treated without significant damage to the young stand. The physical characteristics of weed plants are the chief determinant of the chemical and application technique selected as a control measure. Stem size, density, and canopy height are the most important variables.

The economic return possible from weed control measures in immature hardwood stands is difficult to assess. Few studies have been completed that would indicate the increase in yield or quality of crop hardwoods as a result of weed control. Yield improvement is a function of the density of both crop trees and weeds, relative size or dominance of weeds, site quality, and the degree of weed control achieved. In Southern pine stands, control of as little as 10% of the total basal area in hardwood weeds gives significant economic return (Burkhart and Sprinz 1984). Vegetation management in immature hardwood stands could provide economic returns if product value and investment periods were the same. Unfortunately, as a recent survey of Timber Mart-South indicated (Norris 1986), oak sawlog value averages only 50 to 75% of that for pine, and hardwood rotation lengths are two to three times the 30-year period for pine. As a result, the relative density of weed species must be high, perhaps 20% or more of the basal area, to justify treatment. The potential for rapid crop growth must also be high. As a rule of thumb, investment in weed control on oak sites, site index <75 (base age 50) for oaks, will probably not yield an economic return. On good sites, both crop and weed growth is accelerated. Like many other cultural treatments, the cost-benefit ratio of weed control gets better as site quality increases.

Application Techniques

Herbicide selectivity is heavily dependent on placement; therefore, application of chemicals to individual stems is the main technique used in immature hardwood stands. Individual stem treatments include injection, stump treatment, and basal sprays. Directed foliar sprays to individuals or sprout clumps may also be applied but may be considered a type of broadcast treatment since it is difficult to insure that no chemical reaches the forest floor or crop tree stems.

Single stem injection involves the application of pure or diluted herbicide into a wound made through the bark to the cambial layer. Injection can be done with the simple hack-and-squirt method using a hand ax and a small squirt bottle or with more sophisticated injection devices designed to apply a metered amount of chemical at the same time a wound is made. The hypo-hatchet is the most convenient automatic injector because of its small size and light weight; however, any of the basal injector tubes work equally well to deliver the herbicide. Injected stems may sprout from the base below the injection point; a problem most acute when the injections using the hack-and-squirt or hypo-hatchet methods are spaced too far apart. Production rates are highest using the hypo-hatchet and lowest using the basal injectors (Table 1). One to two ml of herbicide or

herbicide mix is injected into each wound and two-thirds to one injection is made per inch of dbh. Injection at the maximum rate (2 ml/ injection and one injection/inch dbh) results in a calculated use rate of 0.72 gal/100 ft^2 of basal area treated. Actual maximum use rates can range from 0.80 to 1.20 gal/100 ft^2 due to missed strikes. Large trees are often difficult to kill even when girdled completely with injections and small stems are difficult to inject because the stems are too pliable. The recommended range of stem sizes for injection is 2 to 12 inches dbh. Injection is well suited for the control of undesirable tree species in immature hardwood stands.

Table 1. Production rates per hour for injection techniques tested on nine hardwood stands in Indiana (Wiltrout 1976)[a].

Injection method	Stems/hour	Inches dbh/hour	Basal area/hour
			ft^2
Basal injector	181 a	687 a	21 a
Hack-and-squirt	217 a	827 a	25 ab
Hypo-hatchet injector	278 b	1,061 b	33 b

[a]Column means followed by the same letter are not significantly different at the 5% level.

Range of stand conditions: Slope 0 to 23%;
Treated stems/acre 48 to 345;
Average dbh 3.0 to 4.9 inches;
Average treated basal area/acre 6 to 46.

Weed tree stems greater than 12 inches dbh should be felled and the stumps treated with herbicide to prevent resprouting. Stump treatment involves the application of herbicide or herbicide mix to the cambial layer surface immediately after felling. Most herbicides are applied undiluted; however, applications with as much as a 4 to 1, water to herbicide, mix have been successful. The application is made with a small squirt bottle spraying a straight stream completely around the stump only on the cambium. Spraying chemical on the heartwood and/or bark wastes herbicide and does not improve efficacy. Application time ranges from 5 to 10 seconds/tree and does not significantly reduce felling productivity. Chemical use rates range from 0.64 to 0.73 gal/100 ft^2 of basal area treated depending on the season of application (Lewis et al. 1984). Winter applications use more chemical due to its higher viscosity during cold weather.

Woody stems <2 inches dbh are most efficiently treated using basal sprays. These treatments involve the application of an herbicide or an herbicide mix directly on to lower portions of tree, shrub, or vine stems using backpack or small canister (garden variety) sprayers. Applications are made such that the chemical spreads entirely around the stem and is directed so that a minimal amount falls to the ground.

The length of stem treated ranges <1 inch, called the thinline treatment, to 2 feet in high volume basal sprays. The herbicides are applied at full strength or only slightly diluted for thinline treatments down to very dilute solutions (<5% herbicide) for treatments covering more stem length. Diesel fuel and kerosene are the most frequently used dilutants; however, new surfactant/penetrating oils manufactured specifically for basal sprays are gaining acceptance. Productivity rates are dependent on stem density, dilution rate and the length of stem that is to be treated. Productivity and chemical use data for basal sprays are listed in Table 2. Basal sprays are most applicable when the number of stems to be treated is <1,000/acre.

Table 2. Chemical use and application time for basal treatments with kerosene.

Treatment	Herbicide used/ 100 stems	Application time/ 100 stems
	ml	minutes
Thinline (100% herbicide)	172.0	11.1
4-inch band (20% herbicide)	35.5	7.6
18 inches (no runoff, 10% herbicide)	36.2	10.4
24 inches (runoff, 2% herbicide)	22.0	14.7

When the weed plants in immature hardwood stands are <2 inches in dbh, <20 feet tall, and occur at densities exceeding 2,000 stems/acre, directed foliar sprays are most efficient. The time required for individual stem treatment using basal sprays under such conditions usually exceeds 4 hours/acre. Directed foliar sprays can be aplied using backpack sprayers if the plants to be treated are <8 feet tall. Taller vegetation can be sprayed using tractor-mounted or backpack mistblowers depending on access and terrain. Complete coverage of weed foliage is necessary for efficacy. At the same time, care must be taken to avoid crop tree foliage and boles; when using herbicides with soil activity, every effort must be made to minimize throughfall of the spray mixture. Productivity is dependent on the percent of area treated and the ease of movement through the stand. A range of 0.5 to 2.0 hours/acre is normal for 100% broadcast applications with backpack mistblowers. Dilute solutions of herbicides in water are most common. In 100 percent broadcast applications, 10 to 20 gal/acre of total spray solution are used. The lowest carrier volumes consistent with complete foliar coverage should be used to minimize the weight that must be carried in backpacks through the stand. Spray solutions are usually mixed with a set percentage of herbicide active ingredient in the total mix; 1 to 5% active ingredient is common.

However, with some practice, it is possible to calibrate the application for a fixed amount of herbicide active ingredient/acre. Water is used exclusively as the carrier since oil would facilitate movement of herbicides into crop tree stems and increase crop damage.

In general, the use of highly soil active herbicides for foliar or soil applications is not recommended in immature hardwood stands (see soil applied herbicides in Table 3). An exception may be the use of hexazinone in a spot-around treatment for the release of yellow-poplar. Most hardwoods are very sensitive to hexazinone when applied as the liquid formulation in spots on the soil surface. Yellow-poplar is relatively resistant to hexazinone damage and may be a candidate for spot-gun release. This treatment is experimental and should not be adopted on a widespread basis until proven.

Herbicide Properties

The herbicides currently labeled for forestry uses that may have applicability in managing immature hardwood stands are listed in Table 4. Fosamine, glyphosate, hexazinone, and triclopyr are all compounds that have been labeled since the 1978 suspension of 2,4,5-T. Imidazolinone is a very new product that will be labeled early in 1986.

Herbicides are manufactured into different formulations that make them useful. Major herbicide formulations and uses are listed in Table 3. Soluble liquids (SL) are water soluble formulations that can be used undiluted or mixed with water and SL formulated herbicides can be injected, used to treat stumps, or applied as foliar sprays. Emulsifiable concentrates (EC) are oil soluble but can be mixed with water to form an emulsion. These formulations are the best for basal sprays since the bark of woody stems is generally hydrophobic. Mixed in oils, EC herbicides penetrate the bark more readily than SL formulations and EC herbicides can also be used for injection, stump treatment, and foliar sprays. Granular (G) and pelleted (P) herbicides are formulated for soil active compounds that are taken up into woody plants through their root systems. Other, not so common, formulations include soluble powders (SP), flowables (F), dry flowables (DF), and wettable powders (WP).

Efficacy data for the herbicide applications possible in immature hardwood stands is quite limited. Chemical companies are no longer required to provide efficacy data to register an herbicide; a caveat emptor approach (buyer's risk). The use of herbicides for injection has received the most attention from researchers and efficacy data for this application is listed in Table 5. Control by injection is most often measured by the percent of topkill of treated stems. Basal sprouting is not usually accounted for. Efficacy of selected herbicides for stump treatment is provided in Table 6. Percent control of resprouting from stump treatments compares favorably with percent of topkill in injection treatments. Actual percent mortality of stump treated stems may be higher than that for injected stems.

Table 3. Herbicide formulations and application uses for immature hardwood stands.

Herbicide	Formulations[a]	Uses
2,4-D	SL, EC	I, ST, BS, FS
2,4-DP	SL, EC	I, ST, BS, FS
Dicamba	SL, EC	I, ST, BS, FS
Fosamine	SL	I, FS
Glyphosate	SL	I, ST, FS
Hexazinone	SL, G, P	I, F, SA
MSMA	SL	I
Picloram	SL, P	I, ST, BS, SA
Triclopyr	SL	I, ST, BS, FS

[a]SL - Soluble liquid, EC - emulsifiable concentrate, G - granular, P - pellet.
[b]I - injection, ST - stump treatment, BS - basal spray, FS-foliar spray, SA - soil application.

Table 4. Herbicides used for woody plant control in eastern forests.

Common name	Trade name(s)	Manufacturer
Imidazolinone	Arsenal	American Cyanamid
2,4-D	DMA-4, Formula 4D	Vertac
2,4-D	Esteron 99, Weed Rap	Vertac
2,4-D	2,4-D	Rhodia
2,4-D	Weedone 64	Union Carbide
2,4-DP	Weedone 2,4-DP	Union Carbide
2,4-D + 2,4-DP	Weedone 170,Weedone CB	Union Carbide
Dicamba	Banvel, Banvel CST	Velsicol
2,4-D + Dicamba	Banvel 520, Banvel 720	Velsicol
2,4-D + Dicamba	Trimec 450-E	PBI Gordon
Fosamine	Krenite	E.I.DuPont de Nemours
Glyphosate	Roundup	Monsanto
Hexazinone	Velpar L	E.I.DuPont de Nemours
Hexazinone	Pronone 10g, Pronone 5g	Proserve
Hexazinone	Buck shot 10-PH	Forshaw
MSMA	Transvert	Union Carbide
Picloram	Tordon K, Tordon 10K	Dow Chemical
Picloram + 2,4-D	Tordon 101M Tordon 101R Tordon RTU	Dow Chemical
Triclopyr	Garlon 3A, Garlon 4	Dow Chemical

Table 5. Average percent topkill by species using herbicides applied by injection (Campbell 1985; Kossuth et al. 1980).

Species	Herbicide					
	2,4-D	Picloram + 2,4-D	Fosamine	Glyphosate	Glyphosate + 2,4-D	Triclopyr
	(Percent Topkill)					
Blackgum	96	97	96	--	96	100
Black oak	100	97	96	--	98	100
Flowering dogwood	90	100	96	44	72	100
Hickory	96	96	66	46	--	100
Northern red oak	100	92	100	--	100	98
Post oak	92	86	--	100	100	97
Red maple	12	67	71	--	54	94
Sassafras	[a]	100	--	--	--	100
Southern red oak	88	94	98	93	97	82
Sourwood	67	97	96	--	96	100
Sweetgum	96	99	100	--	98	96

[a]Insufficient data.

Table 6. Average percent kill and crown volume control[a] data by species for cut-stump chemical treatments for both dormant and growing seasons application (Lewis et al. 1984).

Species	Herbicide[b]				
	Glyphosate	Hexazinone	Picloram + 2,4-D	Triclopyr	Dicamba + 2,4-D
	%Kill[c] / %Control[d]				
Red maple	25 b / 69 A	13 c / 25 B	54 a / 83 A	48 a / 78 A	8 c / 69 A
Yellow-poplar	80 a / 98 A	19 c / 54 B	83 a / 98 A	87 a / 99 A	61 b / 96 A
Sourwood	80 a / 96 A	10 d / 58 C	51 a / 93 A	30 c / 73 B	51 b / 95 A
White oak	55 a / 89 AB	19 b / 97 A	60 a / 59 C	72 b / 99 A	30 b / 73 BC
Chestnut oak	55 a / 94 A	28 a / 64 AB	52 a / 86 A	52 a / 76 A	11 b / 35 B

[a]Crown volume = (crown diameter)^2(tree height);
Crown volume control %=$\frac{\text{crown volume unsprayed-crown volume sprayed} \times 100}{\text{crown volume unsprayed}}$

[b]Number of stems/species-chemical treatment $\geq$40.

[c]Kill means within each species followed by the same letter are not significantly different at the 5% level.

[d]Control means within each species followed by the same letter are not significantly different at the 5% level.

The herbicides 2,4-D, 2,4-DP, dicamba and triclopyr are the only registered compounds for basal sprays. No comparative efficacy data have been published; however, applications at label recommended rates for triclopyr have resulted in over 90% control of all hardwood species except blackgum. A similar lack of published data exists for directed foliar sprays in the understory. However, many foliar applied herbicides list common woody weed species on their label as plants that they control. Table 7 contains the vine, shrub, and weed

Table 7. Herbicides and genus listed as controlled by the label for directed foliar applications in immature hardwood stands.

Species	Herbicide				
	2,4-D	Dicamba + 2,4-D	Fosamine	Glyphosate	Tricolpyr
Trees					
Acer	x	x	x	x	x
Alnus				x	
Betula	x	x	x		x
Carya	x	x	x		x
Cornus	x	x			x
Fraxinus	x	x	x		x
Liriodendroon	x	x	x		x
Plantanus	x	x	x		x
Populus	x	x	x		x
Prunus	x	x	x		x
Quercus	x	x	x	x	x
Robinia	x	x	x	x	x
Salix	x	x	x	x	x
Sassafras	x	x	x		x
Ulmus	x	x	x		x
Vines					
Campsis				x	
Lonicera	x	x		x	
Pueraria	x	x		x	
Rhus	x	x			x
Rosa	x	x	x	x	x
Rubus	x	x	x	x	x
Sambucus	x	x	x	x	x
Vitis	x	x	x		
Shrubs					
Amelanchier	x	x			
Ceanothus					x
Corylus	x				x
Crataegus	x		x		x

trees listed as being controlled using foliar sprays. Substantial differences in the herbicide application rate necessary for control may occur between easy and hard-to-kill species.

Herbicide Safety and Enviornmental Concerns

The Environmental Protection Agency recognizes two broad categories of pesticides: restricted use and non-restricted use. The vast majority of herbicides fall into the non-restricted use category, requiring no applicators license to purchase or apply. Restricted use chemicals are classified as such because of high toxicity, extreme persistence, a history of misuse, or because they are suspected of being a carcinogen, mutagen, or teratagen. Persistence is the main cause for restriction of some formulations of picloram. The phenoxy compounds are suspected carcinogens. No other commonly used forestry herbicides are restricted (Table 8). The oral acute dose for lethal effect on 50% of the test population (LD_{50}) is the common measure used to compare the toxicity of all chemical compounds. When the LD_{50} values for herbicides are compared with that of chemicals commonly used around the home, the relative safety of forest herbicides becomes apparent. For example aspirin and triclopyr, an herbicide commonly used for basal applications, are about equal in toxicity.

Table 8. Herbicide and household chemical toxicity and use restrictions.

Herbicide/ household	LD_{50}[a]	Toxicity class	Restricted use
	(mg/Kg)		
Aspirin	750	Slight	No
2,4-D	300	Moderate	Yes
2,4-DP	300	Moderate	Yes
Dicamba	1,028	Slight	No
Caffeine	200	Moderate	No
Fosamine	24,400	Non-toxic	No
Glyphosate	4,900	Slight	No
Hexazinone	1,700	Slight	No
MSMA	1,800	Slight	No
Picloram	8,200	Relatively non-toxic	Yes[b]
Table salt	3,320	Slight	No
Triclopyr	713	Slight	No

[a]LD_{50} acute oral lethal dose at which 50% of the test population dies.
[b]Some formulations of picloram are not restricted.

However, if risks from chemical use are to be minimized, LD_{50} values are not sufficient to evaluate safety. Instead, the chronic no observable effect doses (NOEL) are used in worst case analyses. The NOEL doses determined from chronic lifetime feeding studies are divided by 100 to account for the fact that humans may be more sensitive than the test animals. Exposures necessary to reach NOEL/100 values for herbicides provide ample safety margins even in worst case situations (Table 9).

Even given the relatively innocuous nature of forest herbicides, procedures for safe handling, given on the herbicide label, should be followed closely. Protective clothing should be worn if called for and special care should always be taken when mixing and transporting the concentrated formulations. Field crews should be well-trained in chemical application and informed of the proper chemical handling techniques necessary to insure safety. Every effort should be made to insure that herbicides do not reach open water. Since the applications recommended (Table 9) are all ground based, untreated buffer zones around open water need not be large. A minimum buffer width of 50 feet should be left if motorized vehicles are used for application, 25 feet for hand foliar or basal spraying, and 15 feet for injection or stump treatment.

Table 9. Hypothetical daily intake by a 132 pound person of various substances containing herbicide residue to reach the oral chronic no observable effect level with a safety factor of 100 (NOEL/100) (Walstad and Dost 1984).

Herbicide	Chronic oral NOEL[a]	Substance consumed to reach NOEL/100			
		Spray mixture[b]	Stream water[c]	Foliage area[d]	Animal meat[e]
	mg/Kg/day	oz	gal	ft^2	lbs
2,4-D	20	0.017	32	5.8	264
2,4-DP	10	0.008	16	2.7	132
Dicamba	5	0.004	8	1.4	66
Fosamine	30	0.025	48	8.5	396
Glyphosate	30	0.025	48	8.5	396
Hexazinone	25	0.021	40	7.1	330
MSMA	5	0.004	8	1.4	66
Picloram	20	0.017	32	5.8	264
Triclopyr	30	0.025	48	8.5	396

[a]NOEL-no observable effect level from long-term feeding studies; daily intake.

[b]Assumes an herbicide spray mix containing 2 lbs/ai/10 gal water; an average concentration.

[c]Assumes a concentration of 0.1 ppm of herbicide in stream water; a worst case highest concentration ever detected.

[d]Assumes 10 gal of spray mix applied/acre and a leaf area index of 10 ft^2 foliage/ft^2 ground surface; an average case.

[e]Assumes 0.1 mg/Kg herbicide in meat, a worst case - 5 X highest concentration ever detected in animal livers.

Summary

There are many options open to silviculturists interested in eliminating weed trees, shrubs, and climbing vines in immature hardwood stands. Selection of the most efficient application technique and most effecive herbicide can be facilitated by following the guidelines provided; however, a knowledge of the stand structure specific to the area to be treated and a familiarity with local conditions that may affect herbicide efficacy are equally important. As with any new cultural technique, vegetation management in immature hardwood stands using herbicides should be tried on a small test basis before large-scale treatment is attempted.

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MICROCOMPUTERS: A TOOL TO MANAGE IMMATURE APPALACHIAN HARDWOODS

Arlyn W. Perkey and Lloyd Casey, Jr.

Forest Management Field Representative
NE Area State and Private Forestry
Morgantown, WV 26506

and

Forester
NE Area State and Private Forestry
Northeastern Forest Experiment Station
Broomall, PA 19008

ABSTRACT

This paper identifies several examples of computer programs that may be used in managing immature Appalachian hardwoods. The purpose of the software, input required, output produced, recommended uses, and required hardware are described for six programs--SILVAH, Central States TWIGS, GROAK, GROPOP, TSI, and CRUISE.

SILVAH

Program Description

SILVAH (Silviculture of Allegheny Hardwoods) was developed by Marquis et al. (1984) of the Northeastern Forest Experiment Station at Warren, PA. The SILVAH program provides a prescription based on data generated by a 10 basal area factor (BAF) variable plot cruise of overstory conditions combined with a regeneration and stand condition survey. The program offers the practicing forester a powerful tool for performing calculations and preparing prescriptions. One part of the program's output, a "plain English" summary of the stand and prescription can be particularly useful to consulting or service foresters dealing with private landowners. The current BASIC version of SILVAH that is available for the IBM PC is suitable for use with stands that consist predominantly of yellow-poplar, black cherry, white ash, red oak, sugar maple, and red maple. A second version will be available in about a year that will be suitable for use in oak stands.

Output

The program transforms overstory sample data into a comprehensive stand summary by species, including basal area and number of trees/acre, relative stand density (stocking), board foot volume,

cubic foot volume, cordwood volume, and approximate dollar value. Diameters and years to maturity are also calculated for each species and for the stand as a whole. Understory information is summarized by the user in percentages of sample plots that meet the various guidelines. Certain external factors, such as deer pressure and management constraints on even-age harvesting practices, are considered if provided by the user.

When a cut is prescribed, key variables describing the cut and residual stand are produced. This includes the "plain English" summary (see Appendix B), a basal area table by species and size class, a marking guide for any prescribed cut, and an estimate of error from the overstory cruise.

Input

Input for the program should be recorded on tally sheets designed to facilitate efficient entry of data into the computer. The overstory is sampled with 10 BAF points: every tree 1.0 inch dbh and larger is recorded by species and 1- or 2-inch diameter class. Merchantable height and a quality code may also be recorded. Understory sampling is based on a 6-foot radius plot for some categories and a 1/20-acre (26.3-foot radius) plot for others. On the 6-foot radius plot, numbers of established desirable seedlings, saplings, potential residual trees, beech root suckers, and striped maple stems are checked against guidelines. On the larger plot, percentage of cover of interfering ferns and grasses are checked, as well as limiting site conditions (wetness and rockiness). Ten overstory plots are recommended in small uniform stands; additional plots will be needed in stands with less uniform conditions or areas with >20 acres. Two understory plots should be taken for every overstory plot, as understory conditions tend to vary more than conditions in the overstory. The output from this, or any program, is only as good as the data it processes.

Recommended Use

Prescription's from SILVAH are designed to complement the forester's good judgment, not supersede it. No computer program can "analyze" a forest stand with the insight a practicing forester brings to the job. No stand is exactly average, and only a person who knows the woods can tell when the special features that distinguish a particular stand from the average are important enough to merit special consideration. Successful silviculture still depends on skilled, professional application.

SILVAH and its prescriptions are intended to serve as a tool for the forester to do the routine and repetitive calculations involved in stand summary and methodically check common contingencies and guidelines involved in prescription writing. This frees the forester for more productive work, and ensures that the work is backed up by the best guidelines available. For owners with 50 or more stands, it may be worth combining SILVAH with a data base management system to

enable the forester to electronically sort and compile stand information for the landowner.

Users in the Appalachian Region need to be particularly aware of the species composition and site characteristics in their stands, and to compare them to the data base used to construct the model. It is recommended that anyone intending to use the program extensively attend the week-long Allegheny hardwoods silvicultural training course at the Kane Experimental Forest in northwestern Pennsylvania. This training provides insight into the prescription process used by the program, and a feeling for the forest conditions in the region where much of the program data base originated.

When version 3.01 becomes available, it should be very useful in the Appalachian Region since it will make more valid prescriptions for oak stands that we so frequently encounter in our area. The new version will also incorporate: a) a soils subroutine; b) a wildlife subroutine; c) a growth simulator for Allegheny hardwoods; and d) an installation subroutine that allows users to adapt SILVAH to their region and organizations.

Data from two undisturbed immature Appalachian stands were processed using SILVAH. Both stands had stocking percentages just below the threshold for thinning, so a no-work prescription was produced. The new version (3.01) of SILVAH will have a statement advising the user that the stand is near the threshold for thinning, so the manager will be alerted, and may consider doing the practice. The preliminary copy of version 2.10 of SILVAH that I tested does have several bugs and pitfalls that can cause frustration. However, there is a documented list of warnings to help avoid these pitfalls. These bugs will be eliminated when version 2.10 is officially released in 1986. SILVAH is a good labor-saving tool to use in many immature Appalachian hardwood stands.

Central States TWIGS

Program Description

TWIGS (The Woodsman's Ideal Growth Projection System) is a microcomputer program that projects the growth of individual trees in stands (Belcher 1982). It is an offshoot of STEMS (Stand and Tree Evaluation and Modeling System), and like STEMS, it was developed at the North Central Forest Experiment Station. Cental States TWIGS is a version of TWIGS that is based on data collected in Missouri, Indiana, and Illinois. It uses an individual tree distance-independent model that provides detail about trees and stand dynamics. Because each tree within the stand is projected individually (as a member of a competing community), the system offers users the opportunity to tailor output and silvicultural treatments to meet specific objectives. TWIGS is designed for the user to examine one forest stand at a time, and explore the effect of various management alternatives on stand growth and yield. A menu of basic cutting actions allows stand management to be simple or complex according to the combination of actions the user selects.

An economic subsystem in TWIGS allows simple investment analysis of the results of management actions. Values are computed for cut trees and for the residual stand based on stumpage prices set by the user. Income from the sale of cut trees as well as other costs and incomes are used to calculate net present value and a benefit cost ratio at a range of interest rates also set by the user.

Output

The output includes a stand summary table that indicates the number of trees/acre, basal area/acre, average dbh, and average current annual increment. A volume table presents board feet/acre, cords/acre, cubic feet/acre, and tons/acre by species (see Appendix C). Economic output is displayed in table form when requested by the user.

Input

The input can be obtained from data collected on variable radius plots, fixed radius plots, or almost any other type of cruise. Input can take the form of an actual tree list, entered by the user, or a list can be generated using a Normal or Weibull distribution curve. To create a viable tree list, the field inventory should include stand age, stand site index, and inventory year. In all aged stands, use the age of the component most likely to be managed. If a variable plot cruise is used, it is necessary to record the basal area factor, and tally the trees by U. S. Forest Service Forest Survey code, dbh, and tree class. Crown ratio may be collected in the field, or the program can calculate it for individual trees. To assure the best results, the following cautions should be observed: include at least 10 sampled trees/tree list; avoid projection of plantations; limit the total projection to 30 years.

Recommended Use

Central States TWIGS is designed for use in the Midwest, not in the Appalachians. It predicts average growth and mortality for the region where it was developed. However, there are numerous stands in the Appalachians that may be expected to respond similarly to stands in the Midwest. Consequently, there are instances when this program can be applied here, but some precautions must be observed. The species composition of Appalachian hardwood stands may vary significantly from central hardwood stands, so some Appalachian species may not be used in TWIGS. Also, all species used in the program are not equally represented in the data base. The species with greatest representation were the oaks, hard maple, and shortleaf pine. Eastern redcedar, yellow-poplar, and tupelogum are poorly represented in the data base, and confidence in projections for the species is diminished accordingly. Best results can be expected for species that have many samples in the data base, and are growing within the range of stand conditions described as follows:

Even-aged and uneven-aged mixed hardwood forest stands and softwood stands of natural origin;
Site indices--40 to 99 feet (majority between 65 to 75 feet);
Basal areas--25 to 125 ft^2;
Mean stand diameters--2 to 20 inches dbh (majority between 4 to 21 inches dbh).

Six runs were processed through TWIGS with data from growth plots measured at the West Virginia University Forest near Morgantown, WV. Basal areas for all commercial species 4 inches dbh and above were projected and compared to actual measured basal areas for those plots. Three of these runs were with data from cove hardwood plots, and three were from oak plots (Table 1). The program did very well at predicting basal area for the oak plots, but was poor at predicting basal area for the cove hardwood plots. Yellow-poplar was the predominant species on the cove hardwood plots, and as noted earlier, it is poorly represented in the TWIGS data base.

Table 1. Predicted versus actual measured basal area on six West Virginia plots using Central States TWIGS and GROAK programs.

Stand	Hardwood type	Initial age	Site index	Predicted period	Predicted BA		Actual BA
					GROAK	TWIGS	
		years	feet	years	-----square feet------		
1951-5	Cove	17	77	25	-	93.5	116.7
1951-6	Cove	17	83	10	-	98.1	112.9
1951-6	Cove	27	83	15	-	100.9	134.1
1953-2	Oak	19	77	15	84	83.9	81.1
1953-3	Oak	19	77	15	88	79.5	85.7
1953-5	Oak	19	77	15	90	93.7	90.0

This cursory test with these plots does not provide conclusive evidence that the model is or is not appropriate for use in this area. Until more validation is done, we suggest using the program with caution in the oak type, and do not advise using TWIGS in cove hardwood stands.

Pocket Computers and Programmable Calculators

Electronic data processing does not necessarily require elaborate equipment. Sometimes the most cost effective option is to use a short program on a small machine. Pocket computers are compact microcomputers that are relatively inexpensive and portable. The memories are small, often less than 16K, but these pocket computers have the capability of performing a surprising number of functions. Pocket computers and programmable calculators may be used in the field

to perform some rather handy calculations. The following are three brief examples.

1. Basal Area Calculation

Foresters may calculate the basal area of individual trees, and summarize it by species, or any other grouping. This can be done by starting with the familiar equation as $A=\pi R^2$, to calculate the cross-sectional area of the tree at dbh. R (radius) is equal to dbh/2, so our equation becomes $A=\pi(dbh/2)^2$. To get A in square feet, dbh must be in feet, so our equation becomes

$$A=\pi(dbh/2/12)^2 \text{ or } A=\pi(dbh/24)^2$$

Many programmable calculators and pocket computers can be programmed to prompt the user for input, and perform the calculation after receiving the response. For example, a program could easily be written to query the user for dbh in inches, and then calculate and display basal area in square feet. This output could then be summarized and held in memory for later use.

2. Compute the Limiting Distance for "In" Trees on Variable Plot Cruises

Foresters doing variable plot cruises need to measure the limiting distance for borderline trees to determine if they are "in" trees that must be sampled. Traditionally these distances have been obtained from tables for various basal area factors and tree diameters. As an alternative, these distances can easily be calculated after the user inputs the dbh of the borderline tree.

The following is an example of how this program, written in BASIC, calculates the limiting distance from the plot center to the edge of the tree.

```
 10:  Print "LD-VP, PC-1"
 30:  Input "Basal Area Factor?",B
 40:  Input "Dia. Borderline Tree?",D
 50:  Let L=1/(√(B/10890))
 70:  Let R=L*D
 80:  Let R=R/12-D/24
 90:  Using "####.##"
100:  Print "LD-VP = ";R;" Feet."
```

3. Individual Tree Volume Calculation

Foresters may calculate and summarize the volumes of individual trees in the field. This may be done by programming an individual tree volume equation into a programmable calculator or pocket computer, and having it display the volume after the user identifies variables like diameter, merchantable height, and cull

percent. These tree volumes may be in cubic feet, cords, or board feet, and the volumes may be summarized by species or species/product classes.

The above examples are intended to give an indication of the type of very simple, but potentially valuable services this type of equipment can provide. Each user should examine their own work activities for similar opportunities.

The following programs were written for use on the Radio Shack PC-2; however, each could be easily adapted to other similar pocket computer makes and models. Current Microsoft BASIC versions of these programs are also available on the IBM PC, a full size microcomputer.

I. GROAK

Program Description

GROAK (GROw oAK) is an adaptation of Dale's (1972) FORTRAN GROAK program. It provides quantitative estimates of growth and yield for even-aged upland oak stands that will aid resource managers in selecting from among alternative management practices. GROAK is a stand level model, so the projected volume and basal area estimates apply to the stand as a whole; they cannot be segregated by species or size class (Perkey nd).

Output

For any given year, the program estimates include the following:

(1) Total basal area/acre;
(2) Number of trees/acre;
(3) Average diameter;
(4) Stocking %;
(5) Total volume ft^3;
(6) Cordwood volume (includes trees 4.6 inches dbh+ to a 4.5-inch top dob);
(7) Merchantable volume in board feet (includes trees 8.6 inches dbh+ to an 8.5-inch top dob);
(8) Merchantable volume in board feet (includes trees 12 inches dbh+ to an 8.5-inch top dob).

Appendix D is an example of GROAK output from a microcomputer.

Input

The user must specify the following stand conditions:

(1) The year from which to begin predictions;
(2) Initial stand age;
(3) Initial basal area;
(4) Initial number of trees/acre;

(5) Site index (upland oak);
(6) Output interval;
(7) Number of years to predict.

Recommended Use

This model was developed from data collected on 154 plots in the oak type in Ohio, Kentucky, Missouri, and Iowa. Species composition on these plots was primarily white and black oak. It is appropriate to use this program on sites in the Appalachians where the stand type is 80% oak-hickory, including white oak, black oak, chestnut oak, shagbark hickory, etc. The program should not be applied in stands with a significant composition of yellow-poplar, black cherry, white ash, or red oak.

The equations used in this program are valid only for the following ranges. Any predictions made based on numbers that fall outside these ranges may not be reliable.

Characteristic	Valid Range
Age	19 to 110 years
Basal area	15 to 130 ft^2
Number trees	20 to 750 trees/acre (Note: When age is greater than 50, number of trees/acre cannot exceed 500)
Site index	50 to 90 (base age: 50)

This program was tested with data from three growth plots on the West Virginia University Forest near Morgantown, WV (Carvell 1973). The predicted basal areas were quite close to the measured basal areas for those plots (Table 1). Although it was a very small sample, the results were consistent with those experienced in the Appalachian Region over the past 2 years of program use.

II. GROPOP

Program Description

GROPOP (GROw POPlar) provides quantitative estimates of growth and yield for even-aged yellow-poplar stands to help resource managers evaluate alternative management practices (Perkey nd). The model is based on data measured on 123 permanent sample plots located in Greenbrier, Monongalia, Preston, Randolph, and Nicholas Counties, West Virginia (Schlaegel et al. 1969a, b). The species composition of the stands in the data base consisted of at least 75% yellow-poplar varying in age from 26 to 80 years on sites with a site index of 57 to 110 feet. GROPOP is based on a stand-level model, so the projected volume and basal area estimates apply to the stand as a whole, and they cannot be segregated by species or size class.

Output

For any specified year, the program estimates include:

(1) Total basal area/acre;
(2) Total volume in ft^3 (to a top dob of 4.0 inches);
(3) Merchantable volume in cords (to a top dob of 4.0 inches;
(4) Merchantable volume in board feet (includes trees 10.0 inches dbh+ to a top dob of 5.0 inches).

Appendix E is an example of GROPOP output from a microcomputer.

Input

The user is prompted to input the following stand conditions:

(1) The year from which to begin predictions;
(2) Initial stand age;
(3) Initial basal area;
(4) Site index (yellow-poplar);
(5) Output interval;
(6) Number of years to predict.

Recommended Use

This program is suitable for use in northern Appalachia in stands that contain a high percentage of yellow-poplar. It is inadvisable to use the program with stands that do not have a species composition of at least 75% cove hardwoods. An important application is the comparison of management strategies, to obtain estimates of the effect of different treatments on stand characteristics.

A similar stand level model developed for use in the southern Appalachians exists for yellow-poplar. A notable difference between the two is that higher volumes are predicted by the West Virginia model.

III. TSI

Program Description

The TSI (timber stand improvement) program computes estimated costs of stand treatment from removal prescription data obtained from 10 BAF points. It is designed for use with TSI operations that kill trees larger than 3 inches dbh, with or without the use of herbicides. This program is a good example of how a small microcomputer can provide assistance to the land manager by efficiently estimating costs for timber investments that require hand labor and herbicides.

The program is based on information from "TSI Cost Computations" (Ashley 1972). Time required to do the work is based upon a wide range of averages, and the estimates apply principally to using an axe and hand sprayer. However, the overall costs vary little among methods and equipment since the equipment charges are higher for the treatment which yields greater accomplishments. The costs involve all time expended to carry out the operation beginning with the departure from the farmstead and ending with returning to the farmstead. Time estimates are averages for relatively inexperienced personnel.

Output

The program output is:

(1) Landowner's name;
(2) Estimator's name;
(3) Date;
(4) Number of plots;
(5) Number of acres;
(6) Wage rate;
(7) Chemical cost/acre;
(8) Cost data by diameter class;
    (a) Number of trees in sample;
    (b) TSI time estimates/acre;
(9) Treatment time in hours/acre;
(10) Chemical cost/acre;
(11) Total treatment time for the stand;
(12) Total cost/acre;
(13) Total treatment for stand cost;

Appendix F is an example of TSI output from a microcomputer.

Input

The required inputs are:

(1) Number of 10 BAF points;
(2) Chemical cost/acre;
(3) Hourly wage rate;
(4) Landowner's name;
(5) Estimator's name;
(6) Number of acres to be treated;
(7) Date;
(8) Number of treated trees for all sample points in each dbh class.

Recommended Use

This program is suitable for use when estimating TSI costs in many stands, including immature Appalachian hardwoods. It is a good example of how John Anderson, a practicing service forester

in West Virginia, used relatively inexpensive equipment to write a program that enabled him and others to perform a routine task more efficiently.

IV. CRUISE

Program Description

This cruise program estimates volume/acre in board feet, cords, and tons for sawtimber, pine pulpwood, and hardwood pulpwood. It also computes coefficient of variation and error for these estimates at the 95% confidence level. These volume estimates are based on a modification of the shortcut formulae found in "Reference Handbook for Foresters" (Ashley 1980). The program can be used to estimate total stand volume by product, or cut volume by product.

Note: This is not the CRUISE program available from Forestry Suppliers, Inc.

Output

Output from the program is:

(1) Volume;
    (a) Cords/acre and tons/acre for pine and hardwood pulpwood;
    (b) Board feet/acre and tons/acre for sawtimber;
(2) Error estimates for each of the above volume estimates;
(3) Basal area by species/product class;
(4) Summary;
    (a) Total trees/acre;
    (b) Mean stand diameter;
    (c) Total basal area/acre;
    (d) Total cubic foot volume/acre;
    (e) Average volume/acre in cords;
    (f) Total error.

Appendix G is an example of CRUISE output from a microcomputer.

Input

The input for the program is obtained from a 10 BAF cruise, and it includes the following:

(1) Number of points measured;
(2) Number of trees counted on all 1/20-acre plots (this item is optional, and may be disregarded if mean stand diameter and total number of trees/acre are not needed);
(3) Number of small trees (this refers to trees counted as "in" trees on the 10 BAF cruise, but are unmerchantable due to their small size);

(4) Number of trees and 8-foot sticks for each point;
(5) Number of trees and 16-foot logs for each point.

Recommended Use

This program is suitable for estimating timber volume from 10 BAF points. Volume estimates obtained from the program are based on shortcut formulae, not precisely researched volume equations. When selling high value sawtimber on a presale measurement basis, users should utilize one of a number of other programs available on microcomputers.

The sawtimber formula from the "Reference Handbook for Foresters" (Ashley 1980) has been modified for local conditions by the program developer to more accurately reflect the yields experienced in southern Maryland. This modification can be altered by changing one number in the formula used in the program. CRUISE uses conversion factors of 2.7 tons/cord of hardwood pulp, and 2.6 tons/cord of pine pulp. These numbers can also be adjusted.

This program was developed by Kip Powers, a practicing project forester in southern Maryland. It is an example of how a routine job can be done more efficiently by using a relatively inexpensive pocket computer and a short program.

Summary

The software computer programs described were selected as examples of how microcomputers can be used to manage immature Appalachian hardwoods more effectively. SILVAH is a stand summary and prescription program that analyzes inventory data and frees the forester from routine number crunching. Central States TWIGS is an individual tree growth and yield model that predicts future stand characteristics such as basal area and volume. It helps the forester develop realistic expectations of what may happen in the forest under different management strategies. GROAK and GROPOP do the same thing, but they are based on stand level models so they are more limited in the amount of detailed stand information they can provide. They are useful only in stands that meet specified species composition requirements. TSI is a program that estimates the cost of doing timber stand improvement based on the number of trees to be treated by diameter class. CRUISE is a short program designed to give an estimate of stand volume based on shortcut formulae using the number of trees and sticks (or logs) on 10 BAF points.

Appendix A. Software, hardware, and available source.

Software	Hardware	Contact
SILVAH	IBM PC COMPUTER or a compatible microcomputer, 128 K memory capacity, DOS (Disk Operating System), Single or double disk drive, monitor, 80-column printer (optional).	Northeast Computer Institute 1315 South Allen Street State College, PA 16801
TWIGS	APPLE II COMPUTER, 65 K memory capacity, Pascal operating system, 2 disk drives, 80-column printer, monitor, or the IBM PC 192K memory capacity, DOS (Disk Operating System) 1.1 or 2.0, 2 disk drives, monitor, 80-column printer (optional).	Nancy Walters NC Forest Experiment Station 1992 Folwell Avenue St. Paul, MN 55108
GROAK	IBM PC or Osborne Executive computer, monitor, printer- or the Radio Shack PC-2 with printer cassette interface.	Arlyn W. Perkey USDA Forest Service P. O. Box 4360 Morgantown, WV 26505
GROPOP	IBM PC or Osborne Executive computer, monitor, printer- or the Radio Shack PC-2 with printer cassette interface.	Arlyn W. Perkey USDA Forest Service P. O. Box 4360 Morgantown, WV 26505
TSI	IBM PC computer or the Radio Shack PC-2 with printer cassette interface.	John L. Anderson Box 578 Petersburg, WV 26847
CRUISE	IBM PC computer or the Radio Shack PC-2 with printer cassette interface.	Kip Powers Doncaster State Forest Route 1, Box 425 Indian Head, MD 20640

Appendix B. Excerpt from a sample SILVAH output.

```
**************************************************************************
        SILVAH - Silviculture of Allegheny hardwoods - v2.10
    Stand Summary, Prescription and Management Simulator Program
 Developed by the Northeastern Forest Experiment Station, Warren, PA
**************************************************************************
Owner/Agency     -- West Virginia
Forest/Property  -- Coopers Rock
County/District  -- University          Page          -- 4
Compt/Unit No.   -- 1                   File          -- B:COOPER
Stand Number     -- 5                   Date Tallied  -- 10/1976
Acres            -- 1.00                Print Date    -- 10/22/1985
```

This transition stand is dominated by yellow-poplar, red oak, non-commercial species and other oaks which together comprise 92% of the basal area.

This is a large poletimber stand with an average diameter of 9.8 inches. Sapling trees too small to be merchantable do not represent a significant proportion of stand stocking and need not be included in any partial cuttings.

If this stand is managed under an even-age silviculture system, the several species groups will mature at markedly different times. The average number of years to maturity is 50. The effective stand age is about 57 years.

If this stand is managed under an all-age silviculture system, the distribution of diameters and proportion of sawtimber would make it difficult to apply selection cutting.

Relative stocking density is 80% of the average maximum stocking expected in undisturbed stands of similar size and species composition. This density is in the optimum range for best individual tree growth. At this relative density, growth rate of the biggest trees is probably excellent, while growth rate of the medium and smaller-sized trees is probably good and mortality due to crowding low.

Partial cutting to provide more growing space for the better stems is not necessary at this time.

Total growing stock amounts to 120 ft^2 of basal area/acre. Total volume in all trees, to a 4-inch top, is 1,899 ft^3/acre; if divided into pulpwood and sawtimber, the merchantable volume available is 14 cords of pulpwood and 3,200 board feet of sawtimber International 1/4-inch rule, or 1,885 board feet Doyle rule. The total stand value is estimated to be about $131/acre.

----------Recommended Treatment----------

The most desirable treatment for this stand is to defer any cutting now and re-examine the stand in about 10 years. Stand density is presently adequate and no partial cutting is necessary.

Appendix C. Excerpt from a sample TWIGS output.

****

Report for stand "UNIV-53" Year - 1968. After projection cycle.
Age = 34, cycle = 1, stand site index = 77.0

Species Gr.	Live Tree/AC	BA/ Acre	Avg Dbh	Avg CAI	Cut Tree/Ac	Cut BA/Ac	Mortality Tree/Ac	Mortality BA/Ac
Tupelo	106	21.3	5.9	0.07	0	0.0	14	1.9
Soft maple	34	11.9	7.9	0.26	0	0.0	12	1.9
Yellow-poplar	2	0.6	8.4	0.25	0	0.0	0	0.1
White oak	67	18.5	7.0	0.13	0	0.0	5	0.8
Red oak	65	25.5	8.3	0.18	0	0.0	7	1.3
Chestnut oak	54	13.9	6.6	0.12	0	0.0	12	1.5
Othr up.hard	10	2.0	5.9	0.11	0	0.0	10	1.1
Totals	338	93.7	6.9	0.13	0	0.0	60	8.7

++++++++++

Note: Mortality values are for 1953 to 1968

Board foot volumes in International 1/4-inch.

Volumes	Sawtimber		Pulpwood		Residue	
Species Gr.	cuft	bdft	cuft	cords	cuft	tons
Tupelo	0	0	140	1.8	254	7.9
Soft maple	0	0	237	3.0	107	2.4
Yellow-poplar	0	0	9	0.1	7	0.1
White oak	0	0	313	4.0	133	4.1
Red oak	78	520	363	4.6	202	6.4
Chestnut oak	43	290	149	1.9	83	2.6
Othr up.hard	0	0	18	0.2	19	0.4
Totals	122	810	1229	15.6	805	23.9

****

Appendix D. Example of GROAK output from a microcomputer.

```
**********************************************************************
       GROAK - A STAND PROJECTION MODEL FOR UPLAND OAK STANDS
**********************************************************************
INITIAL YEAR = 1985
INITIAL AGE = 50 YEARS
INITIAL BASAL AREA = 65 SQ. FT/AC.
INITIAL NO. TREES/AC = 175
SITE INDEX = 70
OUTPUT INTERVAL = 10 YEARS
PREDICTED INTERVAL = 20 YEARS

                ++++++INITIAL STAND PARAMETERS++++++

MEAN STAND DIAMETER = 8.3 INCHES
STOCKING PERCENT = 61%
CUBIC FOOT VOLUME = 2,159 CU. FT./AC.
CORDWOOD VOLUME = 19.6 CORDS/AC.
BOARD FOOT VOLUME = 3,068 BD. FT./AC.
BOARD FOOT VOLUME = (12 IN.+) = 1,446 BD. FT./AC.

                ===== PROJECTED STAND PARAMETERS =====
YEAR = 1995
AGE = 60 YEARS
BASAL AREA = 80 SQ. FT./AC.
NUMBER OF TREES/ACRE = 157
MEAN STAND DIAMETER = 9.7 INCHES
STOCKING PERCENT = 71%
CUBIC FOOT VOLUME = 2,871 CU. FT./AC.
CORDWOOD VOLUME = 26.3 CORDS/AC.
BOARD FOOT VOLUME = 6,825 BD. FT./AC.
BOARD FOOT VOLUME (12 IN.+) = 4,084 BD. FT./AC.

                ===== PROJECTED STAND PARAMETERS =====

YEAR = 2005
AGE = 70 YEARS
BASAL AREA = 92 SQ. FT./AC.
NUMBER OF TREES/ACRE = 140
MEAN STAND DIAMETER = 10.9 INCHES
STOCKING PERCENT = 78%
CUBIC FOOT VOLUME = 3,456 CU. FT./AC.
CORDWOOD VOLUME = 31.7 CORDS/AC.
BOARD FOOT VOLUME = 10,417 BD. FT./AC.
BOARD FOOT VOLUME (12 IN.+) = 6,953 BD. FT./AC.
----------------------------------------------------------------------
TOTAL GROWTH FOR 20 YEAR PERIOD

BASAL AREA GROWTH = 26.5 SQ. FT./AC.
CORDWOOD VOLUME GROWTH = 12.1 CORDS/AC.
BOARD FOOT VOLUME GROWTH = 7,349 BD. FT./AC.
**********************************************************************
```

Appendix E. Example of GROPOP output from a microcomputer.

```
**********************************************************************
     GROPOP - A STAND PROJECTION MODEL FOR YELLOW-POPLAR STANDS
**********************************************************************

Site Index = 85

+++++INITIAL STAND PARAMETERS+++++

YEAR = 1986
AGE = 40 YEARS
BASAL AREA = 100 SQ. FT./AC.
CUBIC FOOT VOLUME = 3,036 CU. FT./AC.
CORD VOLUME = 37.9 CORDS/AC.
BOARD FOOT VOLUME = 9,763 BD. FT./AC.

===== PROJECTED STAND PARAMETERS =====

YEAR = 1991
AGE = 45 YEARS
BASAL AREA = 116 SQ. FT./AC.
CUBIC FOOT VOLUME = 3,604 CU. FT./AC.
CORD VOLUME = 45.1 CORDS/AC.
BOARD FOOT VOLUME = 12,293 BD. FT./AC.

===== PROJECTED STAND PARAMETERS =====

YEAR = 1996
AGE = 50 YEARS
BASAL AREA = 130 SQ. FT./AC.
CUBIC FOOT VOLUME = 4,135 CU. FT./AC.
CORD VOLUME = 51.7 CORDS/AC.
BOARD FOOT VOLUME = 14,782 BD. FT./AC.

===== PROJECTED STAND PARAMETERS =====

YEAR = 2001
AGE = 55 YEARS
BASAL AREA = 144 SQ. FT./AC.
CUBIC FOOT VOLUME = 4,627 CU. FT./AC.
CORD VOLUME = 57.8 CORDS/AC.
BOARD FOOT VOLUME = 17,188 BD. FT./AC.
----------------------------------------------------------------------
PERIODIC BASAL AREA GROWTH = 43.7 SQ. FT./AC.
PERIODIC CORDWOOD GROWTH = 19.9 CORDS/AC.
PERIODIC BOARD FOOT VOLUME GROWTH = 7,426 BD. FT./AC.
**********************************************************************
```

Appendix F. Example of TSI output from a microcomputer.

****

TSI

****

LANDOWNER: A. Moneymaker
ESTIMATOR: Fred Forester
DATE: 10-28
NUMBER OF PLOTS: 10
NUMBER OF ACRES: 20
WAGE RAGE: $5.00/HR.
CHEMICAL COST: $20.00/acre

** TIME DATA**

DBH CLASS (inches)	NUMBER OF TREES	TIME ESTIMATE/DBH CLASS (hours/acre)
3.0	2	0.9
4.0	4	1.3
5.0	6	1.7
6.0	4	0.6
7.0	5	0.7
8.0	3	0.4
10.0	2	0.2
12.0	1	0.1
14.0	0	0.0
16.0	0	0.0
18.0	0	0.0
20.0	0	0.0
22.0	0	0.0
24.0	0	0.0
26.0	0	0.0
28.0	0	0.0

HOURS PER ACRE: 5.82/hr/acre
CHEMICAL COST: $20.00/acre
TOTAL TIME: 58.2 hr

TOTAL COST/ACRE: $49.10
TOTAL COST: $982.00

END

****

Appendix G. Example of CRUISE output from a microcomputer.

```
**************************************************************************
                                  CRUISE
**************************************************************************
Number of plots = 10

Hardwood Pulp

#TREES      #STICKS
  5.0          14.0
  8.0          28.0
  8.0          24.0
  6.0          14.0
  6.0          21.0
  6.0          16.0
  7.0          17.0
  8.0          27.0
  9.0          30.0
  5.0          15.0

CORDS/AC. = 13.4
TONS/AC. =  36.3
POLE BA/AC = 68.0 SQ. FT.
COEFFICIENT OF VARIATION = 28.1%
ERROR = 17.8% at the 95% confidence level

SAWTIMBER

#TREES      #Logs
  2.0          3.0
  1.0          1.0
  2.0          1.5
  3.0          4.0
  2.0          2.0
  1.0          1.5
  3.0          4.0
  2.0          1.5
  1.0          1.5

BD. FT./AC = 1,595
TONS/AC =    11.2
SAWTIMBER BA/AC = 17.0 SQ. FT.
COEFFICIENT OF VARIATION = 60.0%
ERROR = 37.9% at the 95% confidence level

SUMMARY
TOTAL NUMBER OF TREES/AC = 380
MEAN STAND DIAMETER = 6.4 IN.
TOTAL BA/AC = 85.0 SQ. FT.
CU. FT./AC = 1408
AV.CORDS/AC = 16.6
TOTAL ERROR = 16.1%
```

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Schlaegel, Bryce E.; Kulow, D. L. Baughman, R. N. Empirical yield tables for West Virginia yellow-poplar. Bulletin 574T. Morgantown, WV: West Virginia University Agricultural Experiment Station; College of Agriculture and Forestry; March 1969. 24 p.

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AVAILABLE ASSISTANCE AND INFORMATION--WHERE?

William E. Kidd, Jr. and Arlyn W. Perkey

Professor of Forestry and Extension Specialist-Forest Management
West Virginia University

and

Forest Management Field Representative
Northeast Area State and Private Forestry
Morgantown, WV 26506

ABSTRACT

Great stores of information have been generated by the forestry research community. This paper describes how foresters can gain access to needed information about managing immature stands of Appalachian hardwoods directly from experiment stations. The paper also describes how foresters can gain access to information that is filed in the several electronic databases and reports on the services provided by SOUTHFORNET in retrieving management information from electronic databases.

Nearly 30 years ago a much beloved wildlife management professor at Virginia Polytechnic Institute, Henry S. Mosby, in his parting advice to the six or seven senior forest management students advised that we keep abreast of the times by placing our names on the mailing list of forest research stations throughout the country. Well - I did and my literature file has grown and grown and groan! It has "stood-me-in-good-stead" over the years, serving as a source of information for myself and my colleagues. But it has become unmanageable. I began early to fill out file cards with abstracts and such, but that became such a burdensome job that I finally gave it up. Now research publications that come to me from the Forest Service have a library card with an abstract printed on the inside of the back cover. But it still becomes a lot for one person to manage, and you know what falls by the wayside in the pressure cooker of the everyday work world! Then when you need information it is buried so deep that it is difficult to find.

Today, with the advent of computers and electronic databases one has but to enter a set of keywords and PRESTO! information about everything that has or is being done will materialize instantly before you.

Before we explore the world of electronic databases, let's review some of the more conventional sources of information that are available to foresters and landowners.

Sources of Research Information

Research organizations

The U.S. Forest Service operates experiment stations at various locations about the United States. A list of research publications is available from each of the stations as is a summary of current research projects. Persons interested in receiving copies of research publications need only to ask to be placed on the mailing list indicating their area of interest. Following is a list of these stations in the general area of the Appalachian hardwood region.

Northeastern Forest
Experiment Station
370 Reed Road
Broomall, PA 19008

Southeastern Forest
Experiment Station
200 Weaver Blvd.
Asheville, NC 28804

North Central Forest
Experiment Station
1992 Folwell Ave.
St. Paul, MN 55108

Southern Forest
Experiment Station
Rm. T-10210, 701 Loyola Ave.
New Orleans, LA 70113

Another valuable source of research information comes from the forestry schools at the land-grant universities in the region. All have on-going research programs in the biological, physical, and social sciences which generate new knowledge about the management of forests. One needs only to write to the directors and request they be placed on the mailing list to receive publications on research topics of interest. Following is a list of experiment stations in the general area of the Appalachian hardwood region:

Agricultural Experiment Station
University of Kentucky
Lexington, KY 40506

Agricultural Experiment Station
University of Maryland
College Park, MD 20742

New York Agricultural
Experiment Station
Cornell University
292 Roberts Hall
Ithaca, NY 14853

North Carolina Agricultural
Research Service
North Carolina State University
Box 7601
Raleigh, NC 27695-7601

Ohio Agricultural Research
and Development Center
Ohio State University
Columbus, OH 43210

Ohio Agricultural Research
and Development Center
Ohio State University
Wooster, OH 44691

Agricultural Experiment Station
229 Agricultural Admin. Bldg.
Penn State University
University Park, PA 16802

Agricultural Experiment Station
University of Tennessee
P. O. Box 1071
Knoxville, TN 37901

Agricultural Experiment Station
College of Agriculture and
Life Sciences
VPI & State University
Blacksburg, VA 24061

Agricultural Experiment Station
College of Agriculture and
Forestry
West Virginia University
Morgantown, WV 26506-6108

Additionally the forestry school at Syracuse University and the graduate schools at Duke University, Yale University, Harvard, and the Ohio Agricultural Research and Development Center, Wooster, Ohio, all conduct research programs which generate new knowledge about the management of forests.

Publications

Several of the forestry schools in the region publish research notes. For example, West Virginia University publishes Forestry Notes; Penn State publishes an Annual Report of Research and Extension; Virginia Polytechnic Institute publishes Forestry and Wildlife Series. One has only to write and request these publications. If you are on their mailing list, the publications will be sent to you as they become available.

Then, of course, there are the professional journals: Journal of Forestry; Northern Journal of Applied Forestry; Forest Science; Southern Journal of Applied Forestry; and a Western Journal of Applied Forestry. With the exception of the Journal of Forestry, the above publications are obtained by subscription from:

The Society of American Foresters
5400 Grosvenor Lane
Bethesda, MD 20814

The applied journals are $15/year to members; $22/year to non-members. Forest Science, a quarterly publication, is $20/year to members, $30/year to non-members with a $5 additional fee for subscriptions outside the United States and Canada in each instance.

In the Journal of Forestry, the section on "New Information" is particularly appropriate to this discussion. Each month new books are reviewed. The section has a listing of publications from various sources under the headings of: general, administration, ecology, noncommodity uses, measurement, protection, silviculture and utilization.

CASTANEA, the Journal of the Southern Appalachian Botanical Club is another source of information. "Plant Community Composition and Structure in a Central Appalachian Forest Stand 25 Years After Timber Stand Improvement" appeared in the March 1985 issue. "Vegetation Patterns on a Southern Appalachian Watershed After Successive Clearcuts" appeared in the September 1985 issue. The address of the managing editor is:

Department of Biology
University of North Carolina
Charlotte, NC 28223

CASTANEA is in the library of the Forestry School at West Virginia University. You may find it at colleges and universities in your state, perhaps in the main library, the biology departments or forestry schools.

Two publications list current literature in forestry, Forestry Abstracts and Social Sciences in Forestry - A Current Selected Bibliography. Each has a comprehensive listing of forestry publications from the international community. They are a library resource and are usually available in the libraries of colleges and universities that have forestry programs. A note in the September 1985 issue of Social Sciences in Forestry says that loans or xerox copies of publications indexed are available from:

The Interlibrary Loan Division
St. Paul Campus Libraries
1984 Buford Avenue
St. Paul, MN 55108

Some publications in the Appalachian hardwood region print articles about the management of forests in a somewhat more popularized style than that which appears in research publications or professional journals. Two such publications are the Northern Logger published by:

The Northeastern Loggers' Association
Old Forge, New York 13240

Forest Farmer published by:

The Forest Farmers' Association
P. O. Box 7278, Station C
Atlanta, GA 30309

Both are available by subscription. Copies are available in the reading room of the West Virginia University forestry school. You need to inquire about the availability at other forestry schools.

There are a number of newsletters from different sources. To receive them, you must be on the mailing list of the organization preparing them. For example, I do an "Occasional Letter" which covers topics appropriate to the moment. It is mailed to the foresters and wildlife biologists whose names appear in the "Directory of Natural Resources Professionals Practicing in West Virginia". Likewise the "Hardwood Forestry Bulletin", the newsletter of the Hardwood Research Council is mailed to members of the Council. The address of the Council is:

P. O. Box 131
Asheville, NC 28802

This Bulletin is an excellent source of hardwood management information.

Arlyn Perkey provides information for those interested in silviculture and mensuration, through his "Forest Management Update" which is published at intervals, depending upon the need. To place your name on his mailing list just write him at:

P. O. Box 4360
Morgantown, WV 26505

Additionally State and Private Forestry, U.S. Forest Service both in the Northeast and South publish a monthly paper entitled either Forest-Gram North or South whichever is appropriate. You can have your name placed on the mailing list by writing to:

Southern Region
USDA Forest Service
1720 Peachtree Road, NW
Atlanta, GA 30367

or

USDA Forest Service
Northeast Area State and Private Forestry
370 Reed Road
Broomall, PA 19008

Symposia, Seminars, Workshops, Meetings

Obviously, seminars, symposia, workshops, and other such structured continuing education activities provide you with the opportunity to acquire information in concentrated doses. And just as obvious is the opportunity for information exchange at professional meetings.

Electronic (Computerized) Databases

As you suspected, access to electronic (computerized) databases is not quite as magical as I suggested earlier in this paper. But, I am sure that you knew that! Actually, there is a sort of road map that one can follow if one knows some things about the system.

There are a number of questions. What is an electronic database? What databases contain information on the subject of interest to me? What kind of information does it contain? How can it be accessed? What is the output? What is the cost? What is the best way to do a comprehensive search?

Electronic databases are a collection of records stored in computer readable form. All of the records in a database have a logical

relationship to some entity or concept. The relationship may be to something as generic as the field of forestry, or to something as specific as thinning in 30-year-old stands of northern red oak in West Virginia. The first is certainly too general; the second may be too restrictive. The kinds of information contained in databases is best discovered by reading the descriptions provided in the several directories noted further on in this paper. These directories also tell the reader precisely how to access the database and the cost.

There are several databases that include forestry files. CAB ABSTRACTS includes forestry abstracts, forest products abstracts, leisure, recreation and tourism. It is produced by:

Commonwealth Agricultural Bureau
Farhham House
Farhham Royal SL23BN Slough, United Kingdom.

The file contains more than 1.5 million records dating from 1972 to present. It is updated monthly with 150,000 records added annually. It is bibliographic in nature and includes abstracts. Documents covered by CAB include journal articles, government reports/documents, patents, monographs, books, proceedings, theses/dissertations, papers presented at conferences, newsletters, periodicals, corporate reports, etc.

AGRICOLA provides on-line access to more than 2 million records on agriculture, forestry and related subject matter in bibliographic form. It is produced by:

U.S. Department of Agriculture
National Agricultural Library
10301 Baltimore Boulevard
Beltsville, MD 20705

The file is updated monthly (except for Dialog #110). There are 140,000 new records added each year. The file dates from 1970 to the present. The output is bibliographic/item title. Photocopying and loan services are available for items listed.

CRIS, Current Research Information System, is the U.S. Department of Agriculture's computer-based documentation and reporting system for agricultural and forestry research. It contains over 27,000 descriptions of current publicly supported agricultural and forestry research projects of the USDA agencies, the State agricultural experiment stations, and other cooperating State institutions. The database is updated monthly. Approximately 3,000 new records are added annually. The most common output is usually one page per project. It lists the title, investigator name and location, objectives, approach, latest progress, and citations to the most recent publications resulting from the research.

FORESTS is produced by:

Forest Products Research Society
2801 Marshall Court
Madison, WI 53705

FORESTS covers all aspects of forest products processing from harvest. It also includes topics such as physical and chemical properties of wood. The file contains more than 18,000 records from 1947 to the present. It is updated every 2 months adding 500 to 1,000 new records each year. FORESTS is bibliographic in nature.

TIMBERMARTSOUTH is produced by:

Timber Mart-South
P. O. Box 1278
Highland, NC 28741

It is a file of price records produced since 1976. Ten new records are added each year. Database is numeric and the output is a time series of price information.

There are a number of other databases that contain forestry information but those listed above are the principal ones.

Most of the databases can be accessed directly or through an information utility vendor. If accessed directly, the user must have established an account with each database. If accessed through a vendor, the user establishes an account with the vendor and then uses that account to search the databases that are on-line with the vendor. The user is then billed by the vendor for time spent and other services used. The vendors or the databases are accessed through communications utilities such as TELENET, TYMNET, UNINET, EURONET, or DIRECT DIAL.

AgriData Resources, Inc., AgNet, BRS, Data Resources and Dialog are the names of some of the information utility vendors. Data Resources for example lists FOREST PRODUCTS, RANDOM LENGTHS, PULP AND PAPER, and TIMBERMARTSOUTH among their databases. Dialog has 200 databases on line covering all areas of science, technology, business, medicine, social science, current affairs news and humanities. It includes AGRICOLA, CRIS, and CAB among its listings.

And there are charges incurred in the use of databases. For example, in 1984 Dialog charged $55/connect hour, a telecommunication cost of $8/hour, $.25/full record on line and $.35/full record off line. Consequently, it is important that the user think through the information that is required prior to requesting service. Keywords should be identified that are appropriate and descriptive. Careful consideration of the subject will help to keep the cost of the search down.

As one begins to explore this idea of information searches using the electronic technology and databases, the complexity of the system becomes almost overwhelming to the casual user. After all, foresters in the field seldom need to use such a system. But, because there is a "system", it can be diagramed and at least generally understood. And there are printed aids to guide the inexperienced through the system. Following are several directories that contain valuable information both on databases and database vendors.

DATABASE DIRECTORY
Knowledge Industry Publications, Inc.
701 Westchester Avenue
White Plains, NY 10604

This database is in cooperation with the American Society of Information Science. It gives a description of subject, gives a summary of printed sources, subject area descriptions, producer time and coverage, vendor and price information, etc.

DATAPRO DIRECTORY OF ON LINE SERVICES
Datapro Research Corporation
108 Underwood Blvd.
Delran, NJ 08075

It describes in detail the databases offered.

COMPUTER READABLE DATABASES
Martha E. Williams
American Society for Information Science
Knowledge of Industry Publication, Inc.
701 Westchester Ave.
White Plains, NY 10604, 1982

This book is a directory and source of information for databases.

ENCYCLOPEDIA OF INFORMATION SYSTEMS AND SERVICES
4th Edition
Edited by Anthony T. Kruzas, John Schmittroth, Jr.
Gale Research Company
Book Tower
Detroit, MI 48226, 1981

This is a complete index of organizations, databases, publications, software, library management systems, on line vendors/telecommunications networks, subject index, etc., that deal with information systems.

WHAT CAN YOU USE

But for the casual user who may not have the time or the inclination to develop and maintain a working knowledge of the system, I recommend using an information service. The West Virginia University library system provides such a service. They will search the data bases

available to them after they have the appropriate information, i. e., subject, keywords, timespan, etc., that you provide.

A newly discovered (for me at least) information service is SOUTHFORNET. An anacronym for Southern Forestry Information Network, SOUTHFORNET specializes in forestry and related subject areas. An article in the Compiler 3(1) "Online Information: The SOUTHFORNET Alternative" by Virginia L. Rutherford, Coordinator, Southern Forestry Information Network, describes very well the services provided. And, as I read the article, I realized that SOUTHFORNET is not exclusively limited to databases in the South. AGRICOLA, CAB ABSTRACTS, and CRIS are all comprehensive databases. There is a charge for the services provided by SOUTHFORNET. For more information contact:

SOUTHFORNET
Science Library
University of Georgia
Athens, GA 30602 (404-546-2477)

Briefly, access to database is a matter of choice. Assuming that you have access to the directories of databases you can:

1. Access the database directly through your computer. You will need to have an account established with database-producer and will need to know the protocol for access. You will also need to know how the database is organized.

2. Access, through your computer, an information utility vendor, i.e. a system that allows access to a number of databases. Instead of establishing an account with each of the database producers you establish an account with the "database broker." They then provide you with information that allows you to communicate with them and with databases that they have contracted with.

3. Access the databases through an information service, i.e. a system that will do the information search for you. Libraries will do this, SOUTHFORNET will too.

Finally, there is an extension forester in every state in the Appalachian Region whose job is to help foresters and landowners find the information needed to manage immature stands of Appalachian hardwoods. There is an extension forester who is located at the State's land-grant university. These include West Virginia University, Cornell University, Penn State University, Ohio State University, University of Maryland, Virginia Polytechnic Institute, North Carolina State University, University of Kentucky, University of Tennessee, and University of Georgia.

And every state has a State forestry service that provides technical assistance to landowners, assisted in many ways by the U.S. Forest Service, State and Private Forestry. Additionally, there are consulting foresters and industry foresters who provide technical services to forest landowners. Lists of consulting foresters can usually be obtained either from extension or state foresters.

Hopefully, this presentation will provide you with a road map that will help you gain access to the wealth of knowledge that has been generated over the years.

APPENDIX

Common and Scientific Names of Tree Species

Hardwoods

Alder	Alnus Mill. sp.
Apple	Malus sp.
Apple, crab	Malus coronaria (L.) Mill.
Ash, white	Fraxinus americana L.
Aspen, bigtooth	Populus grandidentata Michx.
Aspen, quaking	Populus tremuloides Michx.
Basswood	Tilia americana L.
Beech, American	Fagus grandifolia Ehrh.
Birch, gray	Betula populifolia Marsh.
Birch, paper	Betula papyrifera Marsh.
Birch, river	Betula nigra L.
Birch, sweet	Betula lenta L.
Birch, yellow	Betula alleghaniensis Britton
Blackgum; Tupelogum	Nyssa sylvatica Marsh.
Boxelder	Acer negundo L.
Buckeye, Ohio	Aesculus glabra Willd.
Buckeye, yellow	Aesculus octandra Marsh.
Catalpa, northern	Catalpa speciosa Warder ex Engelm.
Cherry, black	Prunus serotina Ehrh.
Cherry, fire	Prunus pensylvanica L. f.
Cherry, pin	Prunus pensylvanica L. f.
Cherry, sweet	Prunus avium (L.) L.
Chestnut, American	Castanea dentata (Marsh.) Borkh.
Chokecherry	Prunus virginiana L.
Coffeetree, Kentucky	Gymnocladus dioicus (L.) K. Koch
Cottonwood, eastern	Populus deltoides Bartr. ex Marsh.
Cucumbertree	Magnolia acuminata
Dogwood, flowering	Cornus florida L.
Elm, American	Ulmus americana L.
Elm, slippery	Ulmus rubra Muhl.
Hackberry	Celtis occidentalis L.
Hawthorn	Crataegus L. sp.
Hazelnut	Corylus L. sp.
Hickory	Carya Nutt. sp.
Hickory, bitternut	Carya cordiformis (Wangenh.) K. Koch.
Hickory, mockernut	Carya tomentosa Nutt.
Hickory, pignut	Carya glabra (Mill.) Sweet.
Hickory, shagbark	Carya ovata (Mill.) K. Koch.
Holly, American	Ilex opaca Ait.
Honeylocust	Gleditsia triacanthos L.
Hornbeam, American	Carpinus caroliniana Watt.
Hophornbeam, eastern	Ostrya virginia (Mill.) K. Koch.
Horsechestnut	Aesculus octandra Marsh.
Locust, black	Robinia pseudoacacia L.
Maple, mountain	Acer spicatum Lam.
Maple, Norway	Acer platanoides L.

Maple, red	Acer rubrum L.
Maple, silver	Acer saccharinum L.
Maple, striped	Acer pensylvanicum L.
Maple, sugar	Acer saccharum Marsh.
Mountain ash, American	Sorbus americana Marsh.
Mulberry	Morus rubra L.
Oak, black	Quercus velutina Lam.
Oak, chestnut	Quercus prinus L.
Oak, northern red	Quercus rubra L.
Oak, pin	Quercus palustris Muenchh.
Oak, post	Quercus stellata Wangenh.
Oak, scarlet	Quercus coccinea Muenchh.
Oak, southern red	Quercus falcata Michx.
Oak, white	Quercus alba L.
Pawpaw	Asimina triloba (L.) Dunal
Pear	Pyrus communis L.
Persimmon	Diospyros virginiana L.
Poplar, Lombardy	Populus nigra var. italica Muenchh.
Poplar, silver	Populus alba L.
Redbud	Cercis canadensis L.
Sassafras	Sassafras albidum (Nutt.) Nees.
Serviceberry	Amelanchier arborea (Michx. f.) Fern
Sourwood	Oxydendrum arboreum (L.) DC.
Sumac	Rhus L. sp.
Sweetgum	Liquidambar styraciflua L.
Sycamore, American	Platanus occidentalis L.
Walnut, black	Juglans nigra L.
Walnut, butternut	Juglans cinerea L.
Willow	Salix L. sp.
Witch-hazel	Hammamelis virginiana L.
Yellow-poplar	Liriodendron tulipifera L.

Conifers

Baldcypress	Taxodium distichum (L.) Rich.
Fir, balsam	Albies balsamea (L.) Mill.
Fir, Fraser	Abies fraseri (Pursh) Poir
Hemlock, eastern	Tsuga canadensis (L.) Carr.
Larch	Larix laricina (DuRoi) K. Koch
Pine, eastern white	Pinus strobus L.
Pine, loblolly	Pinus taeda L.
Pine, pitch	Pinus rigida Mill.
Pine, shortleaf	Pinus echinata Mill.
Pine, table mountain	Pinus pungens Lamb.
Pine, Virginia	Pinus virginia Mill.
Redcedar, eastern; juniper	Juniperus virginia L.
Spruce, red	Picea rubens Sarg.

Plants Other Than Trees

Azalea honeysuckle	*Rhododendron roseum* (Loisel.) Rehd.
Blackberries	*Rubus* sp.
Blueberries	*Vaccinium* sp.
Elderberry	*Sambucus canadensis* L.
Grape sp.	*Vitis* sp.
Greenbriers	*Smilax rotundifolia* L.
Honeysuckle	*Rhododendron atlanticum* (Ashe) Rphd.
Laurel, mountain	*Kalmia latifolia* L.
Rasberry	*Rubus* sp.
Rhododendron	*Rhododendron maximum* L.
Rose, multiflora	*Rosa multiflora* Thunb.
Rubus sp.	*Rubus* sp.
Sarasparilla	*Aralia nudicaulis* L.
Sheeplaurel	*Kalmia angustifolia* L.
Spicebush	*Lindera benzoin* (L.) Blume
Sweetfern	*Comptonia peregrina* (L.) Coult.
Viburnum	*Viburnum* sp.
Vine, Dutchman's-pipe	*Aristolochia durior* Hill