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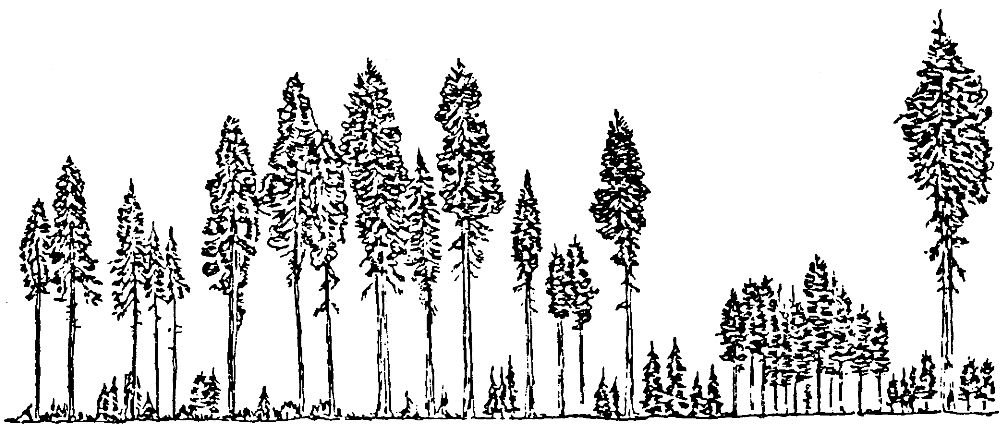
SILVICULTURE AND MANAGEMENT
IN THE EASTERN UNITED STATES



Proceedings of an In-Service Workshop
Morgantown, West Virginia
July 15-17,1975

Timber Management Research, Forest Service
U.S. Department of Agriculture, Washington, D.C.

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FOREWORD

Forest managers are, and will continue to be, constantly confronted with the dilemma of choosing between different silvicultural and management systems to achieve various desired mixes of multiple-use benefits on specific forest properties. Such choices have to be made, unfortunately, because no single silvicultural or management system is ideal for all situations. Complicating these choices is the hard fact that our scientific knowledge is not well distributed over the range of silviculture and management options available to our use. There is no doubt that forest researchers know much more about even-aged silviculture and management than uneven-aged silviculture and management--simply because there has been more research done on the former systems. With the increasing concern over the alleged over-use of clear-cutting, however, it has become more and more evident that forest researchers must be able to provide technically reliable information on <u>all</u> silvicultural and management systems.

The workshop, summarized in this Proceedings, represented a joint effort by personnel from Research, National Forest System, and State and Private Forestry, to review the state-of-the-art knowledge about the applicability of uneven-aged silviculture and management in the eastern United States. One major objective of this review was to develop a much better mutual understanding of the definition of uneven-aged silviculture and management. A number of research gaps and research needs were also identified. Many of these needs are already being incorporated into the program planning for several research work units in the four eastern Experiment Stations. In addition, many of the papers presented at this workshop should serve as interim working guides for forest managers in better understanding the complexities of uneven-aged silviculture and management of public and private forest lands throughout the eastern United States until some of the needed research can be completed.

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CONTENTS

OPENING REMARKS

by

W. T. Doolittle[1/]

Introduction

Welcome to the Eastern Uneven-aged Management Workshop. As you probably know, we originally scheduled a western workshop for next month. But, because of meeting and training restrictions, we had to postpone the western meeting until next fiscal year (October 1976).

We are pleased to have a few research people from the West. Next year we plan to have a few eastern researchers participate in the western workshop. I personally feel that these exchanges of workshop people between the various parts of the country are both informative and stimulating.

We are also pleased to have with us this morning several people from NFS and S&PF. And while the purpose of this workshop is primarily aimed at Research, we need input from our user arms to help us keep our feet on the ground. In fact, you will note that two people from NFS have been asked to present key papers.

In case you are wondering why we chose to hold this workshop in West Virginia, let me give you three reasons:

1. This is a central location in the East.

2. It is near the Fernow Experimental Forest, where research on several levels of uneven-aged and even-aged silviculture has been carried out for over 25 years.

3. We are in the heart of a timber type and area where silviculture and management methods are extremely controversial. I refer to the current court case on the Monongahela National Forest.

1/ Director of Timber Management Research, Forest Service, USDA, Washington, D.C.

Impacts on Management

Forest management practices are generally controlled by three basic constraints: (1) silvicultural, (2) environmental, and (3) socio-economic considerations. Until just a few years ago, silvicultural and economic considerations were the major controlling factor. But today the social and environmental or ecological impacts of forest management practices carry increasing weight in determining the kind of management that will be practiced.

For example, the National Environmental Policy Act of 1969 (NEPA) exerts a significant impact on forest management practices on Federal forest lands. This law has the purposes of (1) encouraging harmony between man and his environment, (2) preventing and eliminating environmental degradation, and (3) enriching our understanding of ecological systems and natural resources.

The National Environmental Policy Act was signed into law on New Years' Day, 1970. NEPA (1) requires Federal agencies to consider the environmental and social costs of their actions, (2) requires them to explore all feasible alternatives to accomplish their objectives, and (3) guarantees citizens the opportunity to participate actively in the making of decisions that have influence on them and their environment. So you can see that ecological impacts on forest management are receiving a good deal of attention.

Timber Supply

Our most serious nationwide supply problem is with softwood sawtimber for lumber and plywood in housing construction, and this is likely to be a continuing problem. In 1970, households in the United States totaled 63 million. Based on medium-level projections, the estimated number of houses for 1980 is 75 million, and for 1990, 88 million. Housing production, which averaged 1.7 million homes a year in the 1960's, can be expected to reach 2.7 million annually in the 1980's.

So even with some expected shifts to wood substitutes and to multifamily units and mobile homes, the requirements for all softwood lumber and plywood will remain critical. And although the annual growth of softwood trees (4 inches in diameter and larger) exceeded removals by about 11 percent in 1970, removal of the sawtimber-size trees (9 inches in diameter and larger) exceeded growth by about 16 percent. Therefore, shortages and rising prices for softwood construction lumber and plywood will probably continue for some time.

The hardwood demand-supply situation presents a different picture. Total growth, in terms of cubic feet of all hardwood tree sizes and species, is some 80 percent greater than removals. However, supplies of the larger and higher quality logs of such species as birch, walnut, maple, and sweetgum continue to decline. Also, in some parts of the East, shortages are more severe than is generally true for the East as a whole.

In the future, hardwood forests will have to support a larger share of the wood needs of the Nation. This is so because 70 percent of the forest lands in the East grow hardwood forests and because softwood production in the West will decline in the years ahead--as the older forests are gradually removed and the young forests take over.

Certainly substitutes for wood--aluminum, steel, plastics, and other materials--will be developed and will help to meet the need for construction material and other uses for which wood is now utilized. However, there are three factors that may limit the extent of these substitutions: (1) the substitutes almost always require consumption of non-renewable resources; (2) the substitute materials often require mining and disturbance of the land; and (3) the substitutes require anywhere from 2 (for plastics) to 45 (for aluminum) times as much energy as wood for conversion to an equivalent useful product--energy that is non-renewable and if it comes from coal often results in stripping or other disturbance of the land 2/. Finally, we should not overlook the fact that wood and wood products are biodegradable in nature and are soon recycled, whereas most substitute material persist for years.

Wood is also one of the few renewable resources; and if our forests are properly managed, successive crops of wood can be produced on most of our forest lands indefinitely. On some lands, this will mean growing trees on an intensive basis, much like agricultural crops. But on other forest lands, wood production will be secondary to other uses such as recreation and municipal watersheds. And in wilderness and parks and in steep and fragile lands, we should expect management mostly for protection.

Timber Harvesting

Other problems facing us in timber harvesting include developing logging equipment that will remove timber from steep or swampy land with little or no impact on the quality of the environment. These may take the form of cable systems, balloons, helicopters, and other systems replacing the tractor skidder. The new equipment would reduce much of the road building that is required in logging today. Since logging roads are one of the sources of erosion and poor aesthetics, some of the problems with timber harvesting as we know them today would be removed.

Another restraint to wood harvesting, particularly here in the East, is the pattern or trend in forest land ownership. More and more small and medium size forest lands are being purchased by non-farmers who have no interest in wood production. Their main interest seems to be in speculation, personal

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2/ Makhijani, A. B., and A. J. Lichtenborg. 1972. Energy and well being. Environment 14(5):10-18.

recreation, and aesthetics. And if eastern forests are to assume their proper role in the production of wood, some way must be found to interest the landowner in a well-planned timber harvesting and management program. Actually, careful harvesting and management can be one of the best ways to maintain an aesthetic forest and benefit many forms of desirable wildlife.

As Rene J. Dubos put it, "In my opinion, the human use of natural resources and of technology is comparable with ecological health, and can indeed bring out potentialities of the earth which remain unexpressed in the state of wilderness."[3]

Silviculture and Management Practices

Forestry has always had a basis in ecology, and a concern for the environment; certainly this basis is stronger today than at any other time in our history. Perhaps at times we have been more concerned with wood production and commercial tree species than we should have been, but I see a future when a more balanced concern for all parts of the forest ecosystem will be paramount and the many uses of the forest will be compatible.

The subjects of the selection system of silviculture and uneven-aged management are the main subjects of this meeting. Unfortunately, the forestry profession has too often accepted and used one method of cutting at a time for all conditions. This trait can be traced here in the East over the past 50 years; during the 1930's, the 1940's, and early 1950's we tried to apply selection cutting to almost all situations. In the late fifties, and up to the present, a switch was made to some form of clearcutting.

Foresters have been too willing to have a simple management method and generally have failed to prescribe alternative management practices that may have been called for.

Our literature generally shows the type of regeneration following harvesting under the various silvicultural systems--clearcutting, seedtree, shelterwood, and selection. There is no one method of cutting that applies to all forest conditions and desires of the forest landowner. The possible prescriptions are numerous, depending on the species of trees desired after cutting, the objective of the owner--whether he is interested primarily in wood production, wildlife, aesthetics, recreation, or some combination. The markets available and prices for wood products are important as well as the owner's need for income.

3/ Address by Dr. Rene J. Dubos at the 139th Annual Meeting of the American Association for the Advancement of Science. December 29, 1972, Washington, D.C.

However, during the past 25 years, both research and application of clear-cutting, shelterwood, and other forms of cutting for even-aged management have moved ahead much more rapidly than selection cutting and uneven-aged management. We needed to make these advances in even-aged management. But, unfortunately, we now find that we need to be giving greater consideration to uneven-aged management--as one of the options or alternatives in the management of our forest resources.

There is no question in my mind, but what even-aged management offers the greatest promise for timber production in the years ahead. This is true on our medium and better sites, on soils and topography that are not fragile or erosive, with intolerant species, with genetically improved trees, and generally under intensive culture methods.

However, on the more fragile soils, steep topography, highly visible or aesthetic areas, and where other values or uses dictate otherwise, we should be in a position to impact as lightly on the forest as possible--and this very well may mean some form of uneven-aged management. Otherwise, foresters may find that they are more and more being shut out of any management on vast areas of our forest lands. We must be flexible! We must be equally capable of applying uneven-aged management as we are of applying even-aged management.

During the next three days, we have been provided with an opportunity to concentrate on the selection system of silviculture and uneven-aged management. So, whether you really believe in it or not, I suggest you participate to the fullest and help us outline the state of the art and pinpoint some gaps and goals for research for the near future.

One last thought! At times, we will need to apply selection cutting to intolerant species and to imperfect situations. We may need to practice silviculture that is not textbook, and accept results in species and growth rates that are far less than optimum. Some of our selection cutting may not look much like single-tree cutting; we may have to move more toward group selection or somewhere between group selection and small clearcuts. Just remember that the less than perfect management for timber production may be most optimum for aesthetics or some other forest use.

HISTORY AND PHILOSOPHY OF SILVICULTURE MANAGEMENT SYSTEMS IN USE TODAY

by

A. P. Mustian[1/]

In trying to trace the history of silviculture, more particularly the development of forest culture systems, we can readily, if not quickly arrive at three conclusions so obvious as to be elementary:

1. Silviculture has been the product of situations of similar character and import in diverse (sometimes widely separated) locations;

2. The same problems and questions that forest managers have encountered and asked since the beginning and which have led to development of the various silvicultural systems and practices are still with us;

3. Either we cannot or will not learn from history, or the experience of others. (Fernow 1911, Smith 1972b, Troup 1952).

I'll not infringe on the next speaker's subject by attempting to define silviculture, because I do not think a definition is critical to just where or when that body of knowledge and experience came of age. Silviculture is still evolving and as we acquire more knowledge of the characteristics and cultural requirements of the respective forest species and types and as forest uses and management objectives change, silviculture in the future is likely to be more varied, more complex, more innovative, and more responsive to forest resource needs and conditions (Smith 1972a). Someone, I do not remember whom, has suggested that silviculture began (begins) when thought first was (has to be) given to reproducing a given species or forest type. If you accept this view, then we can assume that silviculture had its origin not when God put man in the Garden of Eden and told him to dress it and keep it, but when God kicked him out of the Garden and told him to till the ground for his livelihood (Genesis 2-3). Up until that time, Adam had only to be concerned with harvesting the old growth.

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Maybe we better get back on the track here. The point of all this is to say that the development of silvicultural systems and practices began (or begins) in most countries with a situation in which the timber resource was depleted or in danger of being depleted, that is when a timber famine had occurred or was expected or feared. Such situations are attributable in practically every instance to the fact that use of the forest(s) has commenced with unplanned exploitation (Smith 1972a). The initial reaction in most such situations has been to protect what timber was left or to replace (regenerate) the timber resource or a combination of both.

A great host of recorded events, or laws, ordinances and regulations, from Biblical times in the middle east, China in the 12th century B.C., the era of the Roman Empire, and the medieval period in Europe have been cited as being stages or reference points in the development of the classical silviculture systems (Fernow 1911, Heske 1938, Meyer et al, 1961, Troup 1952). Some of the more complete accounts of the chain of events from uncontrolled exploitation of the forests to management systems for sustained yield of forest products are those associated with the development of silviculture and forest management in Europe, particularly Germany, and which greatly influenced the development and growth of forestry in this country.

Henry S. Graves pointed out in the preface to German Forestry that those successive stages in the progress toward sustained yield forest management, the curtailment of the quantity cut, followed by the introduction of silvicultural measures for forest replacement, activities for improvement of stands and finally the organization of the forests for sustained yield were analogous to the stages of forest management progress under different circumstances in this country (Heske 1938). At that time, nearly 30 years ago, Graves indicated we were at the stage of giving emphasis to measures for increasing growth and building up growing stock and for sustained yield management. Any suggestions in just 80 years that we have traversed thusly the whole range of experience of our colleagues and predecessors in Germany and other European countries in the development and use of silviculture systems is not only dangerously naive, but indicative of a debilitating case of not being able to see where we are, let alone where we have been in the light of other people's experience(s).

Because the influence of German foresters and the silvicultural practices and results there are recognized in this country, a brief review of practices and policies there over the years since the 30 Years War (1618-1648) appears in order. That war, with the distress and confusion that followed, largely undid the progress made in regulating cutting and grazing, in artificial regeneration, in establishing rudimentary systems of management such as coppice with standards, and in utilization. As might be expected, response to this situation included numerous ordinances, the most important of which were prohibitions on land clearing and forest destruction, reforestation requirements, rules for orderly felling and hauling, utilization requirements, restrictions on timber trade and free use of fuelwood and other timber by the general populace, and rules to regulate goat-grazing, turpentining, potash burning, and litter-raking.

Paralleling the efforts at protection through ordinances was a renewal of emphasis on regulation of cutting, initially some form of area regulation. As early as 1359 the city forest of Erfurt had been divided into 7 cutting areas (Heske 1938, Meyer et al, 1961). But unregulated selective cuttings still prevailed in many areas after the 30 Years War. The effects of those cuttings were such that the systems of coppice and coppice with standards in the hardwood types and seed tree cuts in the conifer forests developed in the Middle Ages and used as early as 600 A.D. in Germany were widely adopted.

Later on in the 18th century, shelterwood cuttings were introduced to the hardwood forests. Unfortunately, this forest system originally intended for beech was applied mechanically to other species. Frequent failures to get natural regeneration particularly in the types of the North led to a shift away from shelterwood, and in the mid-19th century clearcutting with artificial regeneration had become general practice in the pine types and a little later in the spruce type (Heske 1938, Troup 1952). The early 19th century also saw the growth of a very active interest in exotics for forestation purposes. Eastern white pine, northern red oak, ash, Douglas-fir and larch were major species used, and the area in even-aged stands, often of a single species increased as did the questions and concerns about the effects of pure stands and even-aged silviculture on site quality and susceptibility to insects, disease, windblow, and fire. Needless to say, the even-aged versus uneven-aged battle had been joined.

I think it well to inject here a reminder that transition from one stage in the development and application of silviculture systems to another has not been as steady and smooth and unerringly upward as one may infer from any effort to trace generally the history of silviculture. Rather, it has largely been a trial and error process in which experience and scientifically acquired knowledge and special interests, politics, and the influential views of persuasive foresters have been offsetting or at best deflecting or tangential forces. The diversity of practices from region to region and country to country reflect this influence of personalities as well as of socio-economic factors and resource conditions (Troup 1952, Fernow 1902, Fernow 1908, Larson 1924, Knuchel 1953). They also reflect reaction to problems encountered, real or imagined at various places and times. More often than not the reaction was to the abuse or misuse of a practice and here we begin to see silviculture coming full circle. Hopefully, though, that circling has followed Vico's spiral theory: that each time around things get better.

In Europe, silviculture developed slowly from the early efforts to control (regulate) cutting and to reestablish the devastated forests by coppice and artificial regeneration methods which enjoyed some measure of success and provided the opportunity for development of more sophisticated systems. Economics and ease of establishment favored a few species and even-aged stands. The early successes with even-aged stands and the lower yields and poorer quality of the coppice stands along with organizational problems with partial cuts and mixed stands resulted in heavy emphasis on clearcutting with artificial regeneration and fast growing exotic conifers for a period. The Austrian Forest Ordinance of 1786 recognized clearcutting with artificial regeneration as the general system in force. In Prussia, a 1787 ordinance provided that even-aged forest crops should be grown, and the Darmstadt ordinance of 1776 prohibited use of the selection system. We are not without precedent for the legislation of silvicultural practices.

Neither are we without precedent for the problems encountered with reliance in the extreme on one species, system, or practice. On some sites, growth fell off after several rotations of artificially regenerated pine stands. Blowdowns occurred in pine stands of spruce when partially cut. Defoliators hit other pine stands hard. Mast crops fell off and quality hardwoods, particularly the oaks, were in short supply. The 19th century saw forest management come around again to emphasis on uneven-aged management, mixed stands, and selection cutting, but with some awareness that it was not the panacea for all timber production and ecological problems. The Baden Forest Law of 1833 actually prohibited clearcutting. Later in the 19th century, Karl Gayer led a back-to-nature movement that demanded natural regeneration instead of clearcutting with artificial regeneration and an uneven-aged form of forest rather than one composed of schematically arranged even-aged stands (Heske 1938). The Dauerwald (continuous forest) system was revived and management in many areas of Germany and Prussia shifted to single tree selection and cutting whenever and wherever there is a silvicultural and commercial need. Under that system the tree and not the stand is the unit of measurement (Larsen 1924, Meyer 1961).

In Switzerland, French forester A. Gurnaud's check method became the rage. This system had as its objective a normal forest and would be achieved through single tree selection and periodic (every 6 years) checks of growing stock through careful measurements of removals and residuals. A normal forest was described as one in which "on every site the species belonging to the locality predominates and where the growing stock is everywhere so constituted that it continuously provides the greatest possible amount of valuable timber; the forest should in addition, fulfill its many-sided protective task in all its parts and without a break" (Knuchel 1953). French and German foresters have subsequently been heard to comment that "only the Swiss could practice that kind of gardening in their little forests."

The views and the techniques of Gayer and Gurnaud and others were supported by Professor Heinrich Mayr at the University of Munich and his principles of silviculture. Mayr tried to dispel the "misconception" that there is no science in silvics. He believed his set of principles would hold true wherever tree growth occurred. He made an important point, but he did not do much to temper the revolt against clearcutting and artificial regeneration in Germany and other parts of Europe when he wrote,

> The more silviculture will rest upon its only true foundation, the laws of nature, the more clearly it will be shown that no other form of management corresponds better to the laws of nature than the selection system . . . .. The unregulated selection system is the oldest, easiest, and crudest form of management; the regulated selection system with its individualization is the most perfect and the most delicate and the most difficult form of forest management and approaches closest to the unattainable ideal (Mayr 1907).

The 20th century brought the beginnings of silviculture in America and another loop in the evolutionary spiral of silviculture. This last loop - maybe a double loop - appears to have come around faster and without the drastic changes in practices or the all or none approaches to silvicultural problems which characterized the previous 2 or 3 centuries.

The International Congress of Agriculture and Forestry in 1907 outlined the prevailing theories of silviculture and declared silviculture to be the intelligent cultivation of forests for producing wood and conserving the soil under practices which give due recognition to all relevant facts revealed by the latest advances in the natural sciences. The dye was cast for the stage at which we find the development of silviculture now, at least in Europe and probably most of the other countries more advanced in forest management, one of modifying and adapting present systems to fit more precisely species silvical requirements, site and stand conditions and social and economic objectives. At the same time though, we cannot ignore the revival of heavy emphasis on the even-aged system including clearcutting and artificial regeneration in most of the intolerant types (Troup 1952, Smith 1972, Wolz 1949, Sweden 1970).

How does all this relate to the development of silviculture in the United States? We got on around the turn of the century at the beginning of the last spiral, which meant we started at a little higher level, but the situation was similar, although the local conditions may have been somewhat different. We still had a vast supply of old-growth timber, but cutting was proceeding at such a pace and in such a fashion that fears of a timber famine around the country generated support for establishment of the so-called timber reserves. That was the beginning of the National Forest System, and concerted efforts to protect the forests of the country from impending devastation or destruction. At the same time, the small group of foresters and conservationists heading the movement recognized that the rapidly developing country needed timber and that cutting had to continue (Pinchot 1898, Kirkland 1911). Pretty early in the game, cutting practices reflected an accomodation of the view that the mills should be kept running. The old Forest Service Manual (Use Book, page 113-S) contained the statement relative to the National Forest working management plans, "Intensive methods like the management of timber so as to serve a sustained yield should not be attempted until required by the demands upon the forest or other conditions affecting the use of its resources."

At the same time, however, the stated Silvicultural Policy (page 9-S) provided that except in the case of dead and damaged timber no sales would be made unless it were practicable to require methods of cutting and stand disposal which would retain a sufficient stand for protection and a future cut or which would insure the restocking of the cutover area with desirable species. In exceptional cases, particularly very overmature stands, clearcutting was permitted with the approval of the Chief.

Another statement relative to silvicultural management activities in the Southwest, more particularly on the Santa Fe National Forest in 1915 is revealing, I think. The District (Regional) Forester reported, "The present management cutting is fully justified from the standpoint of silvicultural management. The removal of much mature and surplus growing stock is being secured at a stumpage value equal to that received from other large sales in District 3" (Woolsey 1916). Forty-five years later a GFI of Region 3 by the Washington Office found that a light selection cutting characterized as a "stretch out" manipulation of mature timber through stem selection was still being applied and recommended that the Region start practicing even-aged silviculture in the Ponderosa pine type.

One more tidbit of Forest Service folklore is a statement from the old manual on regulation of yield.

> The first step in the management of the National Forests under existing policy is to sell the overmature timber that is deteriorating and to develop a net revenue. Therefore yield regulation must be secondary to the silvicultural requirements and to market. It is also clearly valueless to impose a local limitation of cut which is impractical because of the necessity of a large annual cut to justify commercial logging. At least until the overmature timber is removed, therefore, the policy of an (rigid) annual sustained yield will not be applied, even a periodic sustained yield will not be attempted until it is clearly and positively necessary for reasons of public policy. In other words, we will not damage the National Forest silviculturally to preserve an academic ideal of sustained yield (Woolsey 1916).

Despite some incongruities and apparent paradoxes, one might infer from the foregoing that, at least insofar as the National Forests were concerned, silviculture was receiving due consideration, or at worst, practicing foresters and administrators recognized its importance.

By World War I, a considerable body of management advice including silvicultural practices was being disseminated by the Forest Service in the form of Agriculture and Technical Bulletins and through trade and professional journals. But already voices were being raised in protest or question about silviculture in the United States.

As early as 1905, Alfred Gaskill questioned whether silviculture as had been learned or acquired largely from Europe was sufficient for the work to be done in this country (Gaskill 1905). Graves in 1908 pointed out that most foresters in America had been engaged in laying the foundations for forestry and had not done much practicing of it. He acknowledged the results and fundamental principles of silviculture from European practice, but cited the fact their methods were not always applicable to the types and situations here and further that we had little or no information on the silvics of our forest trees, on the practical questions such as reproduction, species tolerance, stimulated increment, response to release, resistance to fungus and other factors. He suggested that our silviculture would be, therefore, a conversion, beginning with the selection system and aiming ultimately for the use of many other systems, that is making selection, reproduction, and improvement cuttings toward the end of bringing about even-aged stands (Graves 1908).

A few years later in discussing the selection system Graves pointed out again that the selection system is usually the first development of forestry in a newly developed country. Subsequently he commented that the selection system is used in forests where market conditions are such that only a limited class of trees can be cut at a profit. Somewhere in this comment there may be a clue to some of the cutting practices developing in the National Forests and the initiation of "selective cutting". At any rate he noted that as intensive methods become practicable, the tendency is towards systems resulting in clearcutting and even-aged stands with the choice of the system based on meeting the forest area's objective for present and future returns (Graves 1911). Dr. Carl Schenck wrote very pointedly that the teachings of European silviculture were of no more direct use at the time than Asiatic teachings might be (Schenck 1912).

Other foresters expressed similar views and concerns, all suggesting that forestry in the United States was proceeding along lines exactly similar to those European forestry had taken. The warnings, if they were that, did not seem to have the intended effect. On the National Forests where the old-growth stands were dominant, and in the East and South where some old-growth remained, where extensive areas were occupied by poorly stocked, low quality stands resulting from unregulated selection or economic clearcutting, heavy grazing and burning, or by stands of young growth liberally sprinkled with culls and other vestiges of the original stands, selective cutting became the "in" prescription.

Why foresters who obviously knew and understood the selection system as it had been developed in Europe would start using the term "selective cutting" is open to considerable speculation. One probable explanation is an effort to distinguish between the selection system and the sanitation and salvage, economic selection (high grading), cull removal and release cuttings they felt acceptable until the attitudes, practices, and forests of the country could be converted or become oriented to management by carefully planned silvicultural schemes or systems. Doctor Schenck is reported to have seen such a cutting on the Mont Alto State

Forest in 1926 and to have asked what it was. Upon being told that it was "selective cutting" he commented, "Good! By all means give the bastard a name!" An Appalachian forester at the time described it as "cutting the obviously defective and leaving the apparently sound" (Riebold 1975).

The then Chief of the Forest Service, R. Y. Stuart, in trying to distinguish between "selective logging" and other cutting practices in northern hardwoods did not help matters much when he said, "While selection by species and also by sizes is not new to loggers of northern hardwoods, selective logging. . . involves something of a new point of view and procedure. Thus, the term as used. . . denotes a partial cutting practice which, by a judicious selection of the trees to be removed, meets both the silvicultural and present economic requirements, in such a way as to perpetuate and improve the forest and at the same time maintain or increase the profits to the owner." The authors of the paper which his comments prefaced said that the chief aim of the partial removal of a stand under selective logging was "to remove at lowest cost the greatest value with the least volume and at the same time keep the stand in a healthy growing condition." The paper dealt with information on how to manage the remaining northern hardwood stands so as to make them go as far as possible in providing a continuous supply of timber. It was suggested that each individual forest owner who wished to go into selective logging would have to make an analysis of his own operation and then decide for himself the diameter limit of cutting that would best meet his needs (Zon and Garver 1930).

In the South, where the vast longleaf pine stands were being cut by the large land holding sawmills, studies were made by W. W. Ashe and others to determine the smallest tree size that would pay its way past the headrig and to determine the potential for growth on the residuals being left as too small to harvest economically. The idea of this was that by cutting to a certain diameter limit, growth on the residuals would be such that the lumber company could expect to come back for a second cut in 20-25 years after it had cut through the first time. The forester may have had in mind that by leaving more timber to harvest later the cut-out and get-out policy would be changed and management initiated on those lands. The sawmill owners saw it as an opportunity to get it all at a profit. Anyway, there was not much change in practice and little opportunity to go back for that second cut.

One result of the emphasis of the times on selective cutting was that in some form or other it probably has been done in about every timber type in the country. No doubt some of it was an honest effort to use selection as a management system. With exceptions, it could just as well have been called a first cut in even-aged management. The kind of cut was pretty much determined by the economic and social dictates of the times (Rindt 1966).

Whatever the origin of selective cutting and its purpose, and its role in the development of silviculture in America, the 1920's and 1930's reflected the anomaly of efforts to legislate selective cutting concurrently with some rather strong criticism of silviculture as being practiced at the time.

The adverse silvicultural effects certain practices, particularly diameter limits, had in the western forests were noted very early in the game but apparently the practices were treated philosophically as the first steps in the right direction. The marking favored some species and discriminated against others to the extent that some valuable species such as Douglas-fir were being eliminated from the stands. Marking in the Arizona and New Mexico forests was characterized as the German shelterwood without the final cutting (Carter 1908). A few years later, a supporter of heavier cutting in the Pacific Coast forests suggested that application of the selection method currently in vogue in most National Forest regions was impossible in the existing stands unless the forester could be satisfied with a partially stocked stand of inferior species (Kirkland 1911).

In 1925, the attempt to transfer European silviculture to American forests in practice and teaching was criticized as not fitting the silvics of American species and the range of climatic and other conditions. Note was taken of the warning given by Gaskill in 1905 about the European influence with the comment:

> We have only in recent years begun to appreciate that the child born in our midst could not be brought to full stature on patent fronds bearing the label 'made in Germany'. The time borrowed formulae for handling woodlands, clear cutting and planting, clear cutting in strips, group selection, and shelterwood, with few exceptions, have not proven satisfactory under American conditions, and yet we have substituted for them diameter limits, marking rules, volume control, and other empirical methods which over large areas have produced results which may be called forestry but could hardly be called more than crude silviculture.

The fact that a lack of knowledge of species and types at the beginning of the century had played a role in the preceding 25 years was lamented and recognized. Needless to say, Ralph C. Hawley took issue. Others agreed and one commentator went so far as to write:

> Most teachers of silviculture, most directors of U.S. experiment stations, and most foresters have never practiced it. The art of silviculture must be learned by practice. It is true that under the economic conditions that have existed during the past 25 years, it has been impossible to take many of the inherent silvical factors into consideration. The result was a compromise between destructive lumbering and systematic silvicultural practice (Preston 1925).

About the same time Greeley, the predecessor of Stuart as Chief of the Forest Service had said, "We are in danger of increasing the rate of cutting in advance of adequate management plans and our capacity to provide competent personnel, and in advance of our ability to maintain high standards of silvicultural practice" (Greeley 1925). (Shades of the '70's. We have compressed and tightened the spiral!). He noted that the diameter limit was such a handy rule of thumb that it had been foolishly recommended in the South for "intolerant pine stands, easy to reproduce, which do not require selection cuttings." Greeley went on to point out that Forest Service marking rules were not silviculture and that what most people considered silvicultural systems were merely wise and correct use of improvement cuttings.

A few years earlier, Illick had commented that silviculture in Pennsylvania still appeared juvenile and weak and that efforts to adopt, then adapt the methods and techniques of foreign countries had been found wanting. Consequently, we were compelled to strike out anew with original studies to aid in formulating practical and economical procedures.

With respect to the Adirondack forests the comment had been made:

> Twenty years ago we talked of clearcutting and planting in the eastern forests, ten years ago we were confident that the selection system applied on the basis of a diameter limit was the right practice, today (1920) we may be back again where we were twenty years ago in our ideas of what is right silvicultural practice . . .
>
> * * * * * * * *
>
> The foresters of this country during the past decade and more have been somewhat at fault in their attempt to introduce silvicultural methods into the cutting of the forests and into the treatment of cut-over land (Baker and McCarthy 1920).

Suffice it to say that selective cutting stuck with us, although clearcutting was also practiced in several types. Some USDA publications still recommend it, although more effort is being made now to clarify options. Just when an outwardly obvious effort was made to prescribe and implement a complete silvicultural system for forest lands in this country, I cannot say. Great emphasis developed in the late 1950's on clearcutting with artificial and/or natural regenerations. By the mid 1960's, it and even-aged management were sweeping the country. The then head of timber management for the National Forest System reported in 1962 that most of the commercial forest land in the National Forests was planned and managed under clearcutting systems. Further, the trend was toward larger clearcuts in windfirm types (Morris 1962). With the rapid move to a specific system, this time even-aged, came the abuses and misuses experienced in other countries in other times. Again, we had almost an either/or situation.

One recently retired Forest Supervisor commented that he did not know when the Forest Service shifted from "selective cutting" to clearcutting bypassing other methods along the way. Most of you experienced this shift both on private and public forest lands. At least you know when the flack began in your area over the alleged, potential, or actual environmental impacts of clearcutting. Forestry had made it around the last spiral a little faster than before. The question now is did we just go around the circle or are we a little higher this time. I believe we are a little higher.

I might suggest that what accelerated the last orbit in silviculture in this country was an awakening to the fact that we had second-growth, even-aged stands reaching maturity. We had by accident rather than intent come through the full silvicultural cycle - from regeneration to time of harvest - and suddenly awakened to the question of where do we go from here.

Joe Riebold told me that it was not until 1945 that he had to start deciding on regeneration systems in pine on the Francis Marion National Forest in South Carolina. The shelterwood system was and still is being applied there with prescribed burnings and appropriate thinnings until the next preparatory cuttings begin on an 80-year rotation. I believe it was Don Morris who moved the Pisgah and Nantahala National Forests in North Carolina into active regeneration of cove and other Appalachian hardwood stands by clearcutting and other even-aged methods. In the West, we're really just getting into second growth management and the regeneration of managed stands. There are other examples in both conifers and hardwoods where a precise system for regeneration and management throughout the life of the stand or forest have been implemented and followed through two or more cuts appropriate to the respective system.

We have not arrived yet for sure, if you take seriously the different, often conflicting, views among us, the threats of legislated or regulated silviculture, the regeneration failures, and the less than optimum yields from so-called managed stands. I hesitate to predict where we are on the current swing around the loop, but hopefully we are still moving upward.

Dave Smith predicted a couple of years ago, "Silviculture fitted to demonstrable realities of nature and human need will call forth the evolution of methods of treatment more varied than our wildest present imagination can encompass" (Smith 1972a). I think he left himself room to encompass environmental forestry and ecological forestry, but wait until he encounters the "aesthetic shelterwood" recently conjured up by Dave Marquis and Bud Twombly!

I promised I would not try to define silviculture, but maybe we need some reminding again that "because of the broad differences in climate, physiography, forest vegetation, method of past treatment, natural and introduced animals, insects, and diseases and in economic conditions, a multitude of silvicultural problems exist in the United States" (Westveld 1935). No single cutting method or silvicultural system will solve them all, but uneven-aged management may solve some of them. That is what we are here to talk about.

References

Baker, H. P., and E. F. McCarthy. 1920. Fundamental silvicultural measures necessary to ensure forest lands remaining reasonably productive after logging. J. Forestry 18:13-22.

Carter, E. E. 1908. The silvicultural results of marking timber in the National Forests. Soc. Amer. Foresters Proc. 3:18-28.

Fernow, B. E. 1911. History of forestry. Toronto University Press; Cambridge, Mass., Forest Quarterly. 506 p.

Gaskill, Alfred. 1905. Silviculture applied to virgin forest conditions. Soc. Amer. Foresters Proc. 1:62-69.

Graves, Henry S. 1908. Present condition American Silviculture. Soc. Amer. Foresters Proc. 3:29-40.

____________. 1911. The selection system. Soc. Amer. Foresters Proc. 5:1-17, illus.

Greeley, W. B. 1925. Forest Management on Federal Lands. J. Forestry 23:223-235.

Heske, F. 1938. German Forestry. Yale University Press. New Haven Conn. 395 p.

Jentsch, Fritz. 1911. The rise of silviculture. Forest Quart. 9:544-556.

Illick, J. S. 1920. Some silviculture problems in Pennsylvania. J. Forestry 18:502-511.

Kirkland, Bart P. 1911. The need of a vigorous policy of encouraging cutting on the National Forests of the Pacific coast. Forestry Quart. IX:375-390.

Knuchel, Herman. 1953. Planning and control in the managed forest. Eng. trans. Mark L. Anderson. Oliver and Boyd, Edinburgh. 360 p.

Larsen, J. A. 1924. Trend of silviculture development in Germany. J. Forestry 22:506-512.

Mayr, Heinrich. 1907. Some fundamental principles of silviculture. Forestry Quart. 5:174-189.

Meyer, H. Arther, A. B. Recknagel, D. D. Stevenson, and R. A. Bartoo. 1961. Forest management. 2nd Ed. Ronald Press, New York. 282 p.

Morris, Donald J. 1962. Trends in timber management planning on the National Forests. J. Forestry. 60: 301-305.

Pinchot, Gifford. 1898. Report on examination of the forest resources. USDI - General Land Office: 35-118.

Preston, J. F. 1925. Silvicultural practice in the United States during the past quarter century. J. Forestry 23: 236-244, 496-503.

Rhodes, J. E. 1911. Forestry and the lumber business. Forestry Quart. 9: 195-204.

Riebold, Roland J. 1975. Personal communication.

Rindt, Charles A. 1966. Trends from selection cutting to even-aged management - the national picture. Allegheny Sect. Soc. Amer. Foresters Proc., Feb. 10-11,: 3-7.

Schenck, C. A. 1912. The art of second growth or American silviculture. 3rd Ed. Brandow, Albany, New York. 206 p.

Smith, David M. 1962. The practice of silviculture. 7th Ed. Wiley and Sons, Inc. New York. 565 p.

____________. 1972. The continuing evolution of silvicultural practice. J. Forestry 70: 89-92.

____________. 1972. Even-aged management concept and historical development In Even-aged Management Symposium Proc. Aug. 1, 1972: 1-20, Oregon State Univ., March 1973.

Sweden. 1970. Memo from the Royal Swedish Embassy concerning the use of clearcutting in Swedish forestry. June 6, 1970.

Troup, R. S. 1952. Silvicultural systems, 2nd Ed. E. W. Jones, Editor. Oxford Univ. Press, 216 p.

Westveld, R. H. 1935. Applied silviculture in the United States. Edward Bros., Inc. Ann Arbor, Mich. 415 p.

Wolz, Otto. 1949. Unpublished report on a four months study trip to the states of Michigan, Wisconsin, and Minnesota in the United States of America.

Woolsey, T. S., Jr. 1916. Forest Service silviculture plans. Soc. Amer. Foresters Proc. 11: 1-16.

UNEVEN-AGED SILVICULTURE AND MANAGEMENT? EVEN-AGED SILVICULTURE AND MANAGEMENT? DEFINITIONS AND DIFFERENCES

by

Carter B. Gibbs1/

Introduction

To ease my own task in preparing this paper and to provide what I hope is a base for the technical discussions that are to follow I have confined most of my remarks to the application of silvicultural systems for the production of timber. I recognize that the decision to use uneven-aged silviculture and management is usually based on considerations other than timber production. However, management of a forested area for any purpose, must be based on sound silvicultural knowledge and, I assume that management for wildlife, aesthetics, watershed protection, or timber will require some form of stand treatment to attain the desired objectives. Our current knowledge for the management of a forest to meet specified objectives of species composition, stand structure, stocking, growth, and yield is much more voluminous and more scientifically based than our knowledge for developing a forest for any other purpose. I, therefore, suggest that we must evaluate what we know about the problems of stand development for timber production before we can adequately modify silvicultural practices to meet other objectives.

As do most authors who are confronted with the problem of discussing definitions, I went to text books and bulletins for definitions of uneven-aged silviculture and management. The result, as I'm sure most of you have experienced, was disappointment and frustration. I soon came to the conclusion that existing definitions are designed to be acceptable to 25 percent of the population, objectionable to 25 percent, and relatively meaningless to the remaining 50 percent that must deal with the subject involved. I further came to realize that, at least in terms of uneven-aged and even-aged silviculture, the problems, questions, and confusion arise not from the definitions, but rather from the generally unrecognized differences between the two systems.

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I therefore have limited my definitions to those contained or implied in Agriculture Handbook No. 445, "Silvicultural Systems" and concentrated most of my remarks on the differences that most of us recognize; those that few people recognize; and those that reflect my personal biases after several years of attempting to apply uneven-aged silviculture in both hardwoods and conifers. I hope that I will generate some discussion and in some way contribute to the understanding of uneven-aged silviculture and management that I feel we are all here to achieve.

Before going further, I want to discuss the differences between management and silviculture. Management is the administrative and regulatory process whereby the policies and objectives established for a forest property are attained. In the case of timber production, management is designed to insure sustained yield of forest products, while maintaining the quality of the environment. Silviculture is the process whereby forests are tended, harvested, and replaced resulting in production of a forest of distinctive form. In uneven-aged management there is one silvicultural system--selection. In even-aged management, there are three silvicultural systems--shelterwood, seed tree, and clearcutting.

I am sure everyone here caught the omission of group selection as a silvicultural system. Group selection and its application has been the subject of considerable controversy. It is considered by some as merely a method of regeneration to insure the presence of valuable intolerant species in mixture with tolerant species. Others hail group selection as the "answer" to the silviculture and management of all species except the very intolerant. My personal opinion is that its value lies somewhere between the two.

Group selection may work very well as a harvesting and regeneration method on small forest ownerships or in stands on large properties where the cut is not regulated. Group selection cannot be considered as a system that fits the constraints of uneven-aged management for sustained yield. The main reasons are, that to date at least, we do not have a realistic method for the regulation of small group-selection harvests and the details of applying the method to insure adequate stocking and acceptable growth of individual trees has not been developed.

Definitions

Uneven-aged silviculture and management is the manipulation of a forest for a continuous high-forest cover, recurring regeneration of desirable species, and the orderly growth and development of trees through a range of age or diameter classes to provide a sustained yield of forest products. Managed uneven-aged forests are characterized by trees of many ages, or sizes intermingled singly or in groups. Trees are harvested singly or in very small groups and the process of regeneration of the desirable species occurs either continuously or at each harvest. Each harvest usually includes thinning and cultural treatments to promote growth and maintain or enhance stand structure.

Even-aged silviculture and management is a manipulation of forests for periodic regeneration of desirable species, the orderly growth and development of trees to a given size in each stand, and progressive development of harvestable stands to provide sustained yield of forest products. Managed even-aged forests are characterized by a distribution of stands of varying ages (size classes) throughout the forest. Regeneration occurs at or near the time of complete harvest when the stand reaches the desired age or size. Stands are treated between harvests with thinnings, cleanings, or other cultural treatments designed to promote growth and improve quality.

The basic method for control in even-aged management is area and maximum tree size (rotation age). In uneven-aged management it is some expression of volume such as basal area or number of trees per acre, stand structure, and maximum size tree. Both even-aged and uneven-aged management may be used to produce timber, both are feasible and workable. They are sufficiently diverse so that together they provide the tools for overall forest management to meet effectively all management objectives except wilderness. Neither is the panacea for forest management to meet multiple use objectives and both must be considered in any well formulated plan of management for a large forested area.

The decision of which silvicultural system to use in any given stand should, within the constraints of management objectives, be based on stand conditions, site, and the silvical characteristics of the species present or desired. Stands of irregular structure and tolerant species are best suited to uneven-aged silviculture. Fragile sites, steep slopes, high water tables, and very dry sites that would be adversely affected by complete removal of the forest cover for even short periods are better suited to uneven-aged than to even-aged silviculture. Even-aged silviculture is most effective in even-aged stands of intolerant species and it should be used to return overmature, decadent, diseased or insect infested stands to productivity. Most tolerant species are also amenable to even-aged silvicultural systems.

In multiple-use applications uneven-aged silviculture is best suited to travel influence zones, water influence zones, watershed protection, scenic areas, and wildlife habitat requirements of game and non-game species that require high-forest cover and vertical diversity in vegetation. Even-aged silvicultural systems may be used to provide increased water yields, and the diversity of habitat required by many game and non-game wildlife species, particularly the mammals that require browse.

Let's look more specifically at the differences between even-aged and uneven-aged silviculture implied in the definitions.

Differences

Regeneration

In uneven-aged silviculture, regeneration is a continuing or recurring process, that is, it should occur to some degree at every harvest. Regeneration is dependent on natural seeding and or sprouting. There is little opportunity to introduce genetically superior trees from outside sources. In even-aged management, regeneration occurs during one short period just prior to or after the final harvest. Stands may be regenerated either naturally or artificially and it is easy to introduce improved genotypes.

Stand Composition

In uneven-aged silviculture stand composition is usually restricted to the more tolerant species. In even-aged, stand composition may be either tolerant or intolerant species or a combination of the two. Stand composition in even-aged may also be changed by planting.

Stand Structure

In managed uneven-aged stands, structure is characterized by the presence of all the various size classes from regeneration to the maximum size tree to be grown. These size classes are distributed uniformly over the forest and the numbers of trees in each size class decrease as diameters increase. The pattern of the forest follows the inverted "J" shaped curve.

In managed even-aged stands, all trees are essentially the same age class although several size classes may be represented because of the differences in growth rates between trees and between species. The distribution of trees by size classes in even-aged stands follows the characteristic "bell" shaped curve, with most of the trees occurring in two or three classes.

Stand structure is perhaps the least understood and certainly one of the most important factors in the application of uneven-aged silviculture. To control or maintain an uneven-aged structure it is usually necessary to remove trees across the range of diameter classes at each harvest to provide a suitable environment for regeneration and to promote the growth of the residual stand. Unfortunately, most laymen, and sadly many foresters, sincerely believe that in uneven-aged silviculture only the largest trees are removed. If we are to move to a greater use of uneven-aged silviculture and management, this misconception must be corrected.

Tree Quality

Both even-aged and uneven-aged systems properly applied will produce quality timber. There may be times during the conversion of irregular structures to managed uneven-aged structures in hardwoods when changes in stocking may cause epicormic branching on quality trees. However, this is a result of the conversion process rather than a fault of the system. Heavy thinnings in even-aged stands may also cause the same problem.

Closely related to tree quality is the often heard argument, usually from geneticists, that uneven-aged silviculture is dysgenic. While I agree that some high-grading done in the name of uneven-aged management may have been detrimental to the hereditary qualities of forest stands, I do not believe that continued application of uneven-aged silviculture leads to the elimination of fast-growing quality trees. The data I have to support my belief is as good as the data of those who oppose it, and I don't have any. So when all else fails I resort to logic. I think it is reasonable to assume that under management fast-growing quality trees will be recognized and left to grow to the maximum size desired; that they will produce seed; and that their progeny, because they are fast growing, will always be an integral part of the forest stand.

Growth

Tree growth and development in uneven-aged structures are affected by competition for light and space, both vertically and horizontally. Basically an overstory-understory stiuation. In even-aged structures, competition is mostly horizontal between codominants. The differences in root competition between the two systems are unknown, but there undoubtedly are some.

The presence of vertical competition is the main reason that uneven-aged management is restricted to the more tolerant species. However, there is evidence that the capacity of a tolerant species to regenerate and survive under vertical competition should not be automatically equated with the capacity to grow and develop rapidly under such conditions. Achieving adequate growth of understory trees in the uneven-aged system may require lower-density stand structures than we are now using. In contrast, our ability to predict the impact of competition on growth in even-aged stands is reasonably well understood for the major species.

Yield

The subject of yield in uneven-aged versus even-aged management is one of considerable controversy and even more unknowns. It is possible to develop excellent yields per acre with both systems, however, the question often arises as to which system grows more timber. Since neither system has as yet been fully tested, particularly the uneven-aged, it is difficult to determine whether or not there will be differences in total yield over a given period of management. Most of our uneven-aged silviculture is being applied to stands with an irregular structure that resulted from high-grading for quality trees or desirable species. These stands may not express the full productive capacity of the site for some time.

My personal opinion is that the question of whether even-aged or uneven-aged will produce more timber is mostly of academic interest only, because the system used will be dictated by the management objectives and biological constraints, rather than on whether or not one system will produce more timber than the other.

Regulation

Regulation, in even-aged management, is based on area, and the time that will be required to grow trees to a specified age or size. In uneven-aged management, the problem of regulation is complicated by the fact that there are three strongly interrelated factors that must be considered. One is the size of the tree to be grown. The other is the residual growing stock or volume that must be maintained to provide adequate growth and yield. And the third is the structure of the forest that will be necessary to provide continuing regeneration and orderly growth and development of the small trees for replacement of those harvested.

Regulation of either system requires good inventory data but in uneven-aged the inventories usually must be more frequent, more detailed, and more intensive than in even-aged.

Many of our problems in uneven-aged management are attributable to the fact that for years we considered only volume in the regulation of uneven-aged stands. Regeneration was largely ignored and harvests were confined to the sawlog portion of the stand. Harvests were based on past or projected growth without adequate treatment of the pole and sapling segment of the stand. At best simple volume control has resulted in uneven-aged stands progressing towards an even-aged condition and at worst there have been severe reductions in long-term yields, decreases in stand quality, and undesirable changes in species composition.

Selection of Crop Trees

Crop trees in the uneven-aged silvicultural system must be selected from young understory poles and saplings, and it is often difficult to predict their potential for good growth and development. In the even-aged system crop trees are selected from the easily recognized, vigorous, fast growing individuals in the main canopy.

In addition to these fairly well defined differences between even-aged and uneven-aged silviculture and management, there are other less tangible differences that I feel are contributing significantly to our problems in research and application of uneven-aged.

Among these are: One, the density control that we utilize in uneven-aged silviculture is based largely on our experience with even-aged systems. If we remember that in uneven-aged stands we must be concerned with trees of all size classes is it reasonable to assume that we should base our density control on our experience with stands that have only two or three size classes?

Two, there is a tendency to consider that an uneven-aged stand structure will take care of itself and that we can use the same mass averages (per acre figures) to measure development that we use in even-aged stands. This may or may not be true. Our prime concern in uneven-aged silviculture must be the growth and development of the individual trees. The system is predicated on an orderly movement of trees through the range of diameter classes. For example, it is not sufficient to determine only whether or not we have regeneration, but to be sure that regeneration grows and develops into poles and saplings.

Three, mistakes in uneven-aged management are not easily recognized. If the stand is not developing as it should, the problem is not evident until sometime in the far distant future, when we find that there are no trees of harvestable size and the stand structure we were attempting to maintain is no longer with us.

Summary

In closing, I would like to emphasize two points:

1. Uneven-aged silviculture and management is a viable and workable process for the production of timber and/or other goods and services.

2. There are distinct and unique differences between uneven-aged and even-aged silviculture and we must recognize these differences in our research programs, in our on-the-ground applications, and in our contacts with the public.

APPLICATION OF UNEVEN-AGED SILVICULTURE AND MANAGEMENT ON PUBLIC AND PRIVATE LANDS

by

David A. Marquis[1/]

Now that we know what uneven-aged management is and know a little about the history and philosophy of its use, how do we go about applying it on the ground? In attempting to answer that question, I'd like to look first at the big stumbling block of past efforts at uneven-aged management. The problem of deciding how many of what kind of trees to cut on what schedule to achieve balanced stands that will provide sustained yield with reasonably even flows. So, I'd like to start by describing some of the procedures and guidelines available for stand evaluation, tree marking, control of cutting, and regulation of yield. With that foundation, we can then look at some of the cutting options available and some of the factors that must be considered in removal of timber under uneven-aged management.

In the discussions that follow, I have plagiarized freely from the writings of many, but particularly those of Dick Trimble, Bill Leak, and Ben Roach.

Regulation and Control

The most straightforward and widely understood type of uneven-aged silviculture and management is single-tree selection cutting with regulation of yield achieved through control of diameter distribution. So, let's first consider regulation and control under this classic scheme.

First, let me remind you that many early attempts at selection cutting failed because cutting was concentrated in the larger trees, and limits on cutting were expressed only in terms of the total volume that could be removed. As a result, diameter distributions became badly imbalanced. After several cuts, most of the good timber was depleted and ingrowth into sawtimber sizes had been delayed by the concentration of trees in other size classes. For a more complete discussion of what went wrong with these early selection cuttings, see the recent AFRI paper by Ben Roach (1974).

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The lesson to be learned from the early cuttings is that volume (stocking) control in itself does not provide adequate regulation--some control over diameter distribution is also needed. Let's consider each of these two important control elements.

Stocking Control

The first decision to be made in applying a selection cut to a particular stand is what residual stocking is to be retained after the cut. It is a well-known principle that total stand growth varies only slightly over a moderately wide range of stocking levels. Thus, stands cut back to 60 or 70 percent of full stocking will exhibit essentially the same total growth as a fully-stocked stand, but this growth will be concentrated on fewer trees. It is usually desirable to maintain stands at the minimum stocking that will provide no loss in total growth--this permits concentration of growth on the higher quality, more valuable stems, reduces the time required to grow individual trees to maturity, and maximizes rate of return by keeping the investment in growing stock minimal.

The residual stocking level that provides best growth varies with the species and sizes of trees present, the diameter distribution, and other factors. Most current guidelines for selection cutting provide general recommendations for residual stocking level. For example, 70 to 80 square feet of basal area in trees 5 inches d.b.h. and larger is recommended for northern hardwoods in New England (Leak et al, 1969a), 70 to 85 square feet is recommended for good site Appalachian hardwoods (Trimble et al, 1974), and 80 to 90 square feet is recommended for northern hardwoods in the Lake States (Arbogast 1957). When a range of values is given, it is sometimes recommended that the higher stocking values be used in heavily-stocked, previously uncut stands, and the lower values be used in stands already under management (Trimble et al, 1974).

While these general residual stocking recommendations are probably adequate for many situations, they can be pretty far off in stands whose average size or species composition differ markedly from the typical or average stand. Furthermore, these general recommendations ignore the much more refined guides that have been developed in some forest types for control of stocking under even-aged management.

I'm sure that you're all familiar with the type of stocking guide developed originally by Sam Gingrich for the oak type (Gingrich 1967) which show the normal, full, or A level stocking for stands of varying basal area, numbers of trees, and average diameter (Figure 1). Similar stocking guides have since been developed for northern hardwoods in New England (Leak et al, 1969a), paper birch in the Northeast (Marquis et al, 1969) , spruce--fir in the Northeast (Frank and Bjorkbom 1973), Allegheny hardwoods (Roach 1975), and perhaps other types. These guides are by far the most useful means available to evaluate stocking. The A level on these stocking guides should be just as useful in estimating the full stocking level of a stand to be managed under uneven-aged management as it is for a stand being managed under even-aged management.

Consider an example using the oak stocking chart (Figure 1). If we have a stand nearing maturity with average diameter of 12 inches, normal stocking would be about 122 square feet of basal area, and that stand could be cut back to B level stocking of 72 square feet without losing total growth. A younger stand, with average diameter of 7 inches would contain only about 102 square feet of basal area at full stocking and it could be cut back to 59 square feet without losing total growth. Thus, the desired residual stocking of these two stands varies by about 13 square feet of basal area.

Consider another example using the Allegheny hardwood stocking chart (Figure 2). In the Allegheny hardwood type, Ben Roach has found that the species present differ considerably in their growing space requirements, so that species composition must be considered in the evaluation of stocking (Roach 1975). For ease in field use, he was able to place the various species into one of two species groups based on their growing space requirements. Black cherry, white ash, and yellow poplar require much less growing space than sugar maple, beech and other associated species. Thus full stocking levels are much higher for stands that contain high proportions of cherry, ash, or poplar. For example, a 10-inch diameter stand with no cherry, ash, and poplar could be cut back to 73 square feet of basal area, but a similar stand containing 80 percent black cherry, ash, and poplar should not be reduced below 109 square feet--a difference of 36 square feet. Obviously, the use of a simple basal area recommendation could result in severe over or under cutting in situations such as this.

Ben's stocking charts are the first I know about that have recognized species composition directly as a factor affecting stocking. But I suspect that the same concept will eventually be extended to other types. In Appalachian hardwoods, it is already recognized that site affects stocking (Trimble et al, 1974)--a large part of this may be due to differences in species composition between sites.

Now you may argue that once stands have been under selection management for a period of years, that differences in species composition among stands will be minimal and that average stand diameter will also stabilize. This is true. But, for the foreseeable future, much of our selection cutting will be in unregulated, mostly second-growth stands where these factors <u>do</u> vary widely. Furthermore, even in fully-regulated stands, average diameter, and therefore stocking levels, will vary with the diameter distribution being maintained.

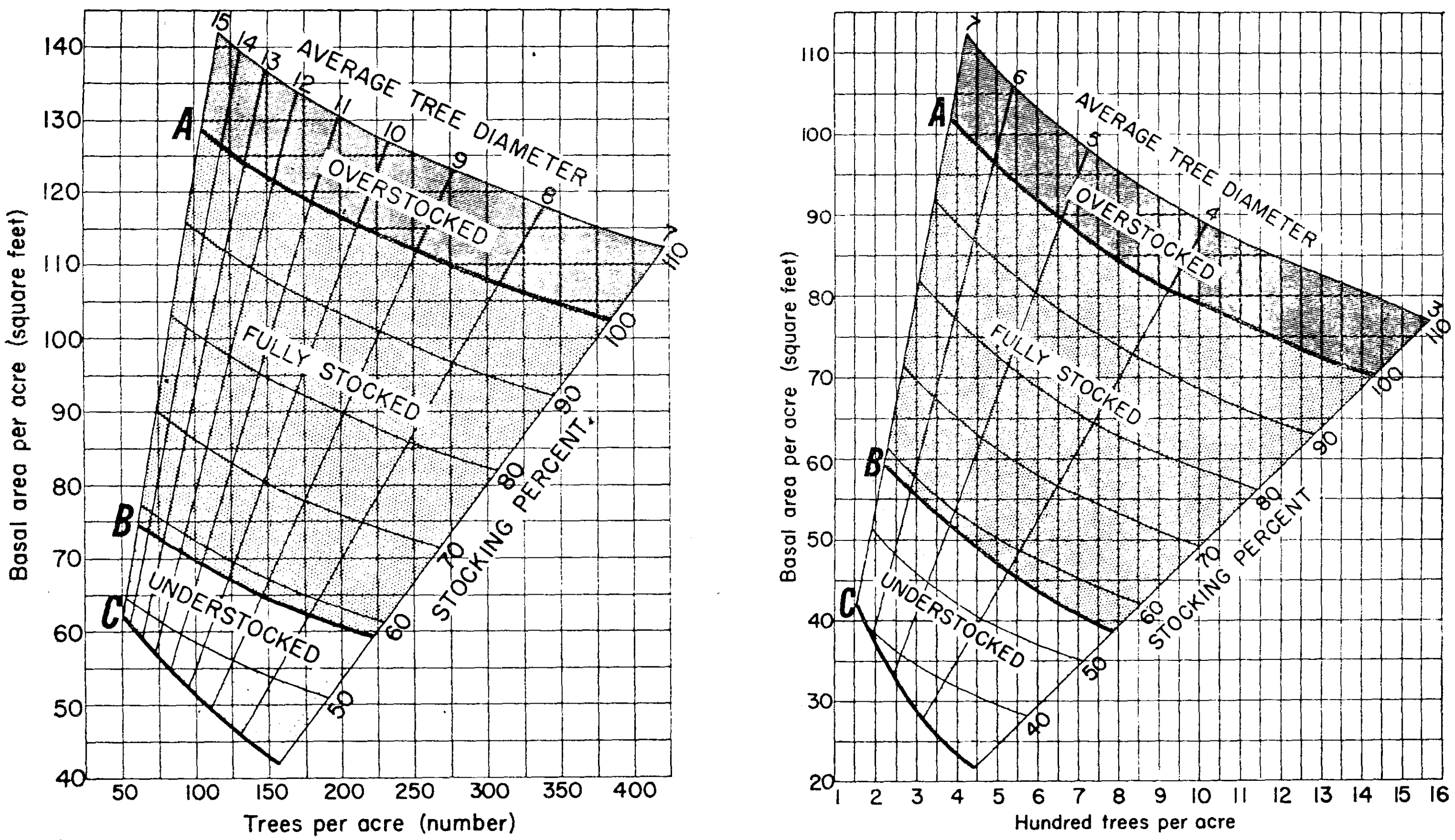

Figure 1.-- Relation of basal area, number of trees, and average tree diameter to stocking percent for upland hardwood forests of average uniformity. Tree-diameter range 7-15 (left), 3-7 (right). The area between curves A and B indicates the range of stocking where trees can fully utilize the growing space. Curve C shows the lower limit of stocking necessary to reach the B level in 10 years on average sites. (Average tree diameter is the diameter of the tree of average basal area.) (Gingrich 1967).

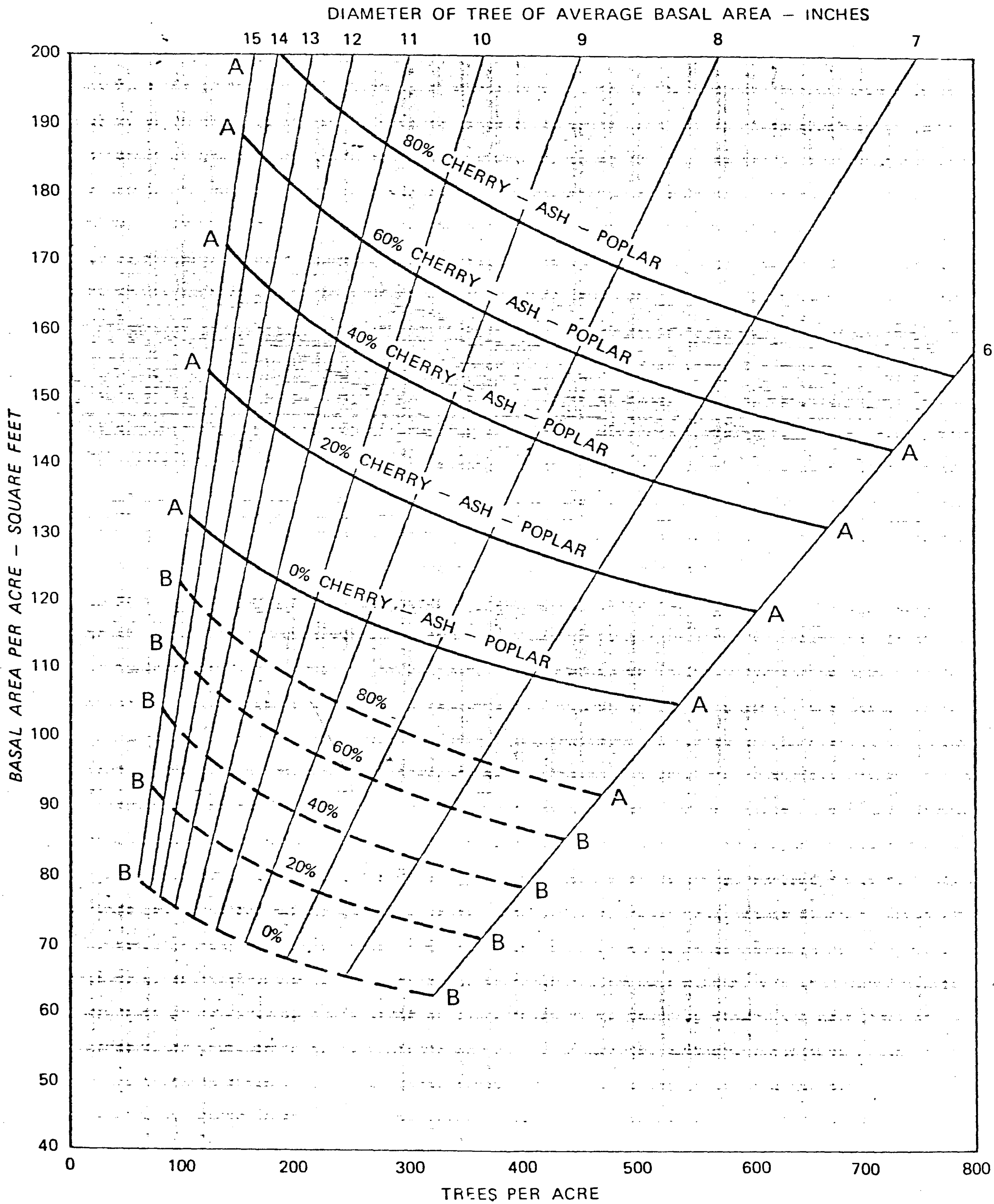

Figure 2.-- Stocking guide for Allegheny hardwoods for stands 6 to 15 inches in diameter (Roach 1975).

For example, in an Allegheny hardwood stand containing only sugar maple and beech, average stand diameter under selection cutting would stabilize at 9.0 inches if the maximum size tree retained was 24 inches in diameter and a "q" factor of 1.3 is used. B level stocking for such a stand is about 71 square feet. The same stand managed with a "q" of 2.0 would have an average diameter of only 4.4 inches and B level stocking would be 58 square feet-- 13 square feet lower than above (Table 1).

The point of all this is to suggest that residual stocking levels under uneven-aged management should be based on stocking guides that express the differences in basal area resulting from differences in stand diameter, species composition, etc. To the extent that such charts are not currently available in particular types, their development is encouraged.

There is some validity to the recommendation previously mentioned, that a higher residual stocking level be used for the first cut in dense, previously unmanaged stands. This too, can be accommodated nicely on the standard stocking charts. Instead of cutting clear to the B level (which is about 60 percent of the A level), cut only to 70 percent of the A level.

Control of Diameter Distribution

As we've already pointed out, control over diameter distributions is also necessary to regulate the yields from selection cut stands. So in addition to a residual stocking goal, it is necessary to establish a diameter distribution goal, i.e., a desired number of trees (or basal area) to be retained in each diameter class.

The accepted procedure for doing this is to utilize the quotient (called "q") between numbers of trees in successive diameter classes as a means of calculating a desired diameter distribution. It has been shown that this quotient tends to be a constant in many undisturbed, uneven-aged stands (Meyer et al, 1952). Thus, if you were to adopt a "q" of 1.3, this means that each diameter class would have 1.3 times as many trees as the next larger diameter class (Table 2).

When the number of trees is plotted over diameter class, the distribution calculated using "q" graphs as a curve with a typical inverse-J (Figure 3). Or, if plotted on semi-log paper, the distribution follows a straight line (Figure 4). The distribution can be expressed mathematically by fitting a logarithmic regression to it. When this is done, the slope of the regression equation is equal to "q"; this provides a useful method of calculating the "q" of an actual stand (Leak 1963). Note that this provides the quotient for 1-inch diameter classes. For some strange reason, foresters usually calculate "q" by 2-inch classes. To get "q" for 2-inch classes, square the value for 1-inch classes.

Table 1.-- Average diameter and B level stocking for Allegheny hardwood stands for various "q" factors.1/

"q" factor	Maximum tree size (inches) 32		24	
	ave. diam. - inches -	B level - sq. ft. -	ave. diam. - inches -	B level - sq. ft. -
1.1402 (1.3)	10.0	73	9.0	71
1.1832 (1.4)	8.4	69	7.8	68
1.2247 (1.5)	7.2	66	6.9	66
1.2649 (1.6)	6.3	64	6.2	64
1.3416 (1.8)	5.2	61	5.1	61
1.4142 (2.0)	4.5	58	4.4	58

1/ for stands with 0 percent black cherry, white ash, yellow-poplar

Table 2.-- Distribution of trees by diameter classes for a quotient of 1.3

D.b.h. class	No. trees	D.b.h. class	No. trees
1	417.54	13	17.92
2	321.18	14	13.79
3	247.06	15	10.60
4	190.05	16	8.16
5	146.19	17	6.27
6	112.46	18	4.83
7	86.50	19	3.71
8	66.54	20	2.86
9	51.19	21	2.20
10	39.37	22	1.69
11	30.29	23	1.30
12	23.30	24	1.00

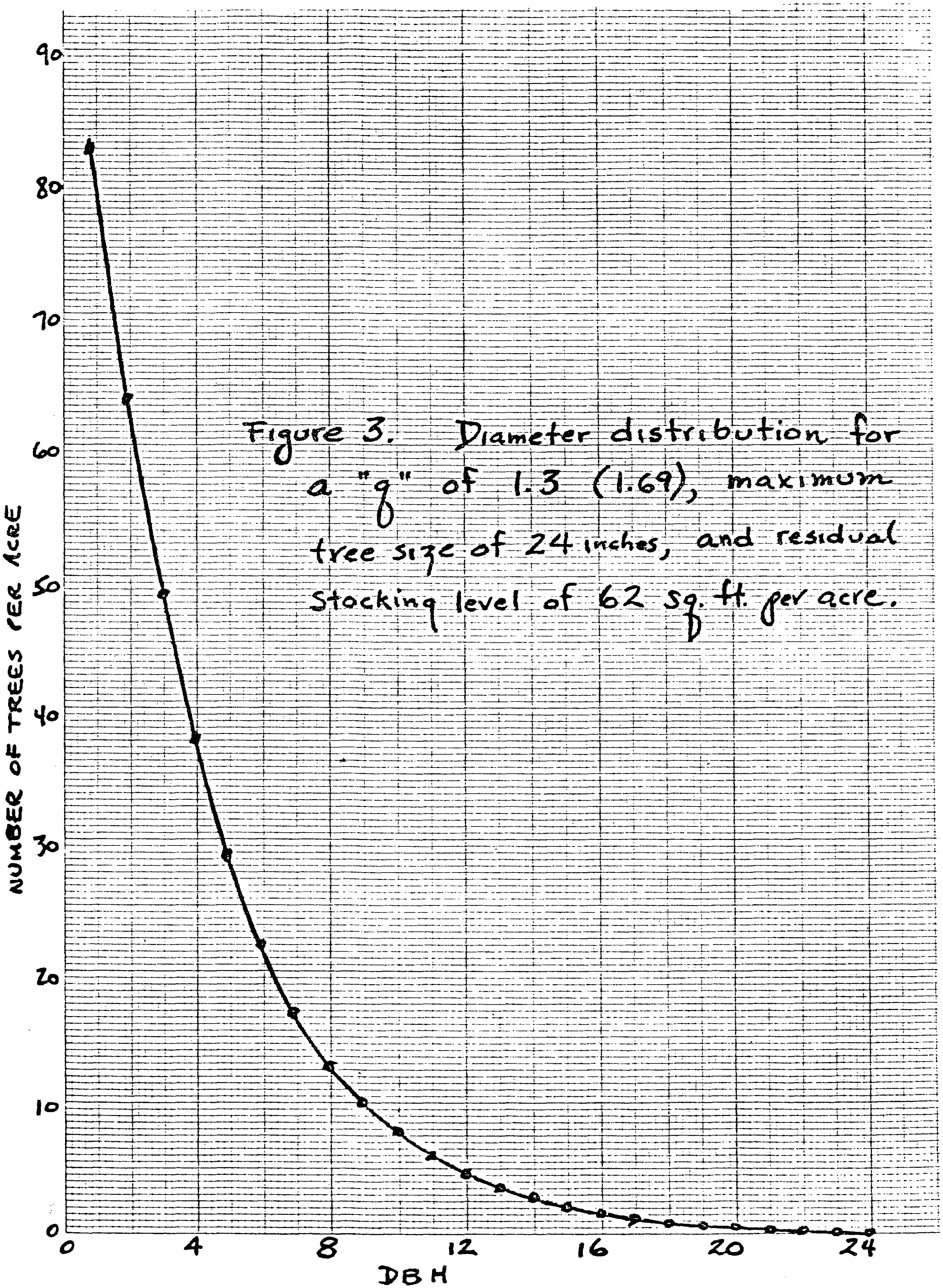

Figure 3. Diameter distribution for a "q" of 1.3 (1.69), maximum tree size of 24 inches, and residual stocking level of 62 sq. ft. per acre.

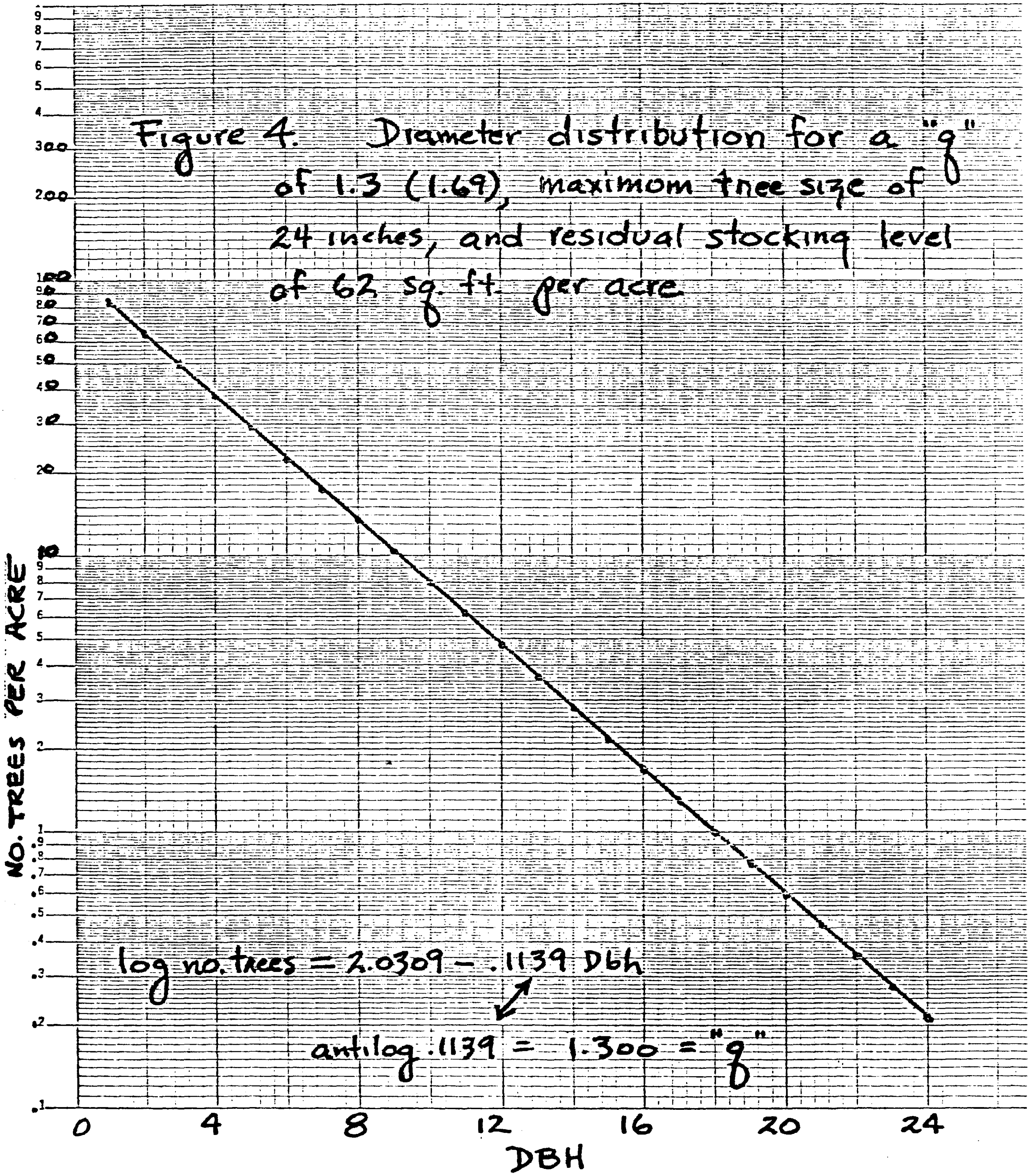

Figure 4. Diameter distribution for a "q" of 1.3 (1.69), maximom tree size of 24 inches, and residual stocking level of 62 sq. ft. per acre

To set up a diameter distribution goal based on "q", you must have decided upon three other parameters. First, you must have decided what residual stocking level you will maintain. Determine this from data on the stand in question, using the stocking charts previously mentioned.

Setting Maximum Tree Size Goals

Secondly, you must decide the maximum size tree to be left after each cut. The largest tree to be left may be as low as 18 to 20 inches d.b.h., or as high as 32 or more inches, depending upon site quality, the species involved, the importance of forest uses other than timber production, and the owner's economic objectives for the tract. The best guidelines available for making this decision are probably the series of papers on financial maturity published over the past 6 or 7 years by the Northeastern Forest Experiment Station. This rate of return information is available for northern red oak, white oak, chestnut oak (Trimble and Mendel 1969), black cherry, red maple, white ash (Grisez and Mendel 1972), sugar maple (Mendel et al, 1973), and yellow birch (Leak et al, 1969b).

For example, the rate of return information in Table 3 (Trimble et al, 1974) shows that sugar maple can be grown only to 18 inches d.b.h. on site 80 if a reasonably high (6 percent) rate of return is desired, but that it can be grown to 32 inches d.b.h. on the same site if the owner is satisfied with a lower (2 percent) return. The lower rate of return and larger trees might very well be appropriate for aesthetic reasons in many areas.

Setting "q" Goals

The third parameter that must be determined before you can set up a diameter distribution goal based on "q" is the level of "q" to be used. Quotients ranging between 1.3 and 2.0 (for 2-inch d.b.h. classes) have all been recommended for various situations. The lower the "q", the smaller the difference in number of trees between diameter classes. Stands maintained to a small "q" have a high proportion of the available growing space devoted to larger, more valuable trees and should theoretically produce somewhat higher yields than stands maintained to a high "q". But maintenance of a low "q" factor means that the excess numbers of small stems that usually develop must be removed periodically at some expense.

For example, consider the numbers of small trees that would be maintained in a stand held at a "q" of 1.3 versus the number in the same stand maintained at 2.0 (Table 4). Obviously, many additional small trees would have to be cut under the 1.3 "q". On the other hand, compare the basal area in large sawtimber in the two stands--there is much more growing space devoted to large sawtimber where the "q" is low.

Table 3. Maximum size trees for various rates of return, species and site index (from Trimble et al 1974).

	Rate of return desired								
	2 percent			4 percent			6 percent		
Species	Site index for oak								
	80	70	60	80	70	60	80	70	60
Yellow-poplar	26	26	24	20	18	18	18	18	18
Beech	24	22	22	20	18	18	18	18	18
Black cherry	32	30	30	22	20	18	18	18	18
Red maple	32	30	30	22	22	18	18	18	18
White ash	30	28	28	22	20	18	18	18	18
Sugar maple	32	32	30	22	22	18	18	18	18
Red oak	26	26	24	22	22	20	20	18	18
White oak	24	22	20	20	18	18	18	18	18
Chestnut oak	24	24	22	20	18	18	18	18	18
Other long-lived species	26	26	24	20	20	18	18	18	18

Table 4. Stand structure goals for various "q" levels in Allegheny hardwood stands.[1/]

	Quotient		
	1.1402 (1.3)	1.2649 (1.6)	1.4142 (2.0)
	Average stand diameter		
DBH group	9.0	6.2	4.4
	- no. trees per acre -		
1-5	81	215	406
6-10	42	66	111
11-16	25	22	21
17-24	13	6	3
All	161	309	541
	- Square feet of basal area per acre -		
1-5	4.2	9.7	12.1
6-10	14.2	21.2	25.4
11-16	23.6	20.4	15.5
17-24	29.1	12.7	5.0
All	71.1	64.0	58.0

1/ for stands with 0 percent black cherry, white ash, yellow-poplar, and 24 inch maximum dbh.

Unfortunately, we do not have good yield data that would allow us to calculate the economic trade-offs of different "q" levels. About the best we can do now is to shoot for the lowest "q" that seems feasible in terms of pulpwood markets and money available for cultural work in small trees. The pre-logging "q" level will also be an important factor. In younger, second-growth stands where the existing "q" level may run over 2.0 and the number of large trees is quite limited, it would be unrealistic to shoot for a very low "q". But in old-growth, or stands that have already received several cuts aimed at balancing the diameter distribution, a lower "q" may be feasible.

There is no reason to establish an unchanging "q" factor for a particular stand. It is quite reasonable to establish a somewhat high "q" factor during the period when a stand is first being brought under management, and to gradually work toward a smaller "q" in successive cuts.

As a very general recommendation, "q" levels of between 1.5 and 1.8 (for 2-inch classes, or 1.225 or 1.342 for 1-inch classes) appear to be reasonable initial goals for most stands, with the exact level within this range determined by the pre-existing distributions.

Determination of Residual Stand Structure Goals

Once goals for residual stocking, maximum tree size, and "q" level have been set, it is a simple matter to calculate the specific stand structure goals. We have a very simple Fortran computer program that will do this and print out the final goal in only a few seconds. But the calculation can be easily done by hand as well, using procedures that Dick Trimble and Clay Smith have outlined (1975).

To make the calculation, arbitrarily assign 1 tree to the largest d.b.h. class to be used. Then calculate the number of trees in each of the smaller diameter classes by multiplying the next larger class by "q". When all have been determined, calculate the basal area of each d.b.h. class and the total basal area.

Now, this basal area will probably be larger or smaller than the residual basal area you wish to leave. Use the ratio between your desired residual basal area, and the basal area just calculated to adjust the number of trees up or down. The end result will be your stand structure goals (Table 5).

When it comes time to do the actual marking of trees, it is impractical to keep track of them by 1-inch or even 2-inch classes. Broader size classes are usually used. But the calculations are easily made by small classes for accuracy, and then combined where necessary for field use.

Table 5. Calculation of stand structure goals for quotient of 1.3 (1-inch classes) for Allegheny hardwood stand using 24 inches as maximum dbh.

	Trial 1		Adjusted for B level stocking			
Dbh	No. Trees	Basal Area	No. Trees		Basal area	
1	417.54	2.28	82.70		.45	
2	321.18	7.01	63.62		1.39	
3	247.06	12.13	48.94		2.40	
4	190.05	16.58	37.65		3.29	
5	146.19	19.98	28.96	262	3.95	11.48
6	112.46	22.08	22.28		4.37	
7	86.50	23.12	17.13		4.58	
8	66.54	23.23	13.18		4.60	
9	51.19	22.62	10.14		4.48	
10	39.37	21.47	7.80	70	4.25	22.28
11	30.29	19.99	6.00		3.96	
12	23.30	18.30	4.62		3.63	
13	17.92	16.52	3.55		3.27	
14	13.79	14.74	2.73		2.92	
15	10.60	13.01	2.10		2.58	
16	8.16	11.39	1.62	21	2.26	18.62
17	6.27	9.88	1.24		1.95	
18	4.83	8.54	.96		1.70	
19	3.71	7.30	.73		1.44	
20	2.86	6.24	.57		1.24	
21	2.20	5.29	.44		1.06	
22	1.69	4.46	.33		.87	
23	1.30	3.75	.26		.75	
24	1.00	3.14	.20	5	.63	9.64
Total	1805.98	313.00	357.75		62.02	

B level stocking for stand of 5.6 inch diameter is 62 sq. ft.

$$\frac{62}{313} = .198 \text{ (correction factor)}$$

What About the Small Trees

You'll notice that I've made the calculations all the way down to the one-inch d.b.h. class and that I've used 1-inch rather than 2-inch classes. One reason for this is that our stocking guide for Allegheny hardwoods is based on all trees 1-inch d.b.h. and larger. Ben has found it necessary to include these small trees in the stocking charts because there are often large numbers of these small stems (mostly sugar maple and beech) and they take up enough growing space in some stands that their impact on stocking cannot be ignored. Furthermore, we are counting on these small trees to provide ingrowth into the more important size classes in any forest type where we intend to practice single-tree selection management. So it doesn't make sense to ignore these trees in our calculations and inventories just because they happen to be below commercial size. Even though it may not be economically feasible to cut in these small sizes, we need to know what is happening there in relation to our goals to aid in evaluation of progress. The extra amount of time and effort required to include the small trees in calculations and in inventories is infinitesimally small.

Although there is little reason to ignore these small trees in record keeping, it may not always be possible to regulate their numbers. Trees less than 5 or 6 inches d.b.h. usually are not merchantable. And, trees less than saw-timber size may be uneconomical to cut and remove in many locations where pulpwood or small product markets are poor. Therefore, regulation of trees below commercial size will require some investment in cultural work.

Most recommendations for single-tree selection suggest that cutting be done down to the 5-or 6-inch d.b.h. class. Trees below that size are unregulated. This creates a hump in the diameter distribution in the small sizes, and means that cutting must always be heavy in the threshold size classes to bring the ingrowth trees down to the desired number.

It also means that more of the growing space is being devoted to small trees than the ideal structure prescribes. It is usually assumed that whatever loss in growth or regulation may result is more than offset in savings realized by not having to do cultural work in these small sizes. However, these trees have to be removed sometime--if not while small, then later when they cross the threshold diameter and are more expensive to treat.

The higher the threshold diameter is set, the larger the proportion of the stand that is unregulated and the greater the amount of growing space that is devoted to trees that will produce only low value products because they will have to be cut as soon as they cross the threshold. If carried too far, we're right back where we were in the early days of selection cutting with unregulated stands that cannot produce a sustained yield without very large fluctuations in yield over time.

There is at least one study underway--at Parsons, West Virginia-- where comparisons are being made between a stand where cutting is done in all sizes down to 5 inches versus a stand where cutting is done only in trees over 11 inches d.b.h. Although this study has been in progress for 24 years, it is still too soon to draw definite conclusions about the effect of these two practices. After 24 years, the stand with cutting down to 5 inches does contain more of its basal area in sawtimber, seems to contain more total board-foot volume, and has been more closely molded to its stand structure goal than the stand with cutting only to 11 inches. And there are signs of a buildup, or hump, in the diameter distribution in trees 5 to 11 inches d.b.h. in the stand with cutting only to 11 inches. But none of these differences are dramatic as yet, and the ultimate effect on yields and regulations are not yet apparent (Trimble and Smith 1975).

Until more complete information is available, the only appropriate recommendation would have to be that cutting be carried down at least to the 5- or 6-inch diameter classes.

Stand Examination

Having discussed all the stand structure goals and calculations necessary to implement them, let's back up to a step that actually would have been done first. This is the stand examination that would have to have been made to provide the data needed for the calculations.

The same procedures recommended in most silvicultural guides for even-aged methods will work equally well for uneven-aged methods. Basically, one must collect data on basal area, and number of trees, broken down into size classes and perhaps species groups and/or growing-stock quality groups. This is easily done using point sampling procedures to get basal area, and using a fixed radius plot (such as 1/20 acre, 26 feet, 4-inch radius) to get numbers of trees. The tree count on a fixed radius plot is needed to estimate average stand diameter. It can be obtained in a matter of a minute or two per plot by walking around the plot center counting all trees and keeping oneself on the circumference by occasional use of an optical rangefinder set at the plot radius.

For the ultimate in simplicity, a prism can be used as the rangefinder by placing at plot center a target of the appropriate size (a target 9.57 inches wide used with a 10 factor prism, for example). Too often, this important measurement is estimated, with very large errors resulting.

The data thus collected is summarized and average diameter, and stand stocking determined by calculation or by reading them from stocking charts. The distribution of trees (basal area) by broad diameter classes is also obtained (Figure 5).

Figure 5

ALLEGHENY	SM-BE	7/7/75
Property or Compartment	Type or Major Species	Date
31	All-aged	DM
Stand No.	Age Class	Crew

BASAL AREA AND TREE TALLY

Sample Point No.	Large Sawtimber	Small Sawtimber	Poles	Saplings	Tree Count, 1/20 Acre
1	3	4	4	1	20
2	2	3	5	2	28
3	1	5	3	2	14
4	2	3	4	2	34
5	1	6	2	1	22
6	1	5	3	2	28
7	4	2	2	3	32
8	2	3	3	1	21
9	1	4	6	0	19
10	1	3	5	1	23
Total	18	37	37	15	241

STAND CALCULATIONS & DISTRIBUTION OF CUT

	Large Sawtimber (2)	Small Sawtimber (1)	Poles (.3)	Saplings (.04)	Total BA per/acre	No. Trees per/acre	Mean Diam.	BA for 100% Stocking	Actual % Stock.
Original Stand	18	37	37	15	107	482	6.4	108	99
Residual Goal									
Residual Stand									
Cut Stand									
Cut Ratio									

Stand Prescription and Marking

Assuming that a decision to use single-tree selection management has already been made, everything needed to write a prescription and set marking guidelines can be obtained from the stand diagnosis.

First, look up and enter on the form (Figure 5) the total basal area to be retained in the residual stand, using the appropriate stocking chart. Keep in mind that the cutting may change average stand diameter, species composition, or other factors that affect B level stocking. You'll have to estimate what these changes will be, if any.

Next, calculate the residual stand structure goal for the residual stocking level thus determined, using the goals for "q" and maximum tree size you determine to be most suitable for this stand. You may wish to calculate the existing "q" before making these determinations. Enter the desired stand structure goals on the form.

Now you'll have to decide what you are going to do about the small trees. Presumably, you'll not be cutting in the sapling size classes, so show this on the line for the residual stand. Using the basal area factors in parentheses for each size class, you can estimate the number of trees, mean stand diameter, etc., and see the effect that not cutting in the small sizes will have on your stand structure goals.

Finally, subtract the residual stand data from the original stand data to obtain figures for the cut stand (Figure 6).

With this information, you can now determine whether or not you have enough volume to make an operable cut. You can see how much basal area is to be cut in each size class, and the average diameter of the trees to be cut. All provide information needed to determine the economic feasibility of the cutting operation.

These same data provide excellent information to be incorporated into the marking instructions. For example, it is apparent what proportion of each size class must be cut, so the markers can be instructed to mark 1 out of every X number of large sawtimber trees, etc., etc. With a little additional calculation, you can also determine the ratio of number of trees to be cut among size classes. Thus, markers can be instructed to cut 1 large sawtimber tree for every X small sawtimber tree, etc., etc.

After having gone through this exercise, it may become apparent that some of the goals previously set were unrealistic or not feasible economically. If so, it's a simple matter to calculate the effect of other "q" levels, other maximum tree sizes, etc.

Figure 6

ALLEGHENY	SM-BE	7/7/75
Property or Compartment	Type or Major Species	Date
31	All-aged	DM
Stand No.	Age Class	Crew

BASAL AREA AND TREE TALLY

Sample Point No.	Large Sawtimber	Small Sawtimber	Poles	Saplings	Tree Count, 1/20 Acre
1	3	4	4	1	20
2	2	3	5	2	28
3	1	5	3	2	14
4	2	3	4	2	34
5	1	6	2	1	22
6	1	5	3	2	28
7	4	2	2	3	32
8	2	3	3	1	21
9	1	4	6	0	19
10	1	3	5	1	23
Total	18	37	37	15	241

STAND CALCULATIONS & DISTRIBUTION OF CUT

	Large Sawtimber (2)	Small Sawtimber (1)	Poles (.3)	Saplings (.04)	Total BA per/acre	No. Trees per/acre	Mean Diam.	BA for 100% Stocking	Actual % StocK.
Original Stand	18	37	37	15	107	482	6.4	108	99
Residual Goal	10	19	22	11	62	358	5.6	103	60
Residual Stand	10	19	22	15	66	472	5.0	100	66
Cut Stand	8	18	15	0	45	72	10.5		
Cut Ratio	2.2	2	2.5	0					

The marking instructions thus prepared will pretty well guide the marking team in selecting how many of what size trees to take out. Within these limitations, there will still be some choices to make among trees in a class. The usual sorts of silvicultural or economic guidelines can be superimposed to provide the marker with information he needs for these choices. He would first remove culls, trees with significant defect, trees of low vigor, short lived species, trees that lack potential to produce a grade 2 butt log, etc. He would retain high vigor trees, trees of the more valuable species, trees with potential for an increase in grade, trees with greater merchantable heights, etc. The general principles described in the financial maturity papers provide excellent guidelines for the types of trees to be favored or discriminated against, so long as they are applied within the stand structure limitations previously mentioned.

Keeping the Markers on Target

During the actual marking operation, frequent checks are needed to insure that the marking actually conforms to the stand structure goals desired. The marking crew normally tallies each tree as it is marked, and it is a simple matter to stop occasionally and count up the number of trees being marked in each size class to insure that the proper ratio of size classes is being removed. This, however, does not provide any clues to residual stocking level unless the area covered is known.

Bill Leak and Stan Filip (1975) suggest that the tallyman of the marking crew periodically stop to take a prism estimate of the residual stand after marking, using a special cumulative tally form that provides built-in conversion to number of trees. This is periodically converted to trees per acre by dividing by the number of prism points sampled, and then compared to the goal. Adjustments in marking procedure are made on the basis of this information, and the marking continues through a process of successive approximation.

The same procedure could also be done using the stand diagnosis form previously described, with comparisons made to basal area goals rather than number of tree goals (Figure 7).

Regardless of the exact procedure, periodic checks on the marking is important if stand structure goals are to be met. Prism samples of this type require very little time so it seems quite feasible to take two or three plots per hour on a fixed or systematic time schedule. Using such a process, it should be possible to mark the residual stand fairly closely to the goal.

Allowable Cut Projections

Allowable cut projections under uneven-aged management are fairly simple in concept. To project the amount that can be removed at the next cut, start with the number of trees and basal area present by diameter class after the current

Figure 7

ALLEGHENY	SM-BE	7/7/75
Property or Compartment	Type or Major Species	Date
31	All-aged	DM
Stand No.	Age Class	Crew

DOT TALLY OF RESIDUAL STAND

No. Sample Points	Large Sawtimber	Small Sawtimber	Poles	Saplings	Total
21	210	378	462	336	

SUCCESSIVE ESTIMATES OF RESIDUAL STAND

Goal	10	19	22	15	66
Estimate 1	7	19	30	14	70
2	8	18	26	15	67
3	8	18	23	15	64
4	9	18	21	16	64
5	10	18	22	16	66
6					
7					
8					
9					
10					

cut. The marking tally, or a special post-logging tally, will provide these data. Apply figures on expected growth by diameter classes to obtain the projected stand at the time of the next cut. The difference between the projected stand and the structural goal is the allowable cut.

The only difficult part about projecting yields by this procedure is the lack of data on growth. Ideally, this would be obtained from semi-permanent growth plots in the stand itself. However, where remeasurement data for a specific stand are not available, published growth figures have to be used to make rough projections.

The published growth figures now available suggest that most hardwood stands that have been cut to B level stocking should produce about 2 square feet of basal area per acre per year unless there are complications from insects or disease attacks.

The distribution of this growth among diameter classes varies with the diameter distribution or "q" level. Stands with a high "q" level (1.7 or above) generally have less than half of their basal area in sawtimber sizes and 50 to 65 percent of the growth will be placed on sawtimber trees. Stands with a lower "q" (1.6 or below) will have over half of their basal area in sawtimber, and 60 to 90 percent of the growth will be on sawtimber trees (Leak & Filip 1975).

Using the figures above, and some growth data from a few northern hardwood stands, I have fitted a free-hand curve to the growth by diameter classes to illustrate the general pattern of growth in stands of high and low "q" levels, assuming 2.0 square feet of basal area growth per acre per year and 24-inch maximum size tree (Figure 8). From these charts, I've prepared a table showing the expected basal area growth for each diameter class (Table 6).

These growth figures can be used to project growth to the end of the cutting cycle. Simply multiply the projected growth figures by the number of years in the cutting cycle, and add to the current basal area for each diameter class. This will provide an estimate of the future stand. Subtract from this the residual diameter distribution goal to get future cut in basal area (Table 7). Graphically, the cut would be the excess above the residual goal (Figure 9). Appropriate conversion factors can then be applied to convert the basal areas to cubic- or board-foot volume (Table 7). A simple computer program could handle this calculation.

The allowable cut for an entire forest is determined by following this same procedure for each stand, and summing the yields. Irregularities in forest yields can be smoothed to some extent by small adjustments in the cutting cycles, i.e., by adjusting the time that particular stands are cut, in much the same way that even-aged stands would be scheduled.

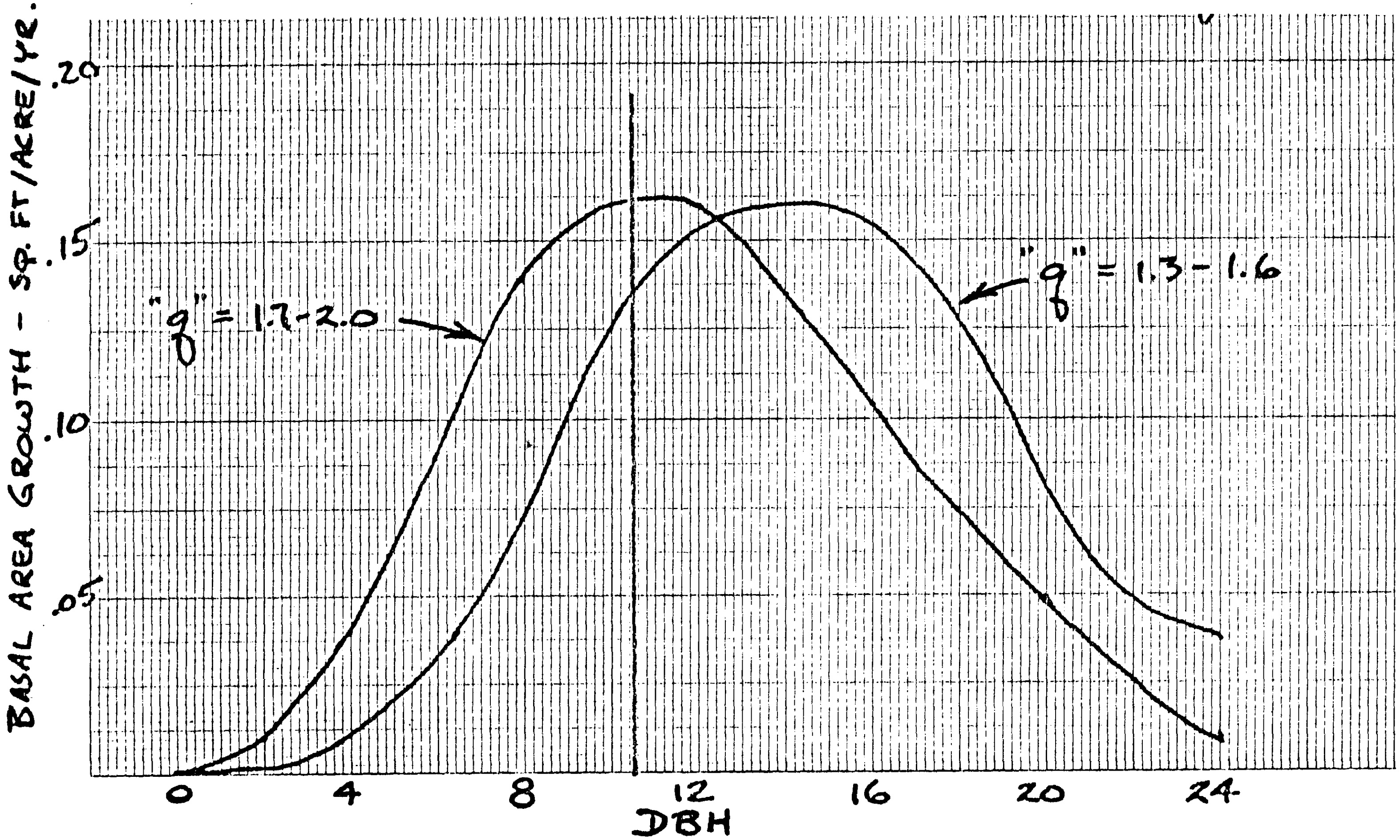

Figure 8. Basal area growth by diameter class for stands of high and low "q" level.

Table 6. Distribution of Growth by Diameter Classes

dbh	"q"=1.3 - 1.6	"q"= 1.7 - 2.0
	- square feet of basal area per acre per year -	
1	.000	.005
2	.000	.010
3	.005	.025
4	.010	.040
5	.020	.065
6	.030	.090
7	.050	.115
8	.070	.140
9	.100	.150
10	.125	.160
11	.140	.165
12	.150	.160
13	.160	.150
14	.160	.135
15	.160	.120
16	.165	.105
17	.140	.090
18	.130	.075
19	.105	.060
20	.080	.050
21	.065	.040
22	.050	.025
23	.045	.015
24	.040	.010
Total	2.000	2.000
% in sawtimber	72	52

Table 7. Calculation of allowable future cut for a 20-year cutting cycle and "q" of 1.3 (1-inch classes) in Allegheny hardwoods.

Dbh	Current Stand	Future Stand	Goal	Cut		Cubic Vol. 1/	Mbf Vol. 1/
	- square feet of basal area per acre -						
1	.5	.55	.45	.10			
2	1.5	1.59	1.39	.20			
3	2.2	2.70	2.40	.30			
4	3.8	4.60	3.29	1.31			
5	4.1	5.40	3.95	1.45	3.36	0	0
6	4.2	6.00	4.37	1.63			
7	5.1	7.40	4.58	2.82			
8	4.1	6.90	4.60	2.30			
9	4.9	7.90	4.48	3.42			
10	5.2	8.40	4.25	4.15	14.32	286	0
11	4.0	7.30	3.96	3.34			
12	4.5	7.70	3.63	4.07			
13	3.1	6.10	3.27	2.83			
14	2.9	5.60	2.92	2.68			
15	2.8	5.20	2.58	2.62			
16	3.4	5.50	2.26	4.24	18.78	470	2.25
17	2.0	3.80	1.95	1.85			
18	3.1	4.60	1.70	2.90			
19	1.5	2.70	1.44	1.26			
20	1.0	2.00	1.24	.76			
21	1.0	1.80	1.06	.74			
22	.5	1.00	.87	.13			
23	.5	.80	.75	.05			
24	.0	1.00	.63	.37	8.06	202	.97
TOTAL	65.9	106.54	62.02	44.52		957	3.22

1/ Conversions used:

pole timber	20 cu. ft. per sq. ft. of basal area
sawtimber	25 cu. ft. per sq. ft. of basal area
sawtimber	120 bd. ft. per sq. ft. of basal area

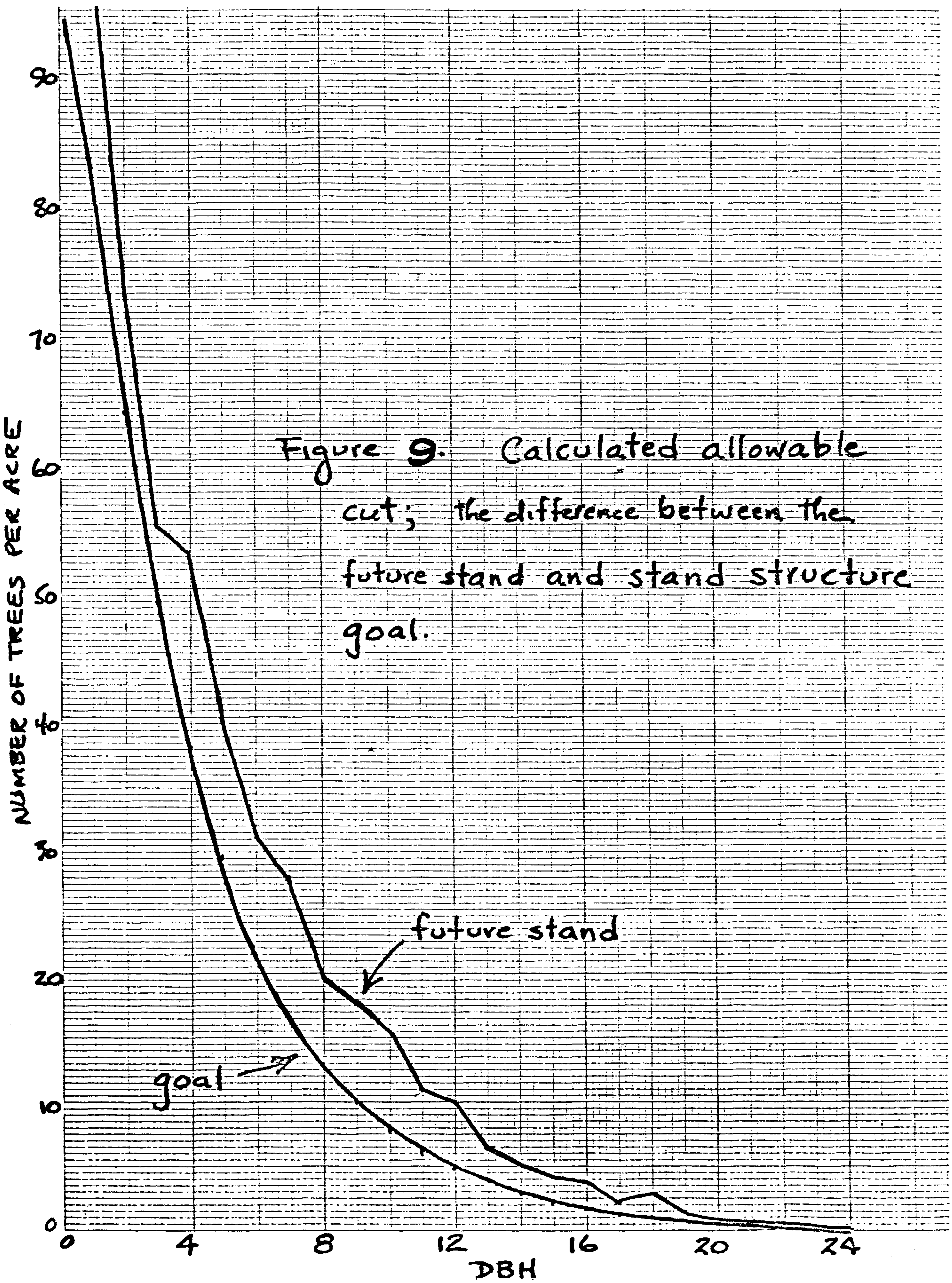

Figure 9. Calculated allowable cut; the difference between the future stand and stand structure goal.
future stand
goal
NUMBER OF TREES PER ACRE
90
80
70
60
50
40
30
20
10
0
0
4
8
12
16
20
24
DBH

Cutting Cycles

The cutting cycle, or interval between cuts, will vary under selection management depending upon growth rate, residual stocking levels selected, site quality, and amount of merchantable volume available for cutting. Cuttings should be timed by the rate of return to full stocking. Cutting should be considered when the stand reaches 80 percent of full stocking, and should generally not be delayed beyond about 90 percent of full stocking.

In Allegheny hardwoods that have been cut back to B level stocking (60 percent of full stocking), and assuming a growth rate of 2 square feet of basal area per acre per year, it takes about 15 years to return to 80 percent stocking and about 20 years to return to 90 percent stocking (Table 8). Similar time periods are appropriate in other eastern types, although cycles as short as 10 years may be possible on good sites. As a general recommendation, a cutting cycle of 15 to 20 years will be appropriate for stands for which specific growth data is not available.

Cutting Method Options

Up to this point, we have considered only single tree selection cutting. This, of course, is the classic type of uneven-aged silviculture and management. In a manner of speaking, it involves both uneven-aged silviculture (culture of trees so that there are several age classes present in the same stand) and uneven-aged management (regulation of growing stock and yields through control over diameter distribution).

The distinction between silviculture (or type of stands grown), and management (or type of regulation used) is quite important in any discussion of uneven-aged silviculture and management, because single tree selection cutting is the only scheme that is truly uneven-aged on both counts. All of the possible alternatives involve either even-aged silviculture with uneven-aged management, or uneven-aged silviculture with even-aged management. Let's look at some of the options.

Single-tree selection consists of the removal of trees throughout all diameter classes on an individual basis, leading to the formation of a stand containing an intimate mixture of size and age classes. Selection of trees to be removed is based on the characteristics of the individual trees in relation to the stand structure goals established for regulation. Trees removed are usually isolated from one another, but if several removal trees happen to occur together, this is still single-tree selection.

Because the openings created by cutting of scattered individual trees are usually quite small, reproduction is generally limited to the shade-tolerant species. If single-tree selection cutting is applied in stands that contain intolerants, the species composition of the stand will gradually change as the

Table 8.--Return to full stocking with time in an Allegheny hardwood stand.

Years since cutting	Average diameter	Residual stocking	A level stocking	Percent stocking
- years -	- inches -	- square feet per acre -		- percent-
0	6.8	65	109	60
5	7.4	75	112	67
10	8.0	85	114	75
12	8.3	89	115	77
15	8.6	95	116	82
18	9.0	101	117	86
20	9.2	105	118	89

intolerants are removed and replaced by more tolerant species (Trimble 1965, Trimble 1970). Complete conversion may take 50 to several hundred years, but true single-tree selection cutting will eventually produce stands dominated by the tolerant species.

The species best adapted to single-tree selection include sugar maple, beech, hemlock, red spruce and balsam fir in the eastern United States. If reproduction of at least one of these species cannot be expected in the stand in question, single-tree selection cutting is probably a poor choice. In general, this means that single-tree selection cutting is likely to be useful in the northern hardwood and spruce--fir types of the eastern United States, and those high elevation or high-site portions of the Appalachian hardwood type where sugar maple is found. On other Appalachian hardwood areas, and in the ash--hickory, oak--pine, southern pine, and bottomland hardwood types single-tree selection is not likely to produce satisfactory results (Minckler 1975).

Group Selection

Group selection cutting involves the removal of trees in small groups of a few to many trees, varying from a fraction of an acre up to several acres in size. Trees are individually examined and marked just as they are in single-tree selection, and the same kinds of trees are removed. But instead of complete emphasis on individual tree characteristics, the predominant characteristics of the entire group of trees is considered.

Because there is more available light, moisture, and nutrients in these small openings, the proportion of shade intolerant species is increased over that of single-tree selection cutting, and this encouragement of intolerant species is the primary reason for using group selection cutting.

The actual manner in which group selection cutting is applied may vary considerably. At one extreme, group selection and single-tree selection cutting may be practiced together, with small group openings of a fraction of an acre created wherever a small group of trees can logically be removed together, and with single-tree selection applied in between these groups. At the other extreme, cutting may be entirely limited to larger openings of an acre or two in size in which all trees down to 2 inches d.b.h. are clearcut without examination and consideration of each individual stem.

The larger group selection openings are really small clearcuttings and have the same effect on regeneration, wildlife habitat, and other resources as patch clearcutting. But so long as the patch is not recognized and recorded as a separate stand, and so long as regulation is achieved through control of diameter distribution, then we consider the patch to be a group selection cutting or patch selection cutting under uneven-aged management rather than a patch clear-cutting under even-aged management. The method of regulation is the deciding factor here.

Group selection cutting--particularly with the larger size openings--creates a stand composed of many small even-aged groups of trees. For this reason, it has sometimes been referred to as even-aged silviculture with uneven-aged management

Obviously, group selection is a bastard. It is an attempt to use a regulatory system designed for an uneven-aged stand in an area that is really a mixture of small even-aged stands. It becomes very difficult or impossible to control diameter distribution when cutting must be restricted to fairly large patches and all trees in that patch must be cut regardless of their size. Even-aged regulation of areas by age class becomes much more efficient and effective as the size of patches gets larger, and should certainly be considered anytime patches of more than an acre or two in size are to be used.

However, uneven-aged regulation can probably be made to work where groups are kept small, particularly if single tree selection cutting is practiced in the area between groups. Thus, the establishment of residual stocking and diameter distribution goals, the actual stand marking, and projection of growth are all handled exactly as outlined for single-tree selection cutting. Obviously, the goals must be applied as an average for the entire compartment or regulatory unit and will not apply within the small individual stands. In some groups of young growth, cutting will really be a cultural operation among only small trees. In other groups of mature trees, cutting will be primarily a harvest of large trees. Hopefully, everything will balance out so that the desired diameter distribution goals for the whole compartment are reached. Frequent checks during marking are even more important under group selection cutting than single-tree selection cutting to insure that the desired residual stand goals are actually being achieved.

Group selection cutting in some variation is suitable for use in all eastern forest types--although it may be less efficient for timber production in some types than even-aged management, it could at least permit perpetuation of the present types if some form of uneven-aged management is required to meet aesthetic or recreation objectives. In a recent analysis for the national forests, it was estimated that over 90 percent of eastern forests would receive group selection if a choice had to be made between single-tree and group selection (U.S. Forest Service 1975).

Diameter-Limit Cutting

Diameter-limit cutting can be used as another bastard method employing the opposite combination of silviculture and management from group selection. In this case, all trees larger than some particular diameter are cut. The diameter may be flexible, varying for trees of different species, quality, etc.

Although diameter-limit cutting has usually been associated with exploitive logging, it does not necessarily have to be such. For example, diameter-limit cutting has usually been associated with exploitive logging, it does not necessarily have to be such. For example, diameter-limit cutting could be employed to create two-age stands, in which one age class is harvested a half a rotation apart from the other age class. Assuming a stand contained half its stocking in trees about 50 years old and half in trees about 100 years old, and using a 100-year rotation for illustration, it would be feasible to harvest all of the 100-year-old trees and thin the 50-year-old trees to leave a residual stocking level of about half of B level stocking. This would provide conditions suitable for regeneration of intermediate and perhaps intolerant species, forming a new age class to replace those harvested. Similar cuts would be made every half rotation, perpetuating a stand containing two distinct age classes. Regulation could be achieved through control of the distribution of age classes by area in the same manner as employed with even-aged management, providing a form of uneven-aged silviculture with even-aged management.

Actually, much of the early cutting done in many hardwood stands was diameter limit cutting of this general sort. Although it was done with little or no thought given to either regeneration or regulation, it does suggest that the procedure is silviculturally feasible. It seems to me that such a system would also be easier to regulate than group selection because it utilizes area control. And it would maintain a stand on the area continuously, thus satisfying aesthetic and recreational demands about as well as group selection cutting. It would appear that the possibilities of this type of cutting need to be explored more fully.

Owner Objectives Affect Choice of Cutting Method

Single-tree selection cutting produces the least noticeable disturbance and leaves a stand that looks more like an undisturbed stand than any other cutting method. For this reason, it is probably the best cutting method to use in areas where aesthetics and recreation are important uses, assuming that the species present are suitable. Single-tree selection is therefore ideal for those portions of public lands where close-in viewing of scenery is especially important. This would include road-side zones along major travel corridors, areas adjacent to recreation sites, and similar locations. Single-tree selection cutting is also ideal for the small private owner who wants to cut a little timber, but whose main reason for holding the land is for reasons other than timber production.

Group selection cutting is very nearly as suitable as single-tree selection cutting for aesthetic purposes so long as the openings are kept quite small--perhaps a quarter-acre or less. But with larger openings, it becomes less acceptable than single-tree selection for aesthetic and recreation areas. Still, it is better on these counts than most of the even-aged methods, so group selection with moderate size openings should be appropriate in those areas where the importance of timber and aesthetics are more nearly equal than on high-use scenic areas.

Diameter-limit cutting of the type described here should serve about the same purposes as group selection with larger openings. It may be easier to regulate than group selection and therefore may be more suitable for larger public and private ownerships where administrative costs of management are a major consideration.

In areas where timber production of intolerant or intermediate species is a major objective, even-aged methods should be considered because of the greater potential volume and value production and reduced administrative costs. Recent calculations made of the impact of several cutting alternatives for the national forests suggest that use of uneven-aged methods exclusively (either single-tree or group selection) could result in a reduction of timber yields of about 13 percent and a reduction of value of about 31 percent while increasing administrative costs of about 9 percent (U.S. Forest Service 1975).

Timber Removal

The problems involved in building roads, choosing proper logging equipment, marketing products, and protecting the residual trees, soil and water are not terribly different under uneven-aged management than they are under even-aged management.

Truck Roads

Under uneven-aged management, a cutting is made in each stand once each cutting cycle (once every 10 to 20 years). Because of the frequent usage, the only feasible approach is to set up permanent truck roads to service all areas. These roads need not be maintained annually, but will have to be opened and repaired for each cyclic cut. This probably means more frequent use than under even-aged management--even where several thinnings might be employed.

There is also a special problem in opening new areas that have not previously been managed, for the cost of the new roads must be borne by the timber removed, and there is no opportunity to harvest a large volume of timber at one time to finance the new road as there is where clearcutting can be employed. This is a particular problem in the remaining virgin stands of the West, but is much less of a problem in the East where forest roads are reasonably well developed.

The number and location of truck roads depends upon the maximum feasible skidding distance; which depends upon equipment used, topography, etc. With tractor arch equipment, maximum skidding distances are somewhat near 1500 feet, which means that each could serve a strip of forest 3000 feet wide. Thus, a mile of truck road could service 350 to 400 acres. The value of timber that can be harvested from this 350 to 400 acres would have to be compared to the cost of building or reopening one mile of road.

In a typical northern hardwood stand in New England a selection cut might produce 5.5 Mbf of sawtimber per acre with a stumpage value of $40 per Mbf, or $220 per acre. This amounts to $88,000 to balance against the road costs (Leak and Filip 1975).

Protection of Residual Trees from Logging Damage

Considerable amounts of damage can be done to the residual stand during felling and skidding operations. The most common injuries are breakage of the major limbs or main stems of trees by the felling of adjacent stems, and skinning of bark from the base of residual trees during skidding operations. Such damage is especially important under uneven-aged methods because of the frequent partial cuttings.

In a study in New York State, logging during partial cutting injured about 30 percent of the residual trees, with major injuries resulting to about 20 percent. Major injuries from felling were nearly twice as frequent as those from skidding, although 70 percent of the trees adjacent to skid trails showed some signs of injury. Felling injuries affected about 35 trees and 8 square feet of basal area, while skidding injuries affected about 22 trees and 4 square feet of basal area per acre (Nyland and Gabriel 1971). There appeared to be greater potential to reduce skidding injuries than felling injuries. Most of the serious skidding injuries were concentrated along the major skidding corridors.

Careful skid trail location and layout are the major ways by which skidding damage can be reduced. Much has been written about proper skid road layout as related to soil and water protection and will not be repeated here (Nyland 1975, Kochenderfer 1970), except for a couple of points related to skidding damage. The skid roads should be laid out as straight as possible since much of the damage occurs on sharp turns. Where a turn or switchback is required, attempt to border the margins of the turn with trees that will be removed during the sale. And make all major skid trails as wide as possible to eliminate border tree damage. Be prepared for some damage along these skid roads, and mark a little lighter in these areas so that you can come back and remove the few damaged trees toward the end of the operation without seriously overcutting that portion of the stand.

The choice of skidding equipment (crawler versus rubber-tired skidders) and the skidding of logs versus tree lengths apparently has less effect on damage to residual trees than commonly supposed. Skidding damage is more frequent along a given length of skid road when rubber-tired skidders are used, but fewer skid roads are required so the total damage balances out. And tree length skidding has been found to cause no additional damage than short length skidding <u>so long as</u> directional felling is practiced (Nyland and Gabriel 1972). So there is little reason to show preference for one method over the other in terms of damage to residual trees.

As mentioned previously, most of the damage to residual trees is done by felling rather than by skidding, and unfortunately this type of damage appears less subject to control. Careful supervision of felling with emphasis on directional felling may help reduce the damage somewhat. Care in marking can also help. Trees with large crowns that cannot be felled without causing damage to adjacent trees should generally not be marked unless the adjacent trees are also marked. Thus, group selection may often be an advantage over single-tree selection cutting for this reason.

Summary

Uneven-aged silviculture and management techniques are most useful in tolerant forest types. In general, timber yields and values are a little lower and costs a little higher under uneven-aged systems, but this is offset in many areas by the advantages to aesthetic and recreational uses.

Application of uneven-aged management requires procedures similar to those used for even-aged management. Regulation of yield is achieved through control of diameter distributions. This requires that a stand inventory be made by size classes prior to cutting, that residual stocking, maximum tree size, and size distribution goals be set, and that trees be marked for cutting on the basis of these goals.

During marking of the stand, frequent checks on the actual marking are needed to insure that the goals are actually being met. Allowable cut projections are made on the basis of stand growth data and the stand structure goals established. Many guidelines and techniques are already available to facilitate the job of applying uneven-aged management on the ground.

Truck roads and skid roads must be laid out carefully to serve the areas to be cut and special attention is needed to minimize damage to residual trees during logging.

Of the several cutting methods available, single-tree selection is most suitable in the northern hardwood and spruce--fir types, while group selection and diameter limit cutting should be applicable in most types. Single tree selection provides best conditions in areas where aesthetics are a primary use, while group selection and diameter limit are slightly less satisfactory for these uses.

Literature Cited

Arbogast, Carl Jr. 1972. Marking guides for northern hardwoods under the selection system. USDA, For. Serv., Lakes States Forest Exp. Sta. Res. Pap. No. 56, 20 p.

Frank, Robert M., and John C. Bjorkbom. 1973. A silvicultural guide for spruce--fir in the Northeast. USDA, For. Serv. Gen. Tech. Rep. NE-6, 29 p.

Gingrich, Samuel F. 1967. Measuring and evaluating stocking and stand density in upland hardwood forests in the Central States. Forest Science 13:38-53.

Grisez, Ted J., and Joseph J. Mendel. 1972. The rate of value increase for black cherry, red maple, and white ash. USDA, For. Serv. Res. Pap. NE-231, 26 p.

Kochenderfer, James N. 1970. Erosion control on logging roads in the Appalachian. USDA For. Serv. Res. Pap. NE-158.

Leak, William B. 1963. Calculation of "q" by the least squares method. J. Forestry 61:227-228.

____________, Dale S. Solomon, and Stanley M. Filip. 1969a. A silvicultural guide for northern hardwoods in the Northeast. USDA, For. Serv. Res. Pap. NE-143, 34 p.

____________, Dale S. Solomon, and Stanley M. Filip. 1969b. Rate of value increase for yellow birch in New England. USDA For. Serv. Res. Pap. NE-120, 11 p.

____________, and S. M. Filip. 1975. Uneven-aged management of northern hardwoods in New England. Manuscript in review, NEFES.

Marquis, David A., Dale S. Solomon, and John C. Bjorkbom. 1969. A silvicultural guide for paper birch in the Northeast. USDA For. Serv. Res. Pap. NE-130, 47 p.

Mendel, Joseph J., and George R. Trimble, Jr. 1969. The rate of value increase for yellow-poplar and beech. USDA For. Serv. Res. Pap. NE-140, 27 p.

____________, Ted. J. Grisez, and G. R. Trimble, Jr. 1973. The rate of value increase for sugar maple. USDA For. Serv. Res. Pap. NE-250, 19 p.

Meyer, H. Arthur, Arthur B. Recknagel, and Donald D. Stevenson. 1952. Forest Management, The Ronald Press Co., New York, 290 p.

Minckler, Leon S. 1975. Woodland Ecology. Environmental Forestry for the Small Owner. Syracuse Univ. Press, Syracuse, NY 229 p.

Nyland, Ralph D., and William J. Gabriel. 1971. Logging damage to partially cut stands in New York State. State Univ. College of Forestry at Syracuse U., Applied For. Res. Inst. Res. Rep. No. 5, 38 p.

____________, and William J. Gabriel. 1972. Injuries from tree-length skidding with rubber-tired vs. crawler tractors. State Univ. College of Forestry at Syracuse U., Applied For. Res. Inst. Res. Rep. No. 8, 11 p.

____________. 1975. Timber harvesting guidelines for New York. Northern Logger and Timber Processor, April 1975, 16-17, 30-31.

Roach, Benjamin A. 1974. Selection cutting and group selection. State U. of NY., Applied Forestry Res. Inst. Rep. No. 5, 9 p.

____________. 1975. Stocking guides for Allegheny hardwoods. Unpublished progress report, NEFES, Warren, PA.

Trimble, George R., Jr. 1965. Species composition changes under individual tree selection cutting in cove hardwoods. USDA For. Serv. Res. Note NE-30, 6p.

____________, and Joseph J. Mendel. 1969. The rate of value increase for northern red oak, white oak, and chestnut oak. USDA For. Serv. Res. Pap. NE-129, 29 p.

____________. 1970. 20 years of intensive uneven-aged management: effect on growth, yield, and species composition in two hardwood stands in West Virginia. USDA For. Serv. Res. Pap. NE-154, 12 p.

____________, Joseph J. Mendel, and Richard A. Kennell. 1974. A procedure for selection marking in hardwoods combining silvicultural considerations with economic guidelines. USDA For. Serv. Res. Pap. NE-292, 13 p.

____________, and H. Clay Smith. 1975. Stand structure and stocking control in Appalachian mixed hardwoods. Manuscript in review, NEFES.

U.S. Forest Service. 1975. The impact of several cutting alternatives on national forest resource values. Unpublished policy paper prepared for the Forest & Rangeland Renewable Resources Planning Act of 1974, U.S. For. Serv., Washington, DC, 112 p.

REGENERATION AND UNEVEN-AGED SILVICULTURE-- THE STATE OF THE ART

by

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I would like to set the stage for this talk by quoting a paragraph from a recent article by Dave Smith: "There are, in other words, at least as many ways of treating forests as there are kinds of forests. The ways that are logical in any given kind of forest are usually those that simulate the ecological effects of the kinds of natural disturbance that create this kind of forest. The trees were around before man was and are adapted to what nature did to them in the past. In the last analysis, they respond to human wants to the extent that man imitates the natural disturbances that lead to what he wants. In a sense, the two extremes just described (clearcut, intensive culture with planting vs. light single tree selection cutting) fail as universal solutions because they include far less than all of the variants of the ecology of real forests. Each, nevertheless represents a sound interpretation of ecological processes that do go on <u>in some places</u>." (Smith 1974). I don't think anyone will disagree with me when I state that most of our difficulties arise when our silvicultural and management objectives don't parallel the ecological facts of life, or when, for a variety of reasons, we are unwilling to accept some of the "variants of the ecology of real forests" that mother nature insists on.

Historical

For the most part, our forests today are the manifestation of ecological responses to past perturbations by man that were probably logical in the context of the times. The result is that in most cases our forests are a patchwork of species and conditions that are a reflection of this past treatment. Like it or not we have to live with it, and to paraphrase Smith, "there are at least as many kinds of forests today as there were 'treatments' in the past."

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Most of you are familiar with the historical progression of logging and lumbering from the early coastal settlements up the major river systems where transportation was easiest. Where railroad logging was practical, areas some distance away from the river systems were opened up. In most regions, the patterns were similar--only the dates and the details change. To put these dates in perspective, Coolidge (1963) states that the first water-powered sawmill in Maine was built in 1634, and by 1790 this had expanded to 150 sawmills. By way of contrast, Marquis (1973) places the date of the first water mill in Warren County, Pennsylvania, as 1800; and a water-powered mill came into use in Tucker County, West Virginia, in 1776. (Anon. 1973).

In most areas the story was essentially the same. Initial lumbering concentrated on the better softwoods--white pine primarily. During this period the major products were lumber and roundwood products used as masts. The impact on the forests was relatively minor with the probable exception of those areas where pure pine stands predominated. I'm ignoring, of course, the impact on the forests of agricultural land clearing.

Westveld (1949) estimated that all virgin eastern white pine was cut by 1870, and by 1900 operations were beginning in second growth stands. Where pure pine stands predominated, clearcutting followed by extensive fire was common, and many of these areas regenerated to various mixtures of successional hardwoods such as grey birch and aspen in mixture with pine. Better sites were converted eventually to hardwoods.

Early logging in most of the hardwood types was a culling or a highgrading operation (Westveld 1948; Blum & Filip 1963; Sander & Clark 1967; and others). The severity of these operations depended primarily on available markets for the hardwoods; markets were usually available for most of the better softwoods in the stands. In the heavily settled areas of the oak region in southern New England, New York, New Jersey and Pennsylvania, clearcutting for fuelwood, charcoal for iron smelters, and mine timber was common and often frequent, relying on coppice regeneration. These stands deteriorated rapidly, especially when followed by fire. This was also true in the upland hardwood region of the Central States in parts of Missouri and Ohio.

Elsewhere the hardwood story varied somewhat depending on accessability, markets, and the suitability of the land for agriculture. Where a large number of species were marketable, the stands, after cutting, were sparse and retained chiefly low value, defective trees. If followed by fire and grazing, as was often the case in the central hardwood region, much of the desirable reproduction following the cut was destroyed, the soil was compacted, and roots of the established trees injured. In some cases this has caused the formation of heavy grass sod that has impaired the establishment of tree seedlings.

Annual burning in many areas caused considerable degrade to overstory trees, and made seedling reproduction sparse.

Clearcutting in the hardwood types became more prevalent with the development of hardwood pulpwood markets. In the northern hardwood types, clearcutting resulted in some fine second growth stands of the intolerant species such as paper birch, white ash and yellow birch. The silvicultural "disasters" after clearcutting were in those new stands comprised of aspen and grey birch--but this judgement is, of course, relative.

Lumbering in the spruce--fir forests of northern New England and New York was restricted to pine and spruce of sawlog size (12"+) in the early days. These species had commercial value and could be transported easily by water. Hardwood stands within the region were rarely harvested except in the most accessible areas. As the pulpwood market developed in the late 1800's, diameter limit cuttings of 8 to 10 inches were employed, and many operators were cutting to a 5-inch diameter by 1915 (Westveld 1949). With the advent of a pulpwood market, fir was utilized but even today the hardwoods are often left standing because of a lack of nearby markets. Where hardwood pulp is marketable it is usually removed along with the softwood.

In Maine, these diameter limit cuttings (often called commercial clearcuts and/or selective logging) left considerable stocking on the land. On the primary softwood sites, these stands usually regenerated to spruce and fir, although occasionally the hardwood seed source available caused the stands to be temporarily converted to low-value hardwoods such as red maple and birch. The better upland sites usually supported a higher proportion of hardwoods, which were able to compete favorably with spruce and fir on these sites. The combination of a standing hardwood overstory and competitive advantage due to site resulted in the conversion of many acres of land to various hardwood species where mixedwood stands once predominated. If fire followed the cutting, aspen--birch stands of very little value sometimes followed.

What has this somewhat disjointed, rambling historical account, that most of you already knew anyway, got to do with regeneration under uneven-aged management? For one thing, while the details may be lacking, it helps explain why we have what we have today--from the degenerate coppice oak stand clearcut twice in the last century to the well-stocked but long neglected northern hardwood stand containing many old, defective veterans interspersed with many young, sound trees that were recruited following the early highgradings. And we can't lose sight of the fact that these stands did regenerate in some fashion; that the same ecological processes that were operating in the last century are operating today (although some people don't like to think so); and that the somewhat haphazard successes and failures of yesterday have led and are still leading us toward the tailored silvicultural prescriptions we hope will be available tomorrow.

Some Basic Principles and Problems in Getting Adequate Regeneration

Most of the forests we have today were the result of natural regeneration from seed, and the regeneration of most of our forests today still depend on natural seeding (Smith 1962). However, the success of natural regeneration is seldom dependent on merely establishing a stand of seedlings; there are, fortunately, few areas where nature will not oblige us with some kind of forest eventually. The key to the success of any regeneration method lies in what kind of seedlings are established, how many are established, how long it takes, and how the seedlings subsequently develop. And, of course, "success" has meaning only in the light of the original objectives that were set out to be accomplished. Many of the clearcuts in the spruce--fir region, for instance, are only partially successful because of the high proportion of hardwoods in the regeneration and/or the long period of time required for this regeneration to fight its way through dense stands of raspberries.

There are a few basic principles involved for obtaining natural regeneration that are universal regardless of what species or timber type we are talking about. Smith (1962) discusses the ecological requirements of natural regeneration but the basic idea is predicted on the creation of ecological niches or microenvironments that are favorable for the regeneration and growth of the desired species and, that ideally, are unfavorable for unwanted species. To the forester this means identifying those microenvironments favorable to the species he wants to grow. His options for manipulation are usually limited to the amount of overhead cover; the surrounding root competition; and the physical characteristics of the seedbed to achieve the most favorable combination of ecological factors--primarily light, temperature and soil moisture.

In recent years, quantification of the "ecological niche" has received a lot of attention from researchers (Marquis, et al 1964; Tubbs 1969; Gatherum, et al 1963; Minckler, et al 1974; Phares 1971; Schomaker 1968, and others). Studies of light, moisture, temperature, and nutrient relationships with germination and subsequent growth have been conducted for some of the key species in the Northeast. These studies have contributed significantly to the body of knowledge regarding factors affecting germination and growth of reproduction, in some cases resulting in more precise silvicultural recommendations. This type of research is by no means complete--for instance, many of the requirements for spruce--fir have not been quantified and we do not know the basic requirements for establishing the oaks (Sander, personal communication)--but such research is continuing. For the most part, this research has not been extended to trees in the sapling and small pole stage and in most cases we know very little about the factors affecting the development of these size classes.

With the exception of coppice stands, you can't have natural regeneration of any kind without seed, and an adequate supply of viable seed of the desired species is such a simple requirement that it seems hardly worth mentioning. There is quite a body of knowledge concerning the seeding habits of various species, their means of dissemination, insect and disease problems, major predators, and duration of viability. The production and dissemination of seed in the major timber types of the northeast does not appear to be a major problem if silvicultural recommendations in the literature are adhered to. One exception in certain areas is white pine, where crop failures due to the white pine cone beetle have been extensive (Wilson & McQuilkin 1963); and there are problems in the oak types (Sander, personal communication). However, in any given year insects, disease, and predators can be a major cause of seed crop failure with most species, and in some cases may be responsible for problems with species composition in regeneration (Hart, et al 1968).

Another basic requirement for obtaining regeneration is, of course, germination. Adequate germination depends largely on moisture conditions which are in turn a function of rainfall and the nature of the seedbed (Smith 1962). In general, mineral soil seedbeds that tend to remain moist are better for the germination of lighter, wind disseminated seed, while large seeds need to be buried and surrounded by a moist medium (Smith 1962). In the Northeast more emphasis has been put on the seedbed requirements for intolerant or intermediate species, or those tolerants to be managed under an even-aged system (Marquis, et al 1964; Frank & Bjorkbom 1973; Place 1955; Tubbs 1969). Rarely is seedbed condition mentioned in the literature as a significant factor under uneven-aged management although the requirements are probably the same. The need for quick, well-timed germination under most even-aged systems and the relative ease by which the seedbed can be manipulated under even-aged conditions, are probably the major reasons. Usually any modification of the seedbed is left to chance scarification by logging equipment, which is seldom sufficient even in the case of even-aged systems where logging is more concentrated (Bjorkbom & Frank 1968; Marquis & Bjorkbom 1960).

The early survival, growth and species composition of regeneration can be influenced strongly by a number of factors ranging from heat injury and drought to frost heaving and damping off. Any number of destructive agents can cause regeneration failures in any given year (Smith 1962). However, in the long run, regeneration under uneven-aged silviculture is more profoundly affected by species differences. The ability to survive and grow in the shade of an understory is the most obvious difference, and tolerance is certainly the most often cited characteristic affecting the survival, growth, and species composition of regeneration under uneven-aged silviculture (Leak & Solomon 1975; Trimble 1973; Sander & Clark 1971, and others).

In general, there is a tendency for the number of intolerant and intermediate species to increase with heavier cutting. Data in Figure 1, showing hardwood reproduction nine years after cutting northern hardwoods to various

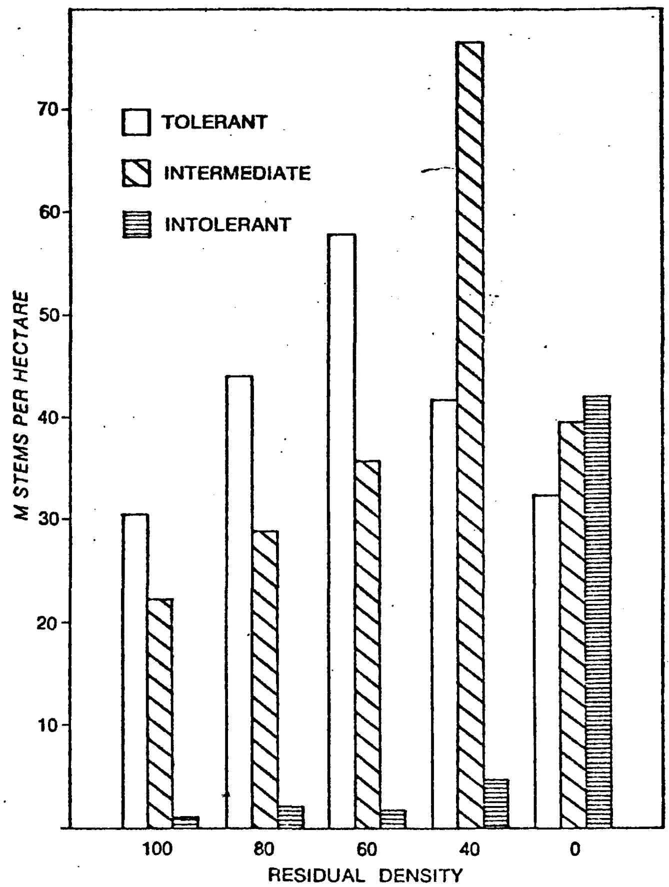

Figure 1.-- Average numbers of stems (in thousands per hectare) of commercial timber species by residual basal area and tolerance group: tolerant (beech, sugar maple, hemlock, red spruce, balsam--fir), intermediate (yellow birch, red maple, white ash), and intolerant (paper birch). Numbers under zero residual density based on 3-year-old patch cuttings (Leak and Solomon 1975).

residual basal areas, illustrates this. Only in the clearcut area are the intolerants significantly represented, and the tolerants comprise more than 50 percent of advance reproduction developing under residual overstories that are in the range of selection management, 60-100 square feet of basal area. Table I shows the same trends operating for large reproduction in Central Appalachian hardwoods (Trimble 1973). It has also been observed in upland hardwoods in the Central States (Sander & Clark 1971; Nelson, et al 1973), to a certain extent in northern hardwoods in the Lake States (Figure 2) and in spruce--fir stands in northern Maine (Hart 1963).

Table 1.--Effect of cutting practice on the proportion of tolerant vs. intolerant reproduction.

Type of cutting	No. of areas	Total acreage	Number of 1- to 5-inch stems	
			Intolerant species	Tolerant species
	No.	Acres	Weighted Pct.	Weighted Pct.
Clearcut	9	110	37	27
Diameter limit	5	151	18	62
Selection	7	198	5	78

I'm sure we're all aware of the limitation imposed by this ecological fact of life--the bulk of reproduction limited to a few tolerant species, quite often of lower commercial value than the intolerants. It is one of the primary problems with uneven-aged silviculture and one we can do little about.

While the degree of overstory removal is probably the overriding factor governing the species composition of regeneration, in some types there is a pronounced interaction with site quality. Such is the case with Central Appalachian hardwoods and spruce--fir.

Trimble (1973), cites data indicating that on excellent and good sites sugar maple and beech will predominate in the long run following light to medium cutting, while the lesser valued red maple will replace sugar maple on the fair sites. In general, the less demanding species can compete better on the lesser quality sites.

In the spruce--fir types, the same principles are operating but the problem is somewhat different. Here, the so-called primary softwood sites are the poorer swamps, flats and other areas of impeded drainage and lower topographic positions, or the thin soils of upper slopes. Hardwoods on these

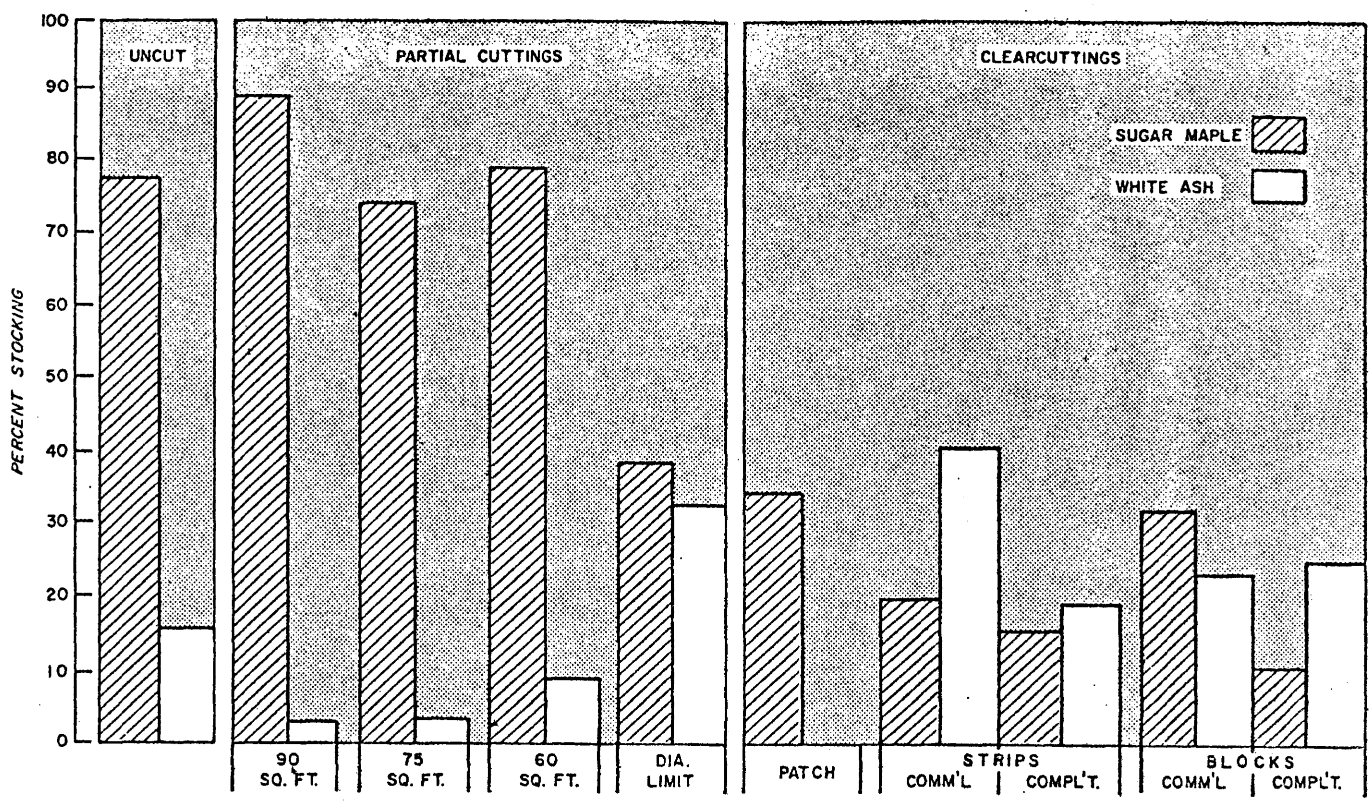

Figure 2. -- Influence of cutting methods upon stocking of dominant sugar maple and white ash seedlings after 15 years (Metzger and Tubbs 1971).

sites--mostly red maple, paper and yellow birch, and aspen--comprise less than 25 percent of the stand, and regenerating the stand to softwood is not usually a problem (Frank & Bjorkbom 1973), except where red maple stump sprouts dominate after very heavy cutting.

On the better sites or "secondary" softwood sites on better drained uplands, northern hardwoods may comprise from 25 percent to 70 percent of the stand and compete harshly with the softwood. In the past, heavy softwood harvests have converted many of these stands to pure hardwood, for which markets have been traditionally poor. These are the areas where deficiencies in spruce--fir reproduction are likely to occur, and according to Westveld (1953), no known method of cutting other than clearcutting followed by planting and intensive TSI can remedy the situation. Even where spruce--fir advance regeneration is present in such stands, it should be 4-5 feet tall before it can be relied on to compete successfully with hardwoods (Westveld 1953).

In the upland hardwoods, site quality interacts with species composition in a general way, but has not been a significant factor, at least in younger reproduction (Sander & Clark 1971). I suspect the same thing is true in the northern hardwood types except on more marginal lowland sites where red maple may predominate in uneven-aged stands. Bill Leak is looking into this at the present time (William Leak, personal communication).

It is evident from the literature that we actually know very little about tolerance; how it changes with age for a given species or to what degree there is interaction between site factors and the ability of a species to survive and grow in the shade. Intolerant and intermediate species will often germinate and survive for a short time under a canopy. If we knew more about the factors affecting tolerance, we might possibly increase their representation in the overstory under selection management by such things as site amelioration (fertilization and drainage), and the precise timing of release cuttings.

There are other physiological differences among species that affect survival, growth, and ultimately species composition (although not necessarily limited to uneven-aged silviculture). Differences in susceptibility to late spring frosts have been observed by Tryon & True (Trimble 1973), that can affect regeneration in locations where frost pockets occur. While trees of all sizes may be damaged, seedlings and saplings are most susceptible.

One difficulty in spruce--fir management is reducing the fir component in the stand to favor the spruces. Part of the problem lies in the fact that fir seedlings initially develop larger primary roots than spruce and thus have a better chance of reaching a permanent moisture supply (Hart 1963). Spruce germinants therefore, are usually weaker, more fragile, slower growing and more susceptible to destructive agents during the establishment period. Light selection cutting tends to offset this difference by producing a more favorable site, but this difference appears to be the primary reason for the low percentage of spruce in our stands.

The ability of some species, notably the oaks, to sprout is often an important characteristic giving them a competitive advantage. Although uneven-aged silviculture tends to discourage oak reproduction, it may be present following a harvest but may not persist very long. Seedling sprouts from this advance reproduction respond to release faster than new seedlings or older advance regeneration (Figure 3) and may be the only way the oak can compete where partial cutting is practiced. Such sprouts may have to be deliberately created through a supplemental treatment (Sander, personal communication).

Subsequent Development of Regeneration

Concern is often expressed about the ability of suppressed seedlings to match the growth rate and quality of seedlings that are free to grow most of their lives, although it is generally assumed that the tolerants respond adequately. Carvell (1967), in a study of oak reproduction, found that suppressed flat-topped oaks will eventually establish a leader and begin to grow normally, although growth for 4 years after release was significantly less than seedlings with normal form. Seventeen of the 32 seedlings studied had developed leaders and begun to grow normally in 3 years. However, this delay in normal height growth increases the likelihood of competing woody vegetation overtopping them. Once released, these oak seedlings also had the ability to straighten and regain a more erect position.

Hatcher (1964), studied balsam fir seedlings growing in uneven-aged spruce--fir--yellow birch stands in eastern Canada. He found that growth response to release is related to seedling age, seedling height, and height growth just prior to release. For seedlings of equal vigor, the smaller and younger seedlings outgrew the larger and older (Figure 4). Seedlings response was rapid, with 88 percent of the stem showing increased diameter growth and 80 percent increased height growth in 3 years.

Trimble (1968) found that sugar maple trees in the 1-6 inch size class and growing in the understory tended to have better form as size increased. He concluded that, since growth differences between the good form and poor form trees were slight, that it was a matter of the trees improving form as they grew larger rather than poor form trees dropping out of the stand.

There appears to be ample evidence that suppressed tree seedlings of tolerant species can and do respond to release. However, the relationship between years suppressed and later quality, growth rate, and incidence of disease have not been thoroughly investigated. In fact, little hard data are available on mortality factors in the sapling - small pole size, although we know that there is a drastic reduction in stems entering this stage.

The size distribution curves for the management intensity demonstration plots on the Penobscot Experimental Forest illustrates this (Figures 5, 6, 7, 8, 9). Stand structure will be discussed elsewhere at this workshop, but these curves show that we are in trouble in the 1-4 inch class on the intensive

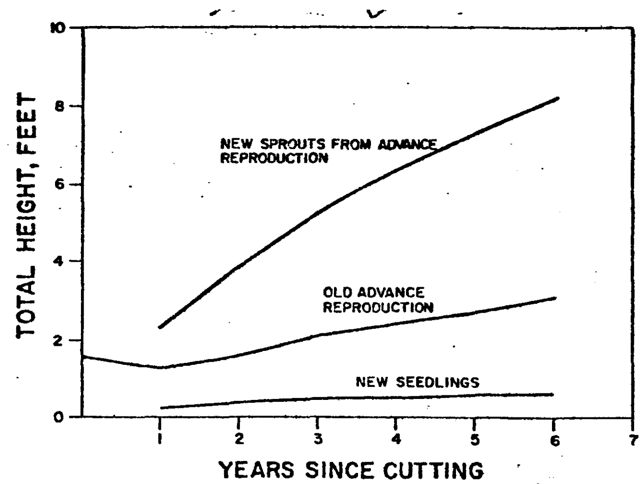

Figure 3. -- Height growth of different kinds of oak reproduction after partial cutting in Illinois (Sander & Clark 1971).

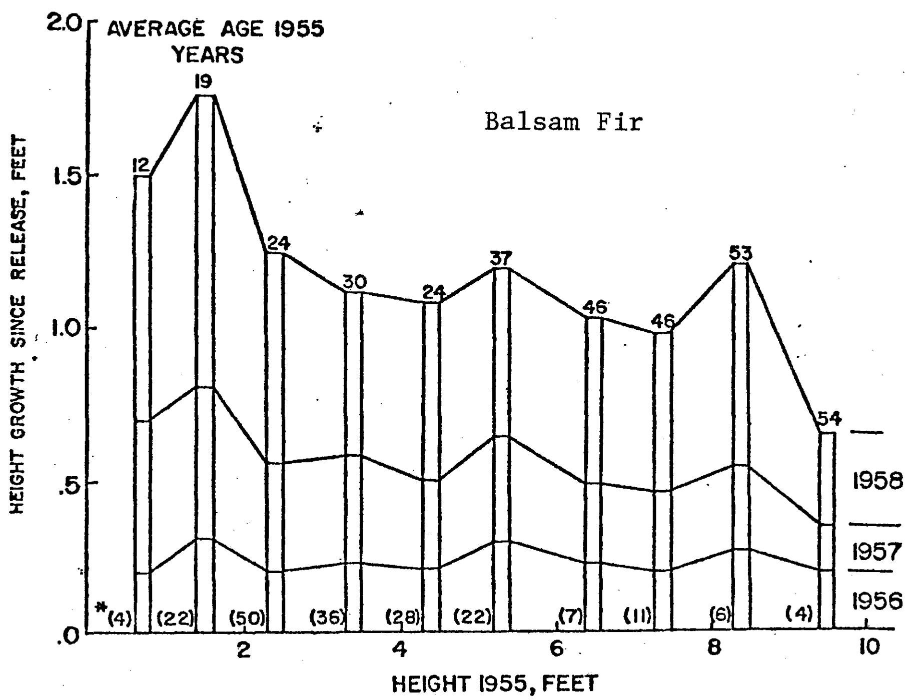

Figure 4. -- Relationship of height growth after logging to height prior to logging, Lake Edward (Hatcher 1967).

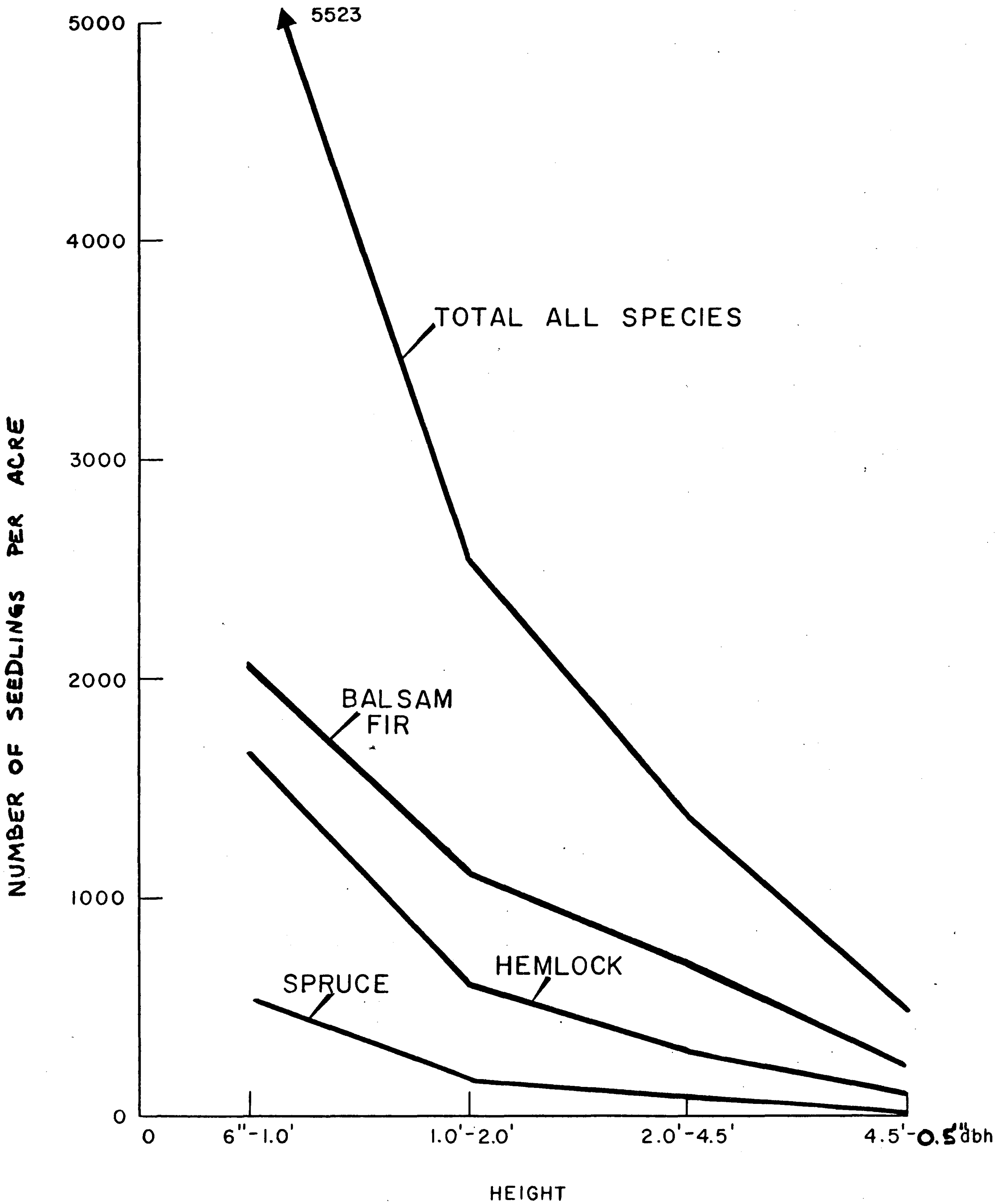

Figure 5. -- Regeneration data from four intensive selection compartments.

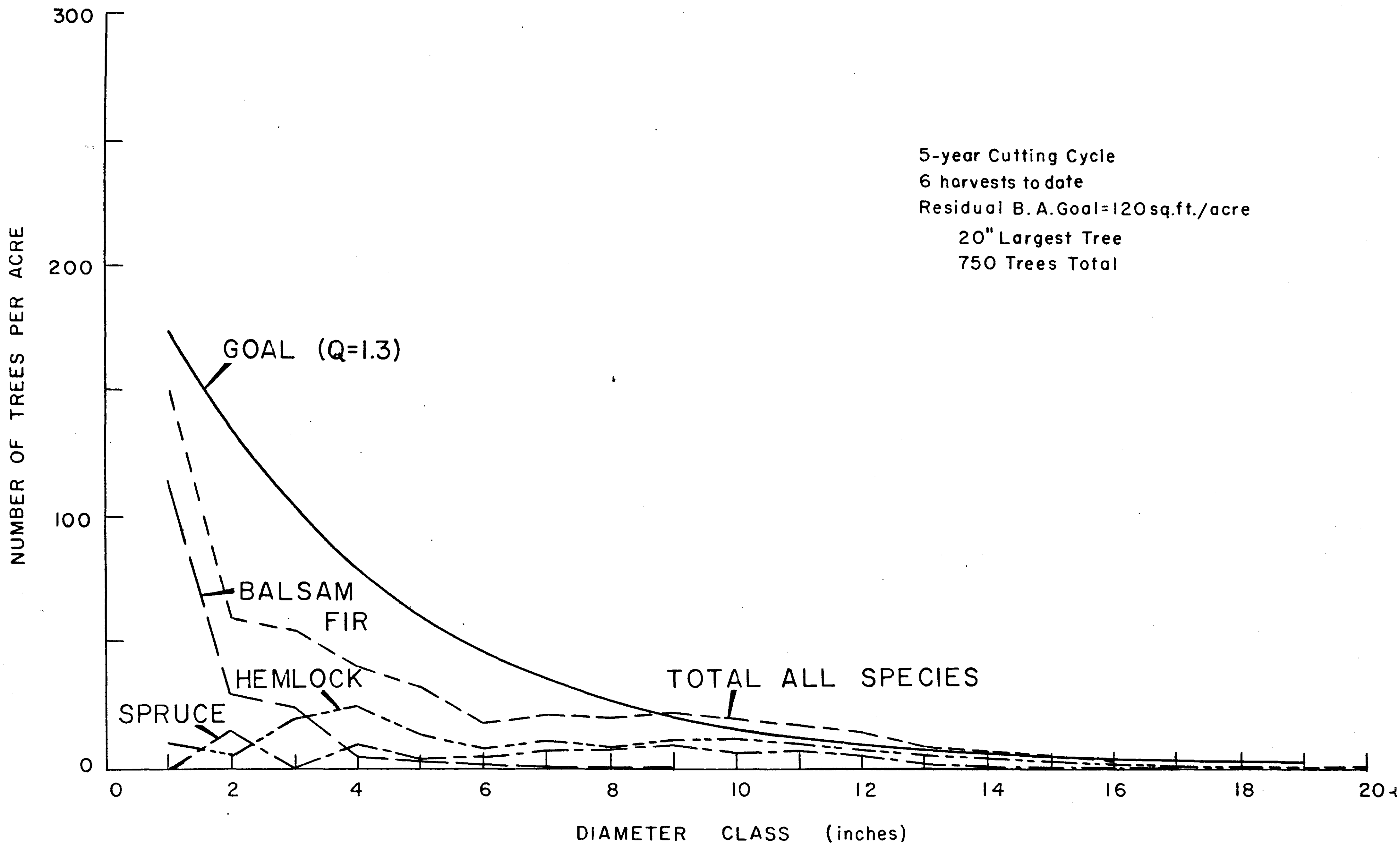

Figure 6. -- Mid-intensive selection - current stand diameter distribution.

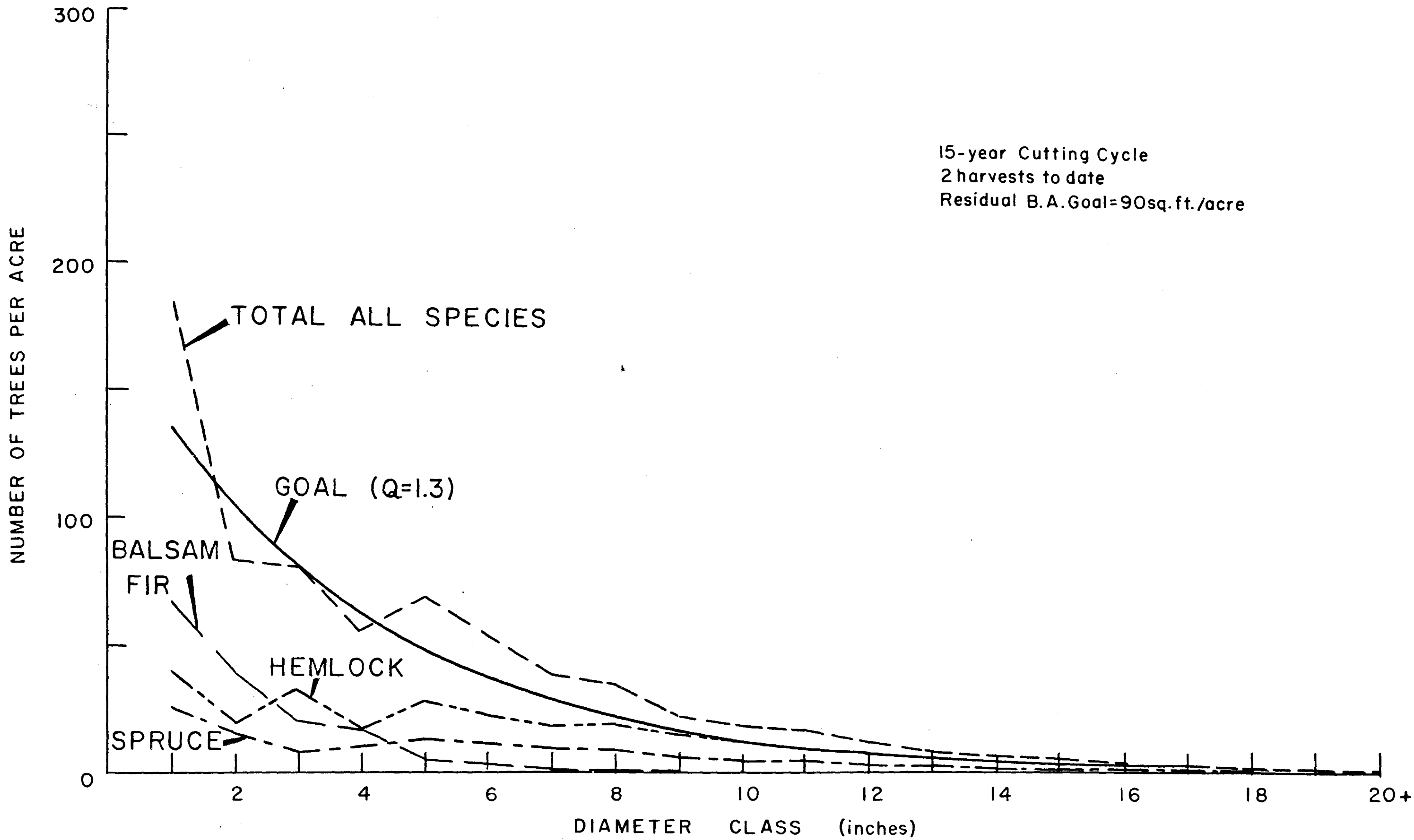

Figure 7. -- Mid-extensive selection - current stand diameter distribution.

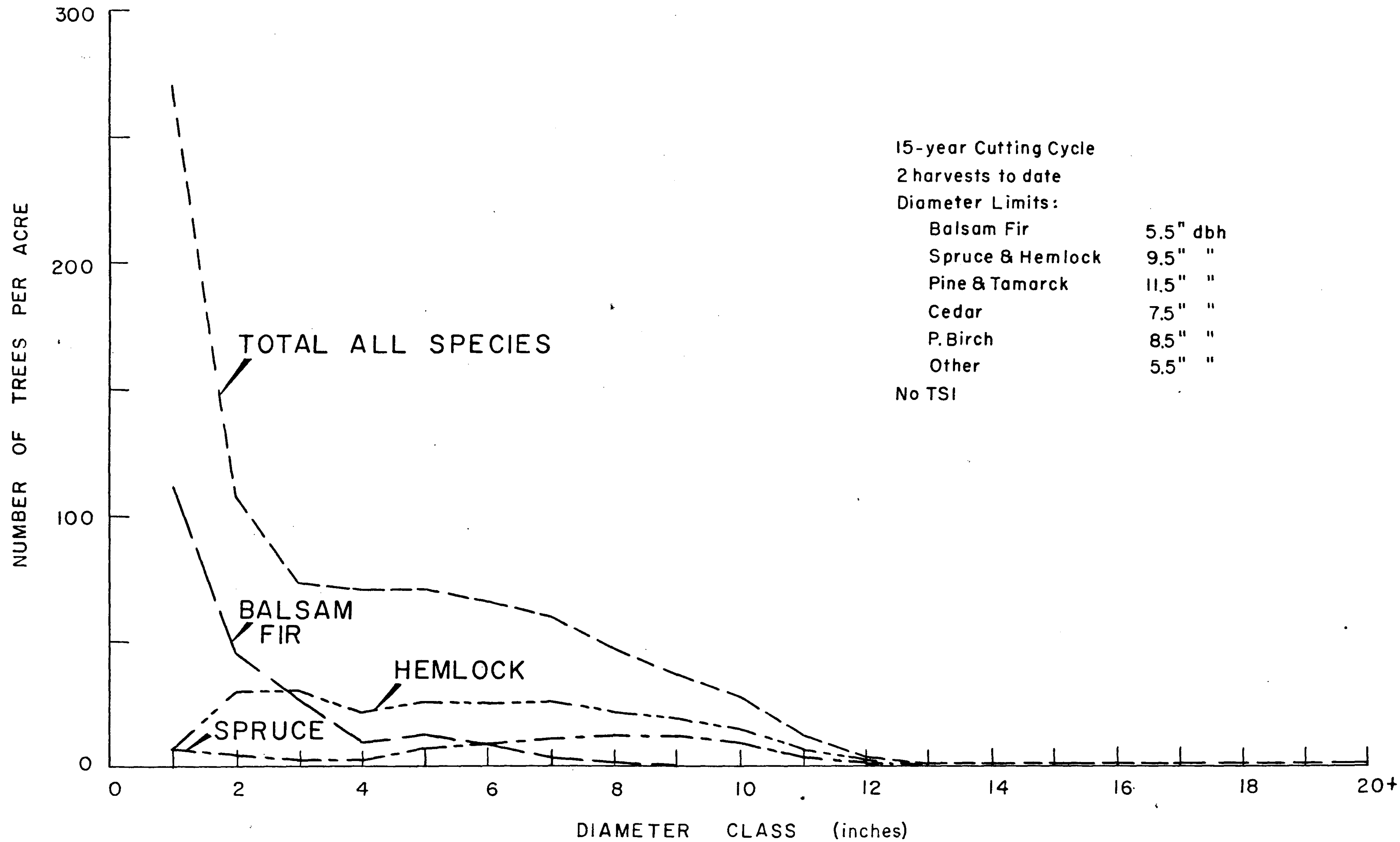

Figure 8. -- Mid-diameter limit - current stand diameter distribution.

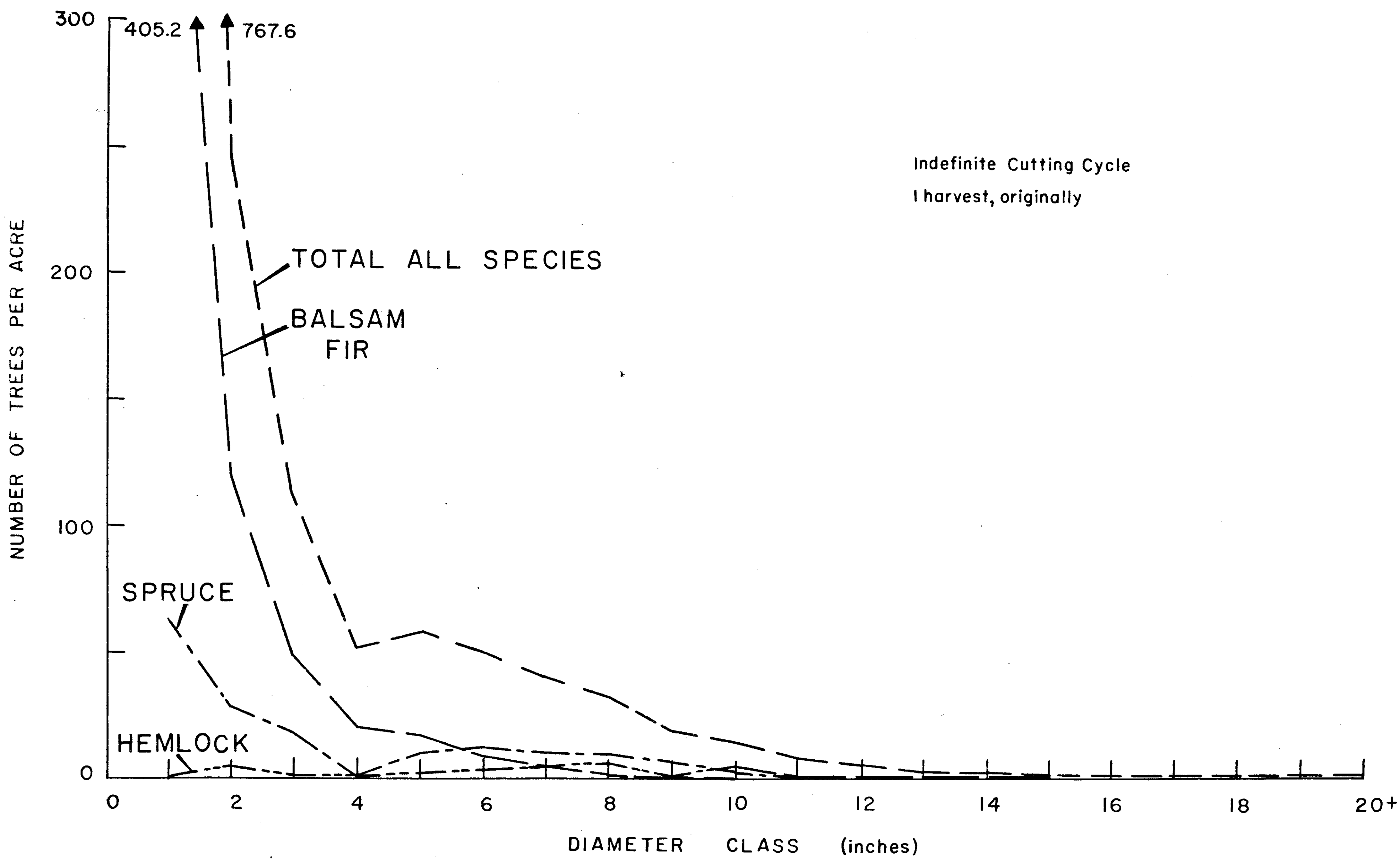

Figure 9. -- Mid-commercial clearcut - current stand diameter distribution.

selection plot, and that in the case of hemlock and spruce the entire regeneration picture is not good. Unfortunately we do not have figures for numbers of trees under 4.5 feet in height on these plots, so the data used was from our intensive selection compartments which have had fewer combined harvest and TSI operations (Figure 4 compared to Figure 6).

We can speculate on a number of reasons for the apparent shortage of softwood saplings in the 1-inch to 4-inch diameter class. First, we know that trees simply aren't growing into this class like they should be, with the possible exception of balsam fir and the hardwoods. The primary reason for this is that we are probably carrying too much residual stand for these trees to respond and move up. The slow juvenile growth of spruce, coupled with relatively low numbers in relation to the aggressive fir is responsible for its poor representation in the sapling class. As an interesting sidelight however, during the period this stand has been under management, the stocking of spruce seedlings has improved from 5 percent (stocked milacres) to 80 percent. So, perhaps we haven't observed these stands long enough and eventually many spruce seedlings will move into the sapling-sized classes.

Probably the major reason for the sapling shortage, however, is logging damage. This size class is highly susceptible to such damage, and immediate losses are significant (Table 2). Repeated entry into these stands on short operating intervals may just be too hard on regeneration. The attendant affects on the soil may also be significant, but this has not been thoroughly studied.

Table 2.--Differences in number of seedlings and saplings before and after harvest.

NUMBER OF TREES

Harvest	1 - 4" immediately before	after	difference	4.5' in ht.-0.5" d.b.h. immediately before	after	difference
First	953.2	667.2	286.0	NA	NA	NA
Second	718.0	678.4	39.6	NA	115.0	NA
Third	452.4	402.4	50.0	90.0	NA	NA
Fourth	397.2	347.6	49.6	170.0	NA	NA
Fifth	302.8	262.8	40.0	115.0	NA	NA
Sixth	347.2	306.4	40.8	270.0	170.0	100.0

Other Factors Affecting Regeneration

Animal damage to regeneration under uneven-aged management seems to be most critical in western Pennsylvania where populations of deer are so high. According to Marquis (personal communication), sugar maple and hemlock are almost completely lost to deer under single tree selection. The less palatable (and less valuable) beech fare better. Elsewhere animal damage may be locally severe but does not seem to be a universal problem.

Competition to regeneration from grape vines can be serious in central Appalachian hardwoods (Clay Smith, personal communication). Raspberries are a problem with spruce--fir in clearcuts but not in truly uneven-aged stands unless the "groups" in group selection are quite large.

The role of artificial regeneration in uneven-aged management is just beginning to be explored. Direct seeding could be a valuable asset where seed source is a problem, but I was unable to turn up any reference concerning it. Underplanting has been attempted to convert poor hardwood stands to pine (Yawney 1961), but these efforts are more aligned to shelterwood than uneven-aged silviculture. Clay Smith (personal communication) is attempting to introduce red oak into uneven-aged stands, and Dave Marquis (personal communication) feels that planting under a shelterwood has valuable possibilities. Neither are probably uneven-aged techniques in the strictest sense. The underplanting of tolerants in a true selection forest is certainly possible, and would be of most value in introducing genetically superior stock. But in my humble opinion, the economic and logistical problems would be overwhelming, except in a truly uneven-aged forest.

I've tried to keep this talk limited to the principles involved in uneven-aged management and have purposely stayed away from specific reference to systems such as group selection, single tree selection, etc. Not only was time a problem, but the line between uneven-aged and even-aged silviculture is not always clear. In reality, there are probably an infinite variety of hybrid systems that could be called uneven-aged. In my haste I'm sure I've overemphasized some minor points, missed some major ones entirely, and failed to refer to your own pet publication on the subject. Perhaps we can make these omissions points for further discussion.

Bibliography

Annonymous. 1973. Land use in West Virginia, Part II: Forest Practices. League of Women Voters of West Virginia, Inc.

Blum, Barton M., and Stanley M. Filip. 1963. A demonstration of four intensities of management in northern hardwoods. USDA For. Serv. Res. Pap. NE-4. U.S. Dept. Agric. For. Serv. Northeast. For. Exp. Sta., Upper Darby, PA.

Bjorkbom, John C., and Robert M. Frank. 1968. Slash burning and whole-tree skidding fail to provide mineral-soil seedbeds for spruce--fir. The Northern Logger and Timber Processor, Vol. 16, No. 7, January 1968.

Carvel, Kenneth. 1967. The response of understory oak seedlings to release after partial cutting. West Virginia Univ. Agric. Exp. Sta. Bull. 553.

Coolidge, Philip T. 1963. History of the Maine Woods. Furbush-Roberts Printing Co., Inc., Bangor, Maine.

Frank, Robert M., and John C. Bjorkbom. 1973. A silvicultural guide for spruce--fir in the Northeast. USDA For. Serv. Gen. Tech. Rep. NE-6. U.S. Dept. Agric. For. Serv. Northeast. For. Exp. Sta., Upper Darby, PA.

Gatherum, G. E., A. L. McComb, and W. E. Loomis. 1963. Effects of light and soil moisture on forest tree seedling establishment. Agric. and Home Econ. Exp. Sta., Iowa State Univ. Res. Bull. 513, Ames, Iowa.

Hart, Arthur C. 1963. Spruce--fir silviculture in northern New England. Proceedings, Soc. Am. Forester, Boston, Mass.

____________, Herschel G. Abbott, and Edward R. Ladd. 1968. Do small mammals and birds affect reproduction of spruce and fir? USDA For. Serv. Res. Pap. NE-10. U.S. Dept. Agric. For. Serv. Northeast. For. Exp. Sta., Upper Darby, PA.

Hatcher, R. J. 1967. Balsam fir advance growth after cutting in Quebec. The Forestry Chronicle, Vol. 40, No. 1, March 1967.

Leak. W. B., and D. S. Solomon. 1975. Influence of residual stand density on regeneration of northern hardwoods. USDA For. Serv. Res. Pap. NE-310. U.S. Dept. Agric. For. Serv. Northeast. For. Exp. Sta., Upper Darby, PA.

Marquis, David A., and John C. Bjorkbom. 1960. How much scarification from summer logging? USDA For. Serv. Res. Note 110. U.S. Dept. Agric. For. Serv. Northeast. For. Exp. Sta., Upper Darby, PA.

____________, John C. Bjorkbom, and George Yelenosky. 1964. Effect of seedbed condition and light exposure on paper birch regeneration. J. For. 62:876-881.

____________, Dale S. Solomon, and John C. Bjorkbom. 1969. A silvicultural guide for paper birch in the Northeast. USDA For. Serv. Res. Pap. NE-130. U.S. Dept. Agric. For. Serv. Northeast. For. Exp. Sta., Upper Darby, PA.

____________. 1973. Pennsylvania's Allegheny Hardwood Forests. Pennsylvania Forests Vol. 63, No. 430, Dec., p. 88-112.

Metzger, Frederick T., and Carl H. Tubbs. 1971. The influence of cutting method on regeneration of second-growth northern hardwoods. J. For. Vol. 69, No. 9, p. 559-564.

Minckler, Leon S., John D. Woerheide, and Richard C. Schlesinger. 1973. Light, soil moisture, and tree reproduction in hardwood forest openings. USDA For. Serv. Res. Pap. NC-89. U.S. Dept. Agric. For. Serv. Northcent. For. Exp. Sta., St. Paul, MN.

Nelson, R. E., R. A. Young, and A. R. Gilmore. 1973. Twenty-two years of management of upland hardwoods in southern Illinois. Forestry Research Rpt. No. 73-3, Univ. of Illinois Agric. Exp. Sta., Urbana-Champaign, IL.

Phares, Robert E. 1971. Growth of red oak (Quercus rubra L.) seedlings in relation to light and nutrients. Ecology, Vol. 52, No. 4, p. 669-672.

Place, I.C.M. 1955. The influence of seed conditions on the regeneration of spruce and balsam fir. Dept. of Northern Affairs and Natural Resources, For. Branch Bull. 117, Canada.

Powell, G. R. 1975. Seedfall studies in red spruce. The Forestry Chronicle, Vol. 51, No. 2, April 1975.

Sander, Ivan L., and F. Bryan Clark. 1971. Reproduction of upland hardwood forests in the Central States. U.S. Dept. Agric. Handb. 405.

Schomaker, C. E. 1968. Solar radiation measurements under a spruce and birch canopy during May and June. Forest Science Vol. 14, No. 1, March 1968. p. 32-38.

Smith, David M. 1974. Dangers in over simplification of forestry. Address to the Eastern Regional Meeting of the American Forest Institute at Boston, Mass., Nov. 21, 1974. Reprinted from: The Maine Forest Review, Vol. 8, 1975 (May).

____________. 1962. The practice of silviculture. Seventh Edition. John Wiley & Sons, Inc., New York.

Trimble, George R., Jr., and George Hart. 1961. An appraisal of early reproduction after cutting in northern Appalachian hardwood stands. USDA For. Serv. Sta. Pap. NE-162. U.S. Dept. Agric. For. Serv. Northeast. For. Exp. Sta., Upper Darby, PA.

____________. 1973. The regeneration of Central Appalachian hardwoods with emphasis on the effect of site quality and harvesting practice. USDA For. Serv. Res. Pap. NE-282. U.S. Dept. Agric. For. Serv. Northeast. For. Exp. Sta., Upper Darby, PA.

Tubbs, Carl H. 1969. The influence of light, moisture and seedbed on yellow birch regeneration. USDA For. Serv. Res. Pap. NE-27. U.S. Dept. Agric. For. Serv. Northcent. For. Exp. Sta., St. Paul, MN.

Westveld, Marinus. 1953. Ecology and silviculture of the spruce--fir forests of eastern North America. J. For. Vol. 51, No. 6, p. 422-430.

Westveld, Ruthford H. 1949. Applied silviculture in the United States. Second Edition. John Wiley & Sons, Inc., New York.

Wilson, Robert W., and William E. McQuilkin. 1963. Silvical characteristics of eastern white pine. USDA For. Serv. Res. Pap. NE-13. U.S. Dept. Agric. For. Serv. Northeast. For. Exp. Sta., Upper Darby, PA.

Yawney, Harry W. 1961. Introducing white pine into poor-site hardwood stands in West Virginia. USDA For. Serv. Sta. Pap. No. 154. U.S. Dept. Agric. For. Serv. Northeast. For. Exp. Sta., Upper Darby, PA.

STAND COMPOSITION IN RELATION TO UNEVEN-AGED SILVICULTURE

by

Carl H. Tubbs[1/]

My job is to discuss stand composition in relation to uneven-aged silviculture. Before focusing on specified problems, it may be helpful to develop a background and offer a few definitions.

Eastern North America is composed of five broad forest regions (SAF Fig. 1). The three of most interest to us are the northern, central and southern. According to SAF definitions there are between 30 and 40 distinguishable cover types in each region--some of these are unique to the region, others are found in more than one region. Braun (Figure 2) has also mapped eastern North America. Her map represents regions whose names reflect common deciduous climax communities. There are nine main regions, with sub-areas denoting some significant change in vegetation. Altogether these number 33.

Many of the climax communities are in more than one region, at least in broad terms. For example, a beech--maple type is found in northern Michigan, Ohio, and New Hampshire. Although she does not dwell on secondary successions, Braun noted and the forestry literature confirms, that commercial logging of the beech--maple forest in the northern Lake States resulted in abundant regeneration of climax species while in more southerly areas logging a similar climax resulted in a drastic shift in species composition. In the latter areas, she predicted that long time periods would pass before the climax vegetation returned.

Both the climate and geography vary widely both within forest regions and between even though they may contain similar forest types. For instance, the northern hardwood area stretches from Minnesota where the annual precipitation is less than 30 inches to the Atlantic coast where it may be over 50 inches annually. Beech--maple forests may be found in unglaciated areas on podzolic soils or in glaciated areas on true podsol soils.

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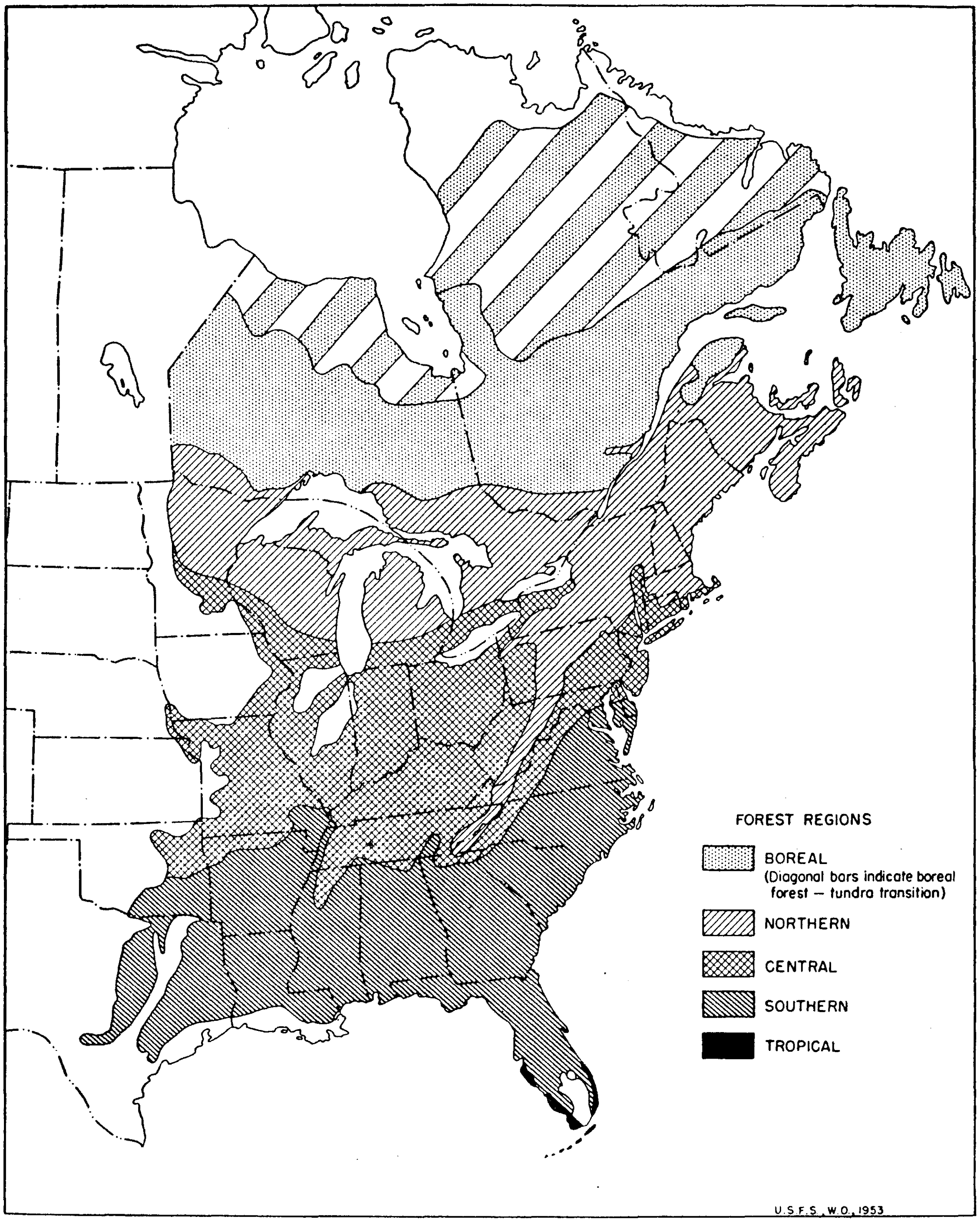
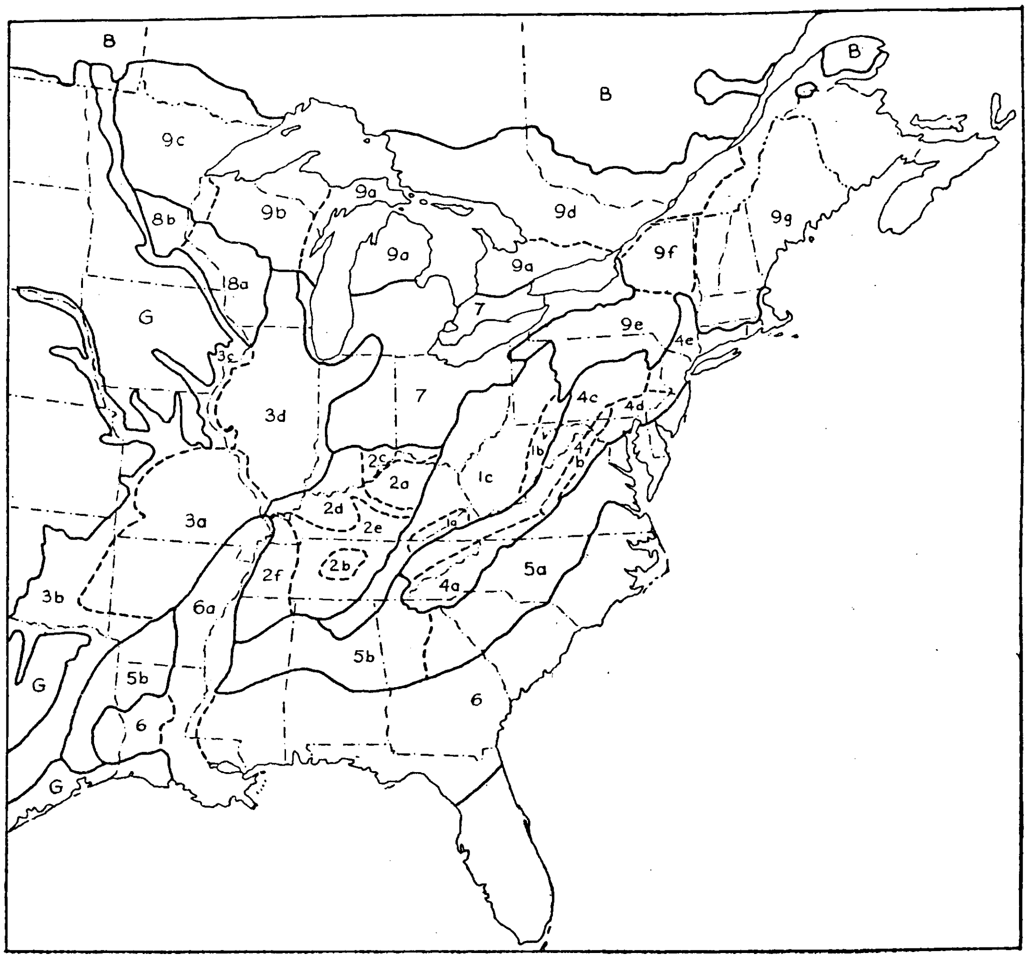


Figure 1.-- Forest regions of eastern North America.



1. MIXED MESOPHYTIC FOREST REGION
   a. Cumberland Mountains
   b. Allegheny Mountains
   c. Cumberland and Allegheny Plateaus
2. WESTERN MESOPHYTIC FOREST REGION
   a. Bluegrass Section
   b. Nashville Basin
   c. Area of Illinoian Glaciation
   d. Hill Section
   e. Mississippian Plateau Section
   f. Mississippi Embayment Section
3. OAK-HICKORY FOREST REGION

   SOUTHERN DIVISION
   a. Interior Highlands
   b. Forest-Prairie Transition Area

   NORTHERN DIVISION
   c. Mississippi Valley Section
   d. Prairie Peninsula Section
4. OAK-CHESTNUT FOREST REGION
   a. Southern Appalachians
   b. Northern Blue Ridge
   c. Ridge and Valley Section
   d. Piedmont Section
   e. Glaciated Section
5. OAK-PINE FOREST REGION
   a. Atlantic Slope Section
   b. Gulf Slope Section
6. SOUTHEASTERN EVERGREEN FOREST REGION
   a. Mississippi Alluvial Plain
7. BEECH-MAPLE FOREST REGION
8. MAPLE-BASSWOOD FOREST REGION
   a. Driftless Section
   b. Big Woods Section
9. HEMLOCK-WHITE PINE-NORTHERN HARDWOODS REGION

   GREAT LAKES-ST. LAWRENCE DIVISION
   a. Great Lake Section
   b. Superior Upland
   c. Minnesota Section
   d. Laurentian Section

   NORTHERN APPALACHIAN HIGHLAND DIVISION
   e. Allegheny Section
   f. Adirondack Section
   g. New England Section

Figure 2. -- Forest regions and sections of the deciduous forest formation (Braun 1964).

The tree species which comprise the various cover types vary genetically also. Sugar maple (Acer saccharum) (5) and red maple (Acer rubrum L.) (11) contain physiological races as does yellow birch (Betula alleghaniensis). "Tolerance" also may change (15) from one region to another. Impact of disease may vary, too. The beech scale nectria disease is a serious problem in beech stands of the East (19) but is not particularly important in the northern Lake States. Biological problems such as deer damage to regeneration also vary in their effect from one part of a region to another even in the same forest type. In the northern Lake States deer damage to northern hardwoods is extensive but because most of it occurs during the dormant season is usually unimportant (19). The same tree species found in the Lake States are severely damaged by deer in Pennsylvania and New York (19). In addition to variations in climate, biological and soil properties, some areas have been subject to several centuries of intensive land uses while others have been lightly touched by farming, repeated fire and logging. These practices have profound effects on soils, species composition, forest structure and tree form. From region to region the same species vary in growth habits; black cherry, a common species in northern Michigan is short lived and subject to defects which adversely affect marketability; in contrast, the same species is very valuable in southern Michigan and is the subject of much research effort in Pennsylvania. Even when species form and physical properties are the same, merchantability varies markedly from locality to locality. While white birch is prized in New England, in many Lake States localities it is scarcely better than a weed unless of high grade saw log or veneer quality.

Examples of variations in economics, marketing, species, ecology, soils, etc., are legion, of course, and are not new to anyone. Even though the responses of trees to forestry practice have many important similarities, the foregoing examples should serve to remind us that sweeping generalities about silviculture practice should be made with caution and making prescriptions requires a high degree of professionalism.

As I read through accounts of silvicultural systems and chat with foresters, I conclude that concepts of cutting practices, forest policy, i.e., sustained yield, and regeneration methods vary widely. Two definitions of uneven-aged forestry appear to have been merged into one in Agriculture Handbook No. 445 (19); an uneven-aged stand is one which contains trees of different ages or sizes which intermingle singly or in groups. The older Forestry Terminology (13) says that more than three age classes must exist in the stand while a textbook (12) suggests that these age classes should be represented on different areas.

At any rate, uneven-aged forestry encompasses any combination of methods that seeks to provide a number of age classes on a small area and consequently covers all cutting methods from clearcutting to selection, apparently (For successful forestry practice, I strongly suspect that each system must be defined for the locality and objectives for which it was designed). For example, in some hardwood types small groups of mature trees are clearcut to provide a seedbed and subsequent good growing conditions for intolerant species while in others stands are clearcut to release advance regeneration which requires an overstory to become established. Both may be called group selections! To simplify matters for this meeting perhaps we should consider clearcuts which attempt to release existing regeneration final removals and call clearcuts which prepare for the regeneration of those species which do not require overstories--clearcuts.

Problems in Developing Satisfactory Species Composition

A survey of silvicultural practices in eastern conifer types (Figure 3) shows that in only one case are tolerant species especially desirable and that is in the spruce--fir type of the Northeast; there balsam fir and red spruce are desirable. In the northern hardwood area, in some cases eastern hemlock is also desirable. In all other conifer areas, the desirable species are neither tolerant or climax species. Usually the tolerant species are undesirable in these type areas. Undesirables range from hazel brush to various oaks and hickories. Forestry practices such as shelterwood can also lead to insect problems. In several types, insects may drop off overstory trees to the regeneration.

For a variety of reasons, drastic treatments of the forest floor must be undertaken in many types. In some cases, prescribed fire is used to prepare a seedbed, reduce disease, or slash. In others, mineral soil must be exposed or undesirable species must be eliminated. Windthrow is common with shallowly rooted trees in partially cut stands and in types like black spruce preclude the possibility of partial cuts. In some types, planting is a preferred practice. While it is often possible to underplant and sometimes even desirable, this practice is usually most efficiently done in openings. Most of these practices eliminate the practical possibilities for the existence of a several-storied stand.

However, many of the conifer types can be regenerated by either group "selection" or shelterwood. The function of the shelterwoods, in those types with which I'm familiar, is not primarily to provide partial shade but to provide seed for natural regeneration or reduce visual impact. An exception is eastern white pine which may benefit from partial shade. Group selection can also be used for intolerant species regeneration. Although exceptions occur, group "selections" generally are an attempt to reduce visual impact or fulfill some wildlife objective and are really just small clearcuts which are necessary to produce intolerant species such as pines.

Hardwood Types

Many of the hardwood types fall into the same silvicultural categories as the conifers. Intolerant species are preferred and the maintenance of composition of these species requires many of the same practices. Alternate silviculture

	Desirable species Tol.	Desirable species Not tol.	Undesirable species Tol.	Undesirable species Not tol.	Site preparation necessary	Preferred management practice for timber	Multiple-use practices possible or desirable
CONIFER							
Black spruce		Yes	Hdwds		Yes	Even-age, patch clearcut	Group selection
Spruce fir	Yes	Yes			No	Even-age, clearcut	Single tree or group selection
Eastern white pine		Yes	Hdwds		Yes	Even-age, clearcut shelterwood group selection	Shelterwood
Loblolly-short (mid-south)		Yes	Hickory		Yes	Even-age, clearcut shelterwood	Patch or group
Longleaf		Yes	Hdwds		Yes	Even-age, clearcut plant or seed	Shelterwood, natural regen.
Slash		Yes	Hdwds		Yes	Even-age, clearcut plant	Shelterwood, natural regen. or group selection
Red pine		Yes	Shrubs		Yes	Even-age, clearcut plant	Shelterwood with site preparation
Jack pine		Yes	Shrubs		Yes	Even-age, clearcut, plant or seed	Shelterwood non-serotinous
HARDWOODS							
L.S. Aspen		Good sites				Even-age, clearcut	Same
Oak-hickory		Yes	Shrubs		?No	Patch, clearcut or shelterwood	Same
Oak-pine		Yes	Hickory		Yes	Even-age, clearcut plant or seed	Group selection
Cypress swamp		Yes			Yes	Even-age, clearcut	Shelterwood
Mixed bottom land hardwood		Most	Beech shrubs		Some yes	Even-age, shelterwood release	Group selection
NE northern hardwoods	Maple birch	White birch	Beech			Even-age, birch: all-age; maple-beech	
Cherry-maple	Yes		Beech			Even-age, clearcut or shelterwood	
Cove hardwoods	Maple	Many	Beech			Even-age, clearcut	Individual tree selection
L.S. northern (1) Sugar maple	Yes					All-age	Even-age shelterwood
(2) Hemlock-Y.birch	Hem.	YB				All-age or even-age shelterwood	

Figure 3

practices to suit economic conditions or multiple-use objectives are also similar. These may be applied in groups or patches to develop an uneven-aged character to fairly large areas.

Types such as cove hardwoods, the cherry--maple type and northern hardwoods (and spruce--fir) fall into a different category. In these types, some desirable species are tolerant. Also, in most, some desirable species are moderately tolerant or intolerant and some of the undesirable species are very tolerant. The tolerant species are ordinarily thought of as prominent members of the climax and regenerate easily under partial overstories without site preparation.

In the northern Lake States portion of the northern hardwood range, few light-demanding species are more desirable than the tolerant maples; consequently uneven-aged silviculture preserves desirable composition in many subtypes. In the Northeast, beech is, for a variety of reasons, a less desirable species; most forms of uneven-aged silviculture produce this species. Clearcutting increases the proportion of valuable light demanding species. Group selection produces a mixture of species but trees remaining on the edges of groups are prone to epicormic sprouting, however. Both the cove hardwoods and northeast northern hardwoods are capable of producing a large number of valuable species after some form of clearcutting (up to 30 species in cove hardwood stands) while Lake States northern hardwoods even-aged stands usually are comprised of a high proportion of maple. In the East, deer browsing may be serious and regeneration in small patches or light partial cuttings may be severely damaged. Deer also avoid beech, which tends to increase its numbers at the expense of more desirable species.

In spite of vast differences in climate, soils and species the broad silvicultural treatments to produce intolerant species are the same in many respects over a broad area. Some way of heavy cutting is always necessary to produce the highest numbers of intolerant species and usually site preparation must take place to prepare seedbeds or reduce "competition". Note that heavy cutting is not always followed by intolerant species but that heavy cutting is always necessary usually in conjunction with other practices. Seeding or planting are often desirable.

On the other hand, repeated partial cutting generally stimulates tolerant species. At least in the northern hardwood area, such cutting does not preclude a fairly wide variety of species, however. After 20 years of selective cutting at the Upper Peninsula Experimental Forest the species composition of the recommended practice (70 sq. ft. 10"+ d.b.h.) remains about the same: originally 77 percent of the stems over 1" d.b.h. were sugar maple but elm, basswood, hemlock, beech, yellow birch and red maple were also part of the stand. Twenty years later, sugar maple made up 75 percent of the stems over 1" d.b.h. and the other species remained in about the same proportions.

Within these two broad categories--practices for tolerant species and practices for intolerants--the environment (i.e., soils, elevation, etc.) plays an important role in determining species composition and the specific practices used to develop desirable composition. For example, in the Lake States higher proportions of moderately tolerant species like yellow birch are found on both wetter or drier than average sites under individual tree selection cutting. When other cutting methods are used, on two sites, "average" and "wet", yellow birch production is a function of the intensity of site preparation; removal of advance sugar maple or red maple reproduction triples birch stocking; coupling this with scarification results in five- or sixfold increases. However, the more poorly drained site had the most birch in any case under a shelterwood overstory. On the other hand, strip clearcutting was essentially a failure on the wetter of the two sites while strip clearcutting with site preparation was very successful on the better drained soil (Figure 4) when seed supplies were abundant.

Once established, maintenance of yellow birch requires periodic thinnings especially where sugar maple is the main competitor (10). Thinnings should start before age 20 to be effective. These thinnings, even in large even-aged stands, in our area will produce tolerant tree seedlings. On the Argonne Experimental Forest, thinnings started at age 11[2/] in a mixed hardwood stand variously composed of elm, birch, ash, basswood and maple carried on at age 19 and 25 have created an all-aged stand structure at age 48. Most smaller stems are sugar maple. Saw log-sized trees are the fast growing elm and basswood.

This may cause problems in succeeding rotations especially where group selection or shelterwood is used since these methods allow seeding in of tolerant species. In a 100-year rotation, some of this tolerant regeneration will be 50-60 years old at a minimum and may be much older as the previous example implies.

Maintenance of Composition

Maintenance of composition appears to be less of a problem when small even-aged or all-aged stands compose the forest than getting desirable regeneration in the first place. In the Lake States, yellow birch is likely to fall out of the stand at an early age unless thinned at regular intervals. Other species such as oak, basswood, ash, etc., once established appear to compete successfully without special thinnings. In all-aged practice, 20-year records indicate that in a cutting unit, at least, there are "adequate" numbers of individuals of each species in each size class to yield <u>some</u> less tolerant species at each harvest.

Individual species growth rates vary widely; elm, American basswood, and red oak grow rapidly in relation to the more tolerant species and as a result do not

2/ Number of years after release of regeneration.

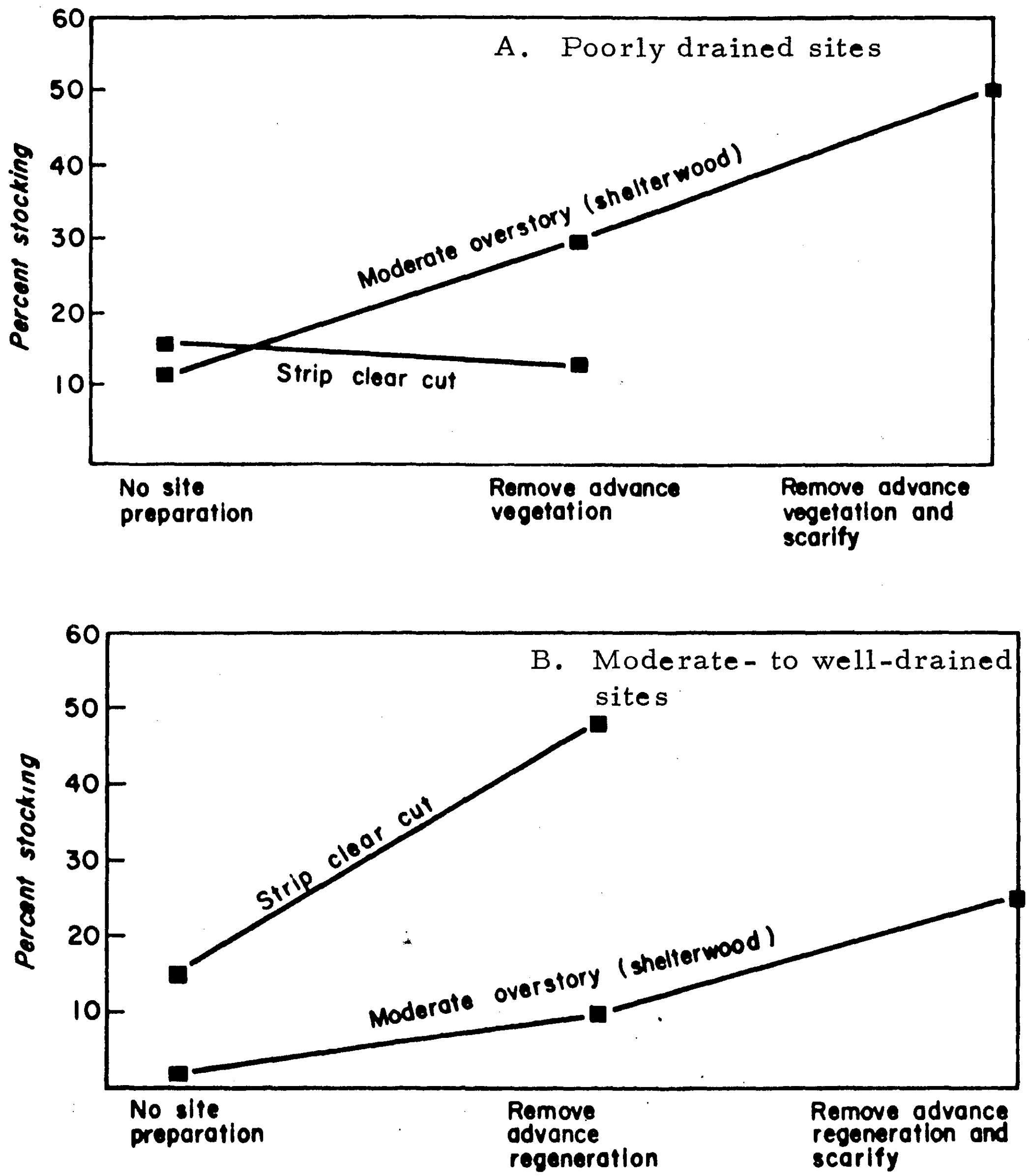


Figure 4.-- Influence of cutting method and site treatment on percent of sample quadrats dominated by yellow birch on: A. Poorly drained sites; B. Moderate- to well-drained sites.

require special attention. Moderately tolerant and tolerant species growth rates are similar in all-aged stands (Table 1) under a variety of conditions.

Very fast-growing, intolerant species are invaded by tolerant species so slowly that little problem should be experienced with them. Clearcuts at rotation end should have only saplings and small poles to deal with.

Invasion by tolerant species such as beech are taken care of by discriminating against them during periodic harvests in hardwood stands in West Virginia (16) but beech in northeast northern hardwood stands may require noncommercial operations for effective control (6). Probably this reflects regional differences in the ecological position of beech.

Maintenance of Quality

Tree quality is often more important than species in the northern hardwood type. Hardwoods are high value only in the veneer and first two grades of saw logs. Consequently, less attention is paid to maintenance of composition than maintenance of value potential. Species discrimination is practiced to a limited extent. Elm species (because of Dutch elm disease), beech and hemlock are discriminated against but individuals of high quality potential are left regardless of species.

Most hardwood species are subject to epicormic sprouting and the presence of limbs and knots reduces value greatly. The use of patch and group cutting to stimulate regeneration, can and does stimulate epicormic sprouting and branch retention on trees bordering the groups.

This problem has not been completely resolved yet, however, it is, I think, commonly held that dominant trees with well formed, vigorous crowns are less likely to sprout. Careful tending should leave trees with such characteristics at the edges of groups. Whether this is possible in all cases has yet to be shown.

Artificial Planting

In the early 30's and 40's many test plantings of a variety of species were made in the young second-growth at the Upper Peninsula Experimental Forest. Although all of the plantings were abandoned for record keeping many are in evidence today.

Most of the planting was done in small groups of one-half to one acre. The conifer plantings were successful in terms of survival especially if weedings were done. Such species as jack pine, red pine, various spruces both native and introduced, and white pine still survive. Some stands have made very good growth and they illustrate the possibility of planting conifers in small openings to develop uneven-aged stands.

Table 1.--Average 20-year diameter growth in inches of sugar maple and yellow birch under various densities and cutting cycles.

Cutting cycle	STOCKING DENSITY											
	30			50			70			90		
	6"	12"	18"	6"	12"	18"	6"	12"	18"	6"	12"	18"
	SUGAR MAPLE											
5				4.28	4.18	4.00	3.50	3.31	3.13	2.73	2.75	2.77
10				3.94	3.87	3.81	3.18	3.20	3.22	2.35	2.48	2.62
15				3.88	3.54	3.20	3.08	3.17	3.26	2.40	2.52	2.65
20	3.97	3.85	3.72									
	YELLOW BIRCH											
5				4.73	3.88	3.05	3.57	3.34	3.11	3.43	3.16	2.90
10				4.09	3.54	3.00	3.64	3.12	2.59	2.52	2.36	2.19
15				4.18	3.50	2.85	3.27	2.89	2.51	2.52	2.42	2.32
20	3.85	3.46	3.07									

On the other hand, planting northern hardwood species in openings has met with limited success (8). Planting yellow birch has only been successful under a shelterwood overstory. Hardwood planting in more southerly areas appears to be less difficult.

Maintenance of Tolerant Species in All-Aged Stands

We have had a shade over 50 years' experience with growing sugar maple and associated tolerant species under various partial cutting methods. Recently, we have turned from optimum stocking studies to studies of the effects of structure on growth and yield.

There are a number of schemes for all-aged structures. Basically they fall into two categories. Empirical structures have been developed by a number of authors (4, 2, 16). In our case the structure currently used as a management guide was simply picked from a number of cutting method studies and represents that which promoted the best growth for the period available.

Actually, the minimum requirements for a structure in which growth equals yield are that each size class have the number of trees which will be cut at harvest. From a silvicultural point of view, these are inadequate numbers obviously. After mortality has taken its toll, the silviculturist wants to have enough trees left to ensure a density adequate for rapid branch death and straight stems. He also needs some freedom to select trees to leave for future growth. The structure should also reflect management objectives, i.e., yields comprised of small saw logs or those composed of large saw logs.

Schemes developed on the basis of De Liocourt's (7) theory provide plenty of trees for the silviculturist to work with and within broad limits actual stand measurements indicate the correctness of the rule.

The structure of any stand is controlled naturally to some extent by stand density. Ingrowth into a size class is partly a function of the density of the whole stand and partly a function of the density of the larger size classes. For example, a stand cut to residual basal areas of 90 square feet of basal area 10 inches d.b.h. + allows fewer saplings to enter the pole class than stands cut to 50 square feet (8). In unregulated stands, simply controlling density of a broad size class at regular intervals is sufficient to start the stand toward regulation. "Deficiencies" which exist at the start of management will maintain themselves for long periods of time (Figure 5). In the example a deficit of trees in the 5-9 class in 1932 is evident in the 10-14 class 30 years later. During this time the 10-14 class dwindled from 26 trees per acre to 19. Because only 5 or 6 trees are cut per acre from the largest size class in stands like this, whether this reduction in numbers in this particular stand represents a real deficiency which will be reflected in reduced yields is uncertain.

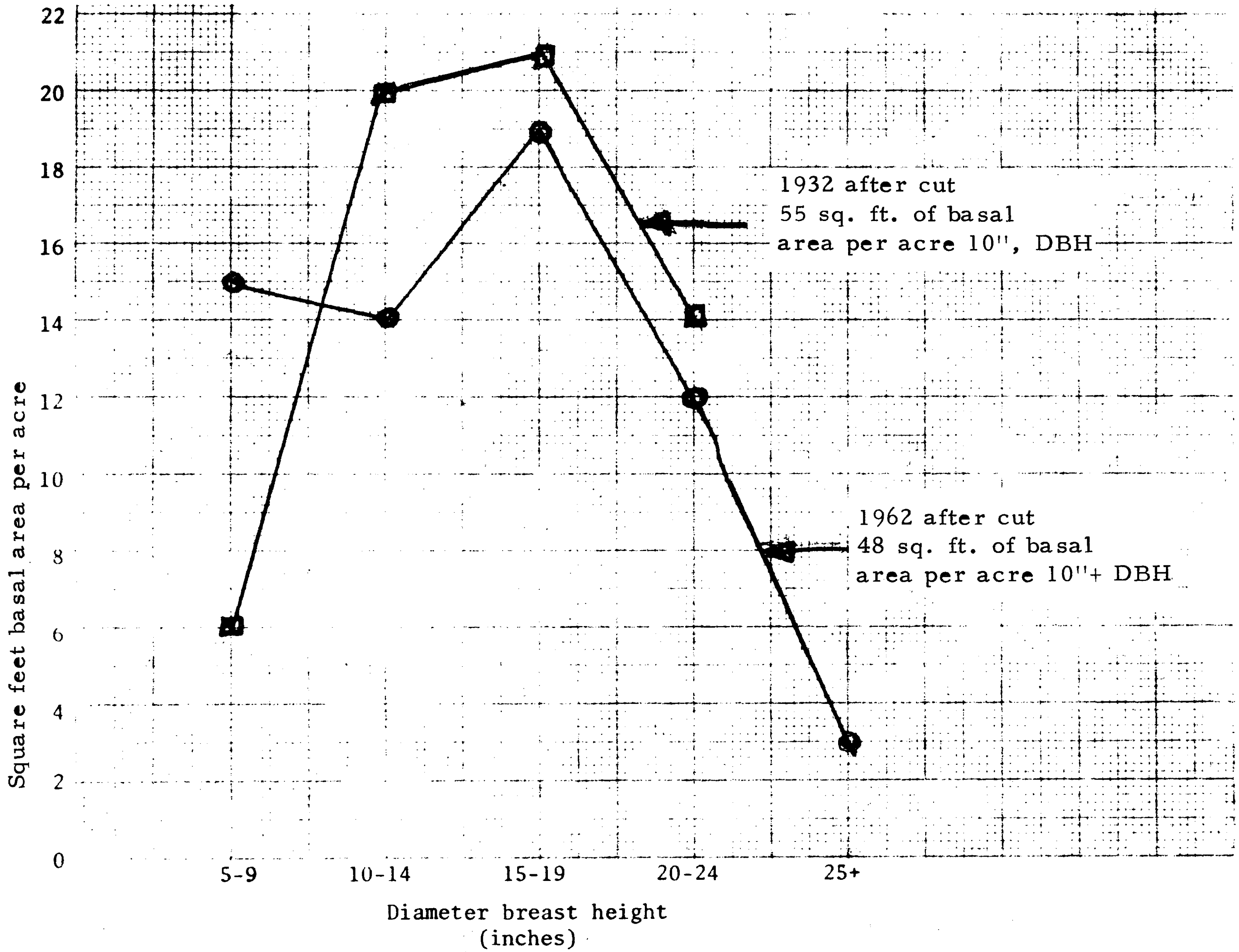


Figure 5. -- Stocking by size class maple--birch--beech stand Upper Peninsula Experimental Forest overmature and defective #2.

More apparent effects of size class deficiencies are found in stands which are deficient in the saw log class. Usually these stands (second-growth) have no or very defective saw log overstories and yields are reduced through the time it takes for the larger poles to attain the desired saw log sizes. Stand density controls ingrowth into the saw log class in these stands, too. The common practice of cutting most marketable saw logs and leaving the pole class untouched tends to perpetuate a stand composed of poles and a few saw logs; this practice if continued also reduces the number of saplings which may produce size class or yield deficiencies at some future date.

In the initial stages of management, control of stocking by very broad size classes seems sufficient. As more size classes appear, control by narrower size classes seems desirable. Control by Q factors is often proposed (16). This simple practice depends on a calculated "Q" factor which describes a "J" shaped progression of size classes; trees which are overabundant in relation to calculated numbers are removed at each cut. In unregulated stands this may, depending on the situation, produce irregular yields for lengthy periods but ultimately will result in regulated stands.

We are attempting to answer some of the more obvious questions such as what constitutes deficient size classes, how intermediate size should be cut and what strategies result in the most efficient production. To develop answers to these questions we are using a stand model developed by Moser (9) which predicts with reasonable accuracy movement of trees through the various size classes for rotation length periods.

Summary

In summary, it seems that group or patch practices are necessary in uneven-aged management to produce adequate numbers of intolerant species in most eastern types. Often this type of harvest must be supplemented by site preparation. Maintenance of composition seems less of a problem than securing adequate regeneration in the first place; exceptions such as yellow birch occur. Maintenance or improvement of individual hardwood tree quality is a problem in group or patch cutting, however. Planting of conifers is feasible in many types. Successful hardwood plantings in forest situations is difficult in the northern hardwood type, at least, although exceptions occur. Where undesirable tolerant species are aggressive, invasion of these species may create problems at rotation age.

Tolerant species may be easily regenerated by all-aged practices in many cases. In some areas (Lake States northern hardwoods, for example) tolerant species can be regenerated by group selection and shelterwood as well as depending on soil conditions. Soil and site conditions alter competitive relationships between trees and varying amounts and varieties of moderately tolerant and tolerant species continue to appear even with all-aged practice although intolerants are rare. Maintenance of species composition is not a particularly important problem in the northern Lake States or the spruce--fir type under all-aged management but beech and other undesirable tolerants must be discriminated against in cove hardwoods or northeast northern hardwoods. In all-aged practice, we need more well-defined methods of producing and maintaining stand structures composed of tolerant species.

Substantial variation in the ecology and economics of cover types occur within and between forest regions. Defining problems and forest practices may be more efficiently accomplished by taking these differences into account.

Literature Cited

1. Braun, E. Lucy. 1964. Deciduous forests of eastern North America. 596 p. Hafner Publ. Co. New York.

2. Eyre, F. H., and W. M. Zillgitt. 1953. Partial cuttings in northern hardwoods of the Lake States. U.S. Dept. Agric. Tech. Bull. 1076, 124 p.

3. Godman, R. M., and C. H. Tubbs. 1973. Establishing even-age northern hardwood regeneration by the shelterwood method--a preliminary guide. USDA For. Serv. Res. Pap. NC-99, 9 p. NCFES, St. Paul, MN.

4. Hart, Arthur C. 1964. The Penobscot management-intensity demonstration plots. USDA For. Serv. Res. Pap. NE-25, 24 p. NEFES, Upper Darby, PA.

5. Kriebel, H. B., and W. J. Gabriel. 1969. Genetics of sugar maple. USDA For. Serv. Res. Pap. WO-7, 17 p.

6. Leak, W. B., D. S. Solomon, and S. M. Filip. 1969. A silvicultural guide for northern hardwoods in the Northeast. USDA For. Serv. Res. Pap. NE-143, 34 p. NEFES, Upper Darby, PA.

7. Meyer, H. A., A. B. Recknagel, and D. D. Stevenson. 1952. Forest Management. 290 p. The Ronald Press Co., New York.

8. Michigan Technological University. 1969. Proceedings Sugar Maple Conference, Aug. 20-22, 1968. Houghton, MI, 166 p.

9. Moser, J. W., Jr. 1973. A system of equation for the components of forest growth. Presented to the International Union of Forest Research Organizations Joint Meeting, Vancouver, B.C., Canada.

10. Northeastern Forest Experiment Station. 1969. Birch symposium proceedings. 183 p. USDA For.Serv. NEFES, Upper Darby, PA.

11. Perry, T. O., and C. W. Wang. 1960. Genetic variation in the winter chilling requirement for date of dormancy break for Acer rubrum. Ecology 41(4): 790-794.

12. Smith, David Martyn. 1962. The practice of silviculture. 7th ed., 578 p. John Wiley &Sons. New York.

13. Society of American Foresters. 1950. Forestry terminology. 93 p. Monumental Printing Co., Baltimore, MD.

14. Society of American Foresters. 1954. Forest cover types of North America. 67 p. S.A.F., Washington, DC.

15. Spurr, S. H., and B. V. Barnes. 1973. Forest ecology. 2nd ed., 571 p. The Ronald Press Co., New York.

16. Trimble, George R., Jr. 1961. Managing mountain hardwoods--a ten-year appraisal. USDA For. Serv. NEFES, Upper Darby, PA. Sta. Pap. 143, 25 p.

17. Troup, R. S. 1928. Silvicultural systems. E. W. Jones, Ed. 2nd ed., 216 p. Clarendon Press. Oxford.

18. U.S. Department of Agriculture, Forest Service. 1965. Silvics of forest trees of the United States. U.S. Dept. Agric. Handbk. 271, 762 p.

19. U.S. Department of Agriculture, Forest Service. 1973. Silvicultural systems for the major forest types of the United States. U.S. Dept. Agric. Handbk. 445, 124 p.

STAND STRUCTURE

by

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A managed uneven-aged forest is a system. By "system", I mean a series of parts that are interconnected so that if you yank on one part, all the other parts move up and down. My assignment is to yank on stand structure. But in doing this, I really can't avoid an examination of what happens to some of the other parts in the system because the real challenge in uneven-aged management is to understand the linkages among parts: e.g. how stand structure relates to growth and yield, allowable cut, cutting methods, TSI requirements, and the entire economic picture.

Definitions and Measures

By the term "stand structure", I'm referring mostly to diameter distribution--numbers of trees by d.b.h. class. A given diameter distribution also determines a given basal area per acre, and probably relates closely to most other measures of density or stocking. Furthermore, size distribution also implies, sometimes imperfectly, an underlying age distribution. In talking about population structure, we cannot get too far away from age distribution because most of the underlying theory of population structure is based on age.

Several measures of diameter distribution are available: (1) q, which implies a negative exponential distribution, where the logarithm of stem number over size plots as a straight line; (2) the power function (Hett 1971), where number over age or size plots as a straight line on log/log paper; (3) the Weibull distribution (Bailey and Dell 1973), which is a flexible curve form that fits a variety of diameter distributions; (4) a sigmoid form that could be fitted by polynomial or nonlinear regression; and (5) empirical forms where numbers over size are built up from field measurements. There are plenty of ways to express, measure, or present diameter distributions. We'll probably need all of them.

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Population Theory

Most literature on the theory of population structure relates to ecology or demography. Hardly any of this theory is found in the forestry literature. A fundamental theorem of population dynamics indicates that if you subject a population to any consistent schedule of fertility and mortality rates, it will settle down to a stable age distribution (a constant proportion of individuals per age class). In a limited environment (a situation that very definitely applies to trees), the population usually will move up or down to a stationary point where numbers by age class settle down to a constant figure. This final age-class distribution represents the survivorship curve --the curve that would be formed if you started with a large number of 1-year seedlings and plotted numbers over time until all were gone.

How does this concept apply to trees? It means that under the natural fertility and mortality schedules in an undisturbed forest, the stand will develop a stationary or constant age and size distribution. Based on the work I've done in virgin northern hardwoods and red spruce in New Hampshire, I would say that this does in fact happen. Meyer (1952) studied such stands in the United States, and found that the size distribution tends to follow the q concept.

However, cutting is simply another form of mortality, so the concept of a stationary age or size distribution applies to managed stands as well. If we adopt any type of consistent cutting policy--cutting of 24-inch trees, cutting a certain proportion of sawtimber stems, cutting a certain proportion of sawtimber and poletimber, etc. --the stand will move around for awhile in response to the prevailing regeneration and removal rates, and then settle down to a unique and constant structure and constant yield. We have achieved sustained yield and a balanced structure at this point. Since cutting is cyclical, structure and yield in a given stand will be cyclical. Stability becomes evident when several stands are averaged together.

Notice that we can achieve sustained yield from an uneven-aged forest by a wide variety of consistent cutting policies. It is not necessary to assume that cutting must be applied throughout all diameter classes--a traditional recommendation. We have a range of options that go from extensive commercial management up to very intensive management involving heavy cultural investments. All approaches, with precautions, can provide for sustained production. The final stationary or balanced structure will no doubt vary greatly--in shape and position--among the different cutting policies. I said before that we will need several ways to represent diameter distribution.

Keep in mind that regeneration feeds the lower end of a diameter distribution. If we adopt cutting practices that produce poor regeneration, the stand may well reach a stationary point, but at a low level of stocking and yield. If cutting rates in the large sizes are too high, we may also reach a stationary point; but the yield may be heavily weighted toward small trees.

Examples of Balanced Structures

Good examples of balanced or stationary structures in managed stands are hard to come by. But let's look first at some of the simulation work of Adams and Ek (1974) based on ingrowth, mortality, and growth rates from 132 permanent plots. Notice in Figure 1 that sustainable residual diameter distributions were derived based on cutting in only the sawtimber sizes. According to the authors, "Trees in the crosshatched region would be removed by cutting while natural mortality and upgrowth stabilize the lower end of the distribution". In Table 1, I have reproduced one of their tables of economically optimum residual diameter distributions. Notice, for example, that their optimum distribution for 80 square feet contains many small trees, no trees over 18 inches d.b.h., and does not follow q. I know firsthand the vagaries of simulation work, but I would say that their results are worth examining because they are in line with what I know about population dynamics, growth, and financial maturity.

In Table 2, I have given some figures from Compartment 42 on the Bartlett Experimental Forest (Filip 1972). Cutting in 1953 was throughout all sizes; an additional 9 square feet were removed by TSI through all sizes 5 inches d.b.h. and larger and some smaller stems were taken as well. In 1972, 19 years later, notice that the diameter distribution is again quite close to the original 1952 condition although there have been some shifts from 10's, 12's, and 14's to 16's and 18's. The cut in 1972 could be quite similar to the 1953 cut. The calculated q remains at 1.7 to 1.8 and I'm not convinced that it can be lowered very feasibly or quickly. And although the stand does not depart greatly from the q-type distribution, I suspect that numbers of 10's, 12's, and 14's are going to stay somewhat above the goal. In examining 20-year data from the Fernow Experimental Forest (Trimble 1970), I think I see similar difficulties in trying to keep numbers of small to medium trees within the bounds of a set q distribution[2/]. Population theory indicates that this is not necessary. Perhaps we should concentrate on setting consistent and economical cutting schedules, scheduling cultural or marginal work where silvicultural and economic justifications are strong, ensuring adequate regeneration, and watching carefully for that point where the structure becomes stationary and production vs. costs appear optimum.

Setting Structural Goals

Let's look at a problem in setting short-term structural goals and examine some of the options. Here's an actual second-growth stand on the Bartlett

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2/ There is a decided tendency for q ratios to increase with d.b.h. throughout sawtimber size classes in managed or disturbed hardwood stands--most noticeable with 4-inch classes.

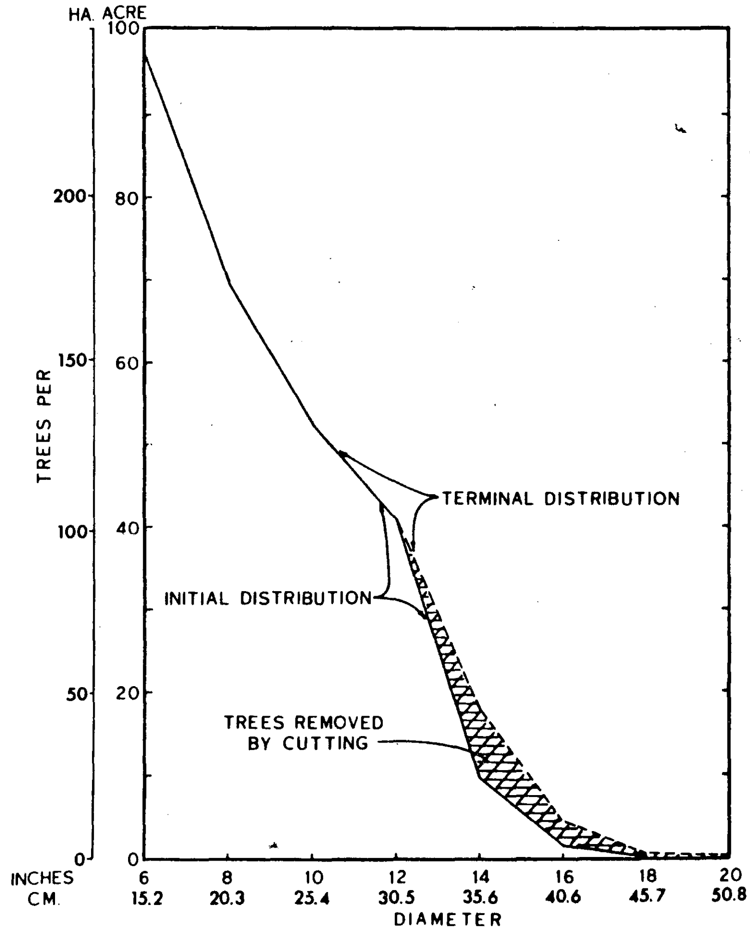

Figure 1.--Example of sustainable diameter distribution. Difference between initial (solid line) and terminal (dashed line) distributions removed by harvest (cross-hatched area). (Adams and Ek 1974).

Table 1.--Optimal diameter distributions, reproduced for Adams and Ek (1974).

	Number of trees/acre subject to stocking level constraint (basal area/acre)							Lake States northern hardwoods guide[b]	Cords/ tree	Board feet/tree	Value/tree
	60	70	80	90	100	110	120				
Diameter class (in.)											
6	159.1	119.4	103.6	96.7	91.8	89.3	76.3	31	0.0305	—	0.04
8	25.3	36.6	43.1	50.0	55.2	59.8	54.5	19	0.0789	—	0.55
10	12.3	21.0	27.6	33.1	38.7	44.6	41.2	14	0.1400	—	1.15
12	10.0	16.8	22.1	26.4	30.6	35.2	32.4	10	0.2137	85.43	2.06
14	2.9	5.0	6.7	8.1	9.6	10.7	26.2	10	0.2999	128.73	3.37
16	1.0	1.7	2.3	2.8	3.3	3.7	6.2	8	0.3982	169.76	4.89
18	0.5	0.8	1.1	1.3	1.6	1.7	0.9	6	0.5087	215.40	6.60
20+	—	—	—	—	—	—	—	9	0.6312	256.10	8.52
Five year value growth ($)	35.00	37.78	40.39	42.76	44.88	46.76	47.91	37.92			
Five year board feet growth	628	631	1049	1154	1484	1608	1599	1015			
Five year cord growth	3.90	3.71	3.73	3.80	3.87	3.94	3.81	2.79			
Value of stocks ($)	72.98	114.10	146.20	173.38	200.62	225.63	271.70	250.31			
Board feet stocking	1518	2540	3378	4053	4755	5379	7387	7367			
Cord stocking	12.22	15.64	18.63	21.37	24.11	26.75	30.10	22.28			
Dual of basal area constraint[c]	+0.283	+0.271	+0.249	+0.224	+0.200	+0.176	−0.310				
Average annual value growth (%)	8.2	5.9	5.0	4.5	4.1	3.8	3.3	2.9			
Marginal value growth	2.78	2.61	2.37	2.12	1.88	1.15					
Marginal value of growing stock	41.18	32.10	27.18	27.24	25.01	46.07					
Marginal value growth percentage	1.3	1.6	1.7	1.5	1.5	0.5					

[a]Metric equivalents are: 1 in. = 2.54 cm; 1 tree/acre = 2.47 trees/ha; 1 cord/acre = 8.96 m^3/ha (overall measure of stacked roundwood); 1 ft^2 of basal area/acre = 0.23 m^2 basal area/ha.
[b]Derived from Arbogast (1957), detail not shown for 20 in. and larger classes. Basal area is 83.1 ft^2.
[c]The value of the "dual" of the basal area constraint may be interpreted as the prospective change in the value of the objective function for a one unit increase in the level of the constraint. For example, at 60 ft^2 basal area, an increase to 61 ft^2 would lead to approximately a $0.283/acre increase in the value growth. Note that a 10 ft^2 increase to 70 ft^2 actually increased value growth by $2.78 while the *estimated* increase from the dual was $2.83. The difference arises due to the curvilinearity of the objective function.

Table 2.--Stand structure in trees per acre for Compartment 42, Bartlett Experimental Forest (Filip 1972).

D.B.H.	Initial Inventory 1952	Post-logging Inventory 1953	2nd Inventory 1972	Goal q=1.5
6	46	43	46	45
8	36	29	33	30
10	34	24	27	20
12	27	20	22	13
14	16	12	15	9
16	8	6	10	6
18	3	2	5	4
20	2	1	2	3
22	1	1	1	2
24+	1	1	1	1
Total	175	139	162	133
q	1.76	1.86	1.76	1.50
BA/sq.ft.	107	75	102	80

Forest (Table 3). I'll assume that markets for 6- and 8-inch trees are poor. One of the common recommendations in hardwoods has been to set a long-term goal of q=1.3 or 1.5[3/] and press toward it. Notice (Table 3) that the use of such low q's as immediate marking guides would lead toward heavy removals in the poletimber, moderate cutting in the 12's and 14's, and almost no cutting or deficiencies in the larger sizes. In a stand of this type, I do not think that heavy removals in the small sizes makes much silvicultural or economic sense. In a typical stand, removal of small trees does little to benefit the remaining stand. The only situation that might lend itself to heavy work in the small sizes would be where the trees actually occur in even-aged groups; here, we could deal with 6- and 8-inch overstory trees and perhaps justify the venture by benefits to better stems of about the same size. Notice that this sort of pattern could be perpetuated only by group or patch selection. Thus, we come to a linkage between structural control, TSI opportunities, and harvest cutting method.

Many silviculturists find it hard to accept the notion that they need not press immediately toward a low q of 1.3 or 1.5. They have their eye on the high proportion of sawtimber growth usually associated with low q values. But remember that the optimum growth in low-q stands is due to the abundance of vigorous large trees <u>not</u> the scarcity of little trees. To encourage sawtimber growth in the short run, silviculture treatments should be directed primarily toward reducing mortality and increasing diameter growth of the small sawtimber trees and larger. Usually, this is not best accomplished by excess work in the smallest size classes although there may be instances where the removal of the understory benefits the overstory. Remember also that we have little basis for setting long-term structural goals based on q, and that repeated application of an unwise removal policy will tend to produce a stand structure in balance with that removal policy. Keep in mind also the economics of harvesting and road building.

A q=2.0 provides a more reasonable basis for current marking in the stand (Table 3), although the residual sawtimber stand does seem a little light. Another option is to maintain a q=2.0 in the poletimber, and press toward a lower q=1.7 in the sawtimber; this maintains slightly heavier stocking in the larger trees. Remember, we threw out the notion of a rigid adherence to q throughout the diameter range a few pages back. We could also use a proportionate rule such as the removal of 1/3 or 2/5 of the sawtimber trees[4/]

3/ Generally, low q's produce a higher proportion of growth in the larger sizes. However, it is important to consider the cost and effort of bringing about and maintaining low q structures.

4/ Cutting schedules based on financial maturity guides (e.g. Trimble et al 1974) seem to be completely consistent with this approach to stand structure control provided that attention is given to maintaining adequate residual stocking, avoiding gaps in the diameter distribution, assessing cultural needs, and providing for good regeneration.

Table 3.--Comparison of marking alternatives in residual trees per acre for an initial stand on the Bartlett Experimental Forest.

D.B.H.	Initial Stand	q=1.3	q=1.5	q=2.0	q=2.0/1.7	2/5 Sawtimber
6	95	27	44	92	92	95
8	54	21	30	46	46	54
10	27	16	20	23	23	27
12	27	12	13	12	12	16
14	16	9	9	6	8	10
16	7	7	6	3	4.5	4.2
18	5	6	4	1.4	2.6	3.0
20	1.6	4.3	2.6	0.7	1.5	1.0
22	0.5	3.3	1.7	0.4	0.9	-
Total BA-sq.ft.	114	79	75	71	82	89
BA 10"+	94	66	56	37	48	52

plus any poletimber removals that could be well-justified as a cultural measure. The consistent removal of a specific proportion of trees, carefully defined for each d.b.h. class on the basis of financial return and cultural benefit, is the approach that probably comes closest to the constant mortality/removal schedule found in population dynamics theory.

Despite the various options available, it is always important to have an immediate structural goal to guide the marking, to set a goal that approximates a survivorship curve with decreasing stem numbers, to keep residual stocking within limits, and to make silvicultural and economic sense.

The future in a stand of this type is somewhat uncertain. Any opportunity to work toward a higher proportion of sawtimber through feasible and well-justified cutting practices should be implemented. The final balanced distribution will be a product of cutting practices--and their effects on regeneration and removal rates--and environment. It is quite possible that an initial lump will develop in the diameter distribution. However, this possibility does not automatically dictate heavy cultural work. Probably, it is better to wait and see. If a lump develops, it can be removed at a profit as small sawtimber. To avoid heavy impacts on the yield from the entire forest, lump removal can be staggered.

Marking Control

There is no use in prescribing a structural goal unless we can apply it. The regulation aspects of uneven-aged forest management fall apart unless we can mark to given structures with some degree of accuracy. Marking is a difficult job because of limited inventory information, the need to mark adequately during one pass through the stand, and the need to apply sound on-the-ground silviculture and economics. And now I've alluded to the possibilities of using group and patch selection, which adds further complications.

However, marking control does not appear much more difficult than operation control problems in other lines of endeavor. Most operation control systems seem to operate through information feedback: the continual receipt of information on current position, goal, and direction to take. That's how bats catch insects, linebackers get ballcarriers, mortarmen hit unseen targets, and missiles hit moving targets. And, apparently, that's how we should take a stand from where it is to where it should be. Suppose we used a marking crew with 2 or 3 markers and a tallyman. On a fixed, short time schedule, the tallyman takes a cumulative prism tally of the residual stand after marking by d.b.h. class, and keeps a running average of numbers per acre by d.b.h. Periodically, the running average is checked against the goal, and new marking instructions are issued to press toward the goal. As the crew moves through the stand, residual and goal should move together as close as silvicultural considerations permit.

Conclusions

The theory of population structure indicates that we have wide options for the practice of uneven-aged management--from extensive to intensive. By applying feasible, consistent cutting policies, well-justified cultural practices, and measures to ensure adequate regeneration, balanced diameter distributions should evolve that can be feasibly maintained.

In the past, balanced structural goals have been defined primarily in terms of low q distributions (q=1.3 to 1.5). Other options should be considered because:

1. Population theory indicates that balanced structures in managed forest stands may vary in shape or position.

2. Recent simulation work indicates that balanced optimal structures may not follow the q distribution.

3. Some managed stands, even those molded toward a q distribution, tend to remain at high q levels of 1.7 to 1.8 or to maintain excess trees in the mid-diameter range.

4. The maintenance of low q distributions may require heavy removals of small trees, and removals of mid-diameter trees that are producing high return as growing stock.

The removal of trees throughout all diameter classes to maintain a certain structure has been considered almost a silvicultural necessity. However, this should not be adopted as blanket policy because:

1. Population theory indicates that tree removal throughout all diameter classes is not necessary to produce a balanced structure.

2. Recent simulation work indicates that balanced, optimal structures may be produced by cutting in only the sawtimber sizes.

3. Experimental cuttings to date (Fernow) do not seem to indicate that cutting in sawtimber sizes only, if carefully applied, will cause structural problems.

4. Cutting in small sizes does not always seem silviculturally or economically sound. However, there are cases where silvicultural justifications are very strong for such work.

Immediate or short-term marking guides should not rely solely on low-q distributions because:

1. Balanced structures may not follow q as indicated above.

2. Marking guides based on low q's may be physically impossible to meet, or may dictate work that is silviculturally unsound or uneconomical.

Literature and Reports Cited

Adams, D. M., and A. R. Ek. 1974. Optimizing the management of uneven-aged forest stands. Canad. J. Forest Res. 4:274-287.

Bailey, R. L., and T. R. Dell. 1973. Quantifying diameter distributions with the Weibull function. Forest Sci. 19:97-104.

Filip, S. M. 1972. Progress report: Compartment 42, Compartment Management Study, Bartlett Experimental Forest, 1952-1972, Unpublished report on file at Durham, N.H., 19 p.

Hett, J. M. 1971. A dynamic analysis of age in sugar maple seedlings. Ecol. 52:1071-1074.

Meyer, H. A. 1952. Structure, growth, and drain in balanced uneven-aged forests. J. Forestry 50:85-92.

Trimble, G. R., Jr. 1970. 20 years of intensive uneven-aged management: effect on growth, yield, and species composition in two hardwood stands in West Virginia. USDA Forest Serv. Res. Pap. NE-154, 12 p.

_____________, J. J. Mendel, R. A. Kennell. 1974. A procedure for selection marking in hardwoods. USDA Forest Serv. Res. Pap. NE-292, 13 p.

GROWTH AND YIELD

by

S. F. Gingrich [1/]

My assignment in this workshop is to discuss the state of the art on growth and yield of uneven-aged stands and to make comparisons with the growth and yield of even-aged stands where appropriate. I started this assignment with an attitude that I would look for unifying concepts--similarities or cross walks between the systems. We all know that there are fundamental differences in the silvicultural requirements but on the other hand the growth rate of a single tree is related to such factors as species, site quality, age, microdensity and climate. It (the tree) does not respond directly to management decisions concerning allowable cut, sustained yield and economics.

Growth estimates are of two types--tree growth and stand growth. Tree growth is the enlargement of the stem over time. It reflects tree vigor and overall performance. Tree growth is measured in terms of radial, diameter or volume growth. It has silvicultural and mensuration utility, but is rarely used in management.

Stand growth is a measure of the productivity of an acre. It is measured in terms of volume or basal area and is used in management as a predictor of yields. It is usually determined from forest inventories.

Stocking and Stand Density

This is a broad subject. Much effort has been devoted to measures of stocking which denote site occupancy and density which denote spacing and a measure of competition. Most of the research in this field dealt with even-aged stands. Stocking and density are important factors in tree and stand growth. In uneven-aged stands there are no equivalent measurements. The q-factor and basal area by broad diameter classes are not measures of stand density or competition and only rough estimates of stocking. The primary purpose for

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managing uneven-aged stands by some structural goals is to provide a balance diameter distribution that will support periodic harvest of nearly equal volume. I have found no published results where stand structure alone in uneven-aged stands is an important growth factor. Structure goals cannot be maintained on small areas and there seems to be some doubt whether they can easily be maintained on a stand (5-10 acres) basis. In general, measures of inter-tree competition for uneven-aged stands are lacking and a growth evaluation of cultural operations in these stands is difficult.

Stand Development

Figure 1 illustrates some basic differences between even- and uneven-aged stand development. In uneven-aged silviculture the objective is to seek a normal volume that is best for a given type and site. This level of stocking may be defined in terms of q, basal area or other measures that result in the maintenance of a balance diameter distribution. Once the ideal level of stocking is reached the volume removed at each cutting cycle will equal the periodic growth since the last cut. Trimble (1970) reported that managed stands should produce 300 board feet/acre annually. The periodic growth could be a measure of site quality. Every cut under this system is a harvest cut--i.e., mature trees are removed and the stand must be replenished by new reproduction. The cut may also serve as a thinning if some consideration is given to spacing in the residual stand.

In even-aged stands the periodic cut is always less than the periodic growth since the volume in growing stock increases with stand age. One harvest cut is made at rotation age.

A comparison of the growth of even- and uneven-aged stands could be made by comparing the sum of the yields, Y. Such comparison can only be made from available yield projections which are rare, but some cursory examinations of yields from balanced uneven-aged forests and yields from managed even-aged forests show the long term yields will be similar. Comparison between the two systems at one point in time when stocking (total basal area), site and average stand diameter are equal show about equal productivity. Recommended basal area stocking is often within 10 square feet of basal area.

Conversion from Even-aged to Uneven-aged Management

The cutting history of eastern hardwood forests has produced many large areas of even-aged stands in the 60-80 year class. At this age many of the stands have a definite diameter structure and might have the appearance of an uneven-aged stand (Figure 2).

The question is often asked--how can you convert an even-aged stand to an uneven-aged stand? What are the growth consequences? Let's take a closer look at a typical stand table for an upland oak stand. There is a good possibility that the trees from 6" to 16" are of the same age class. A few larger

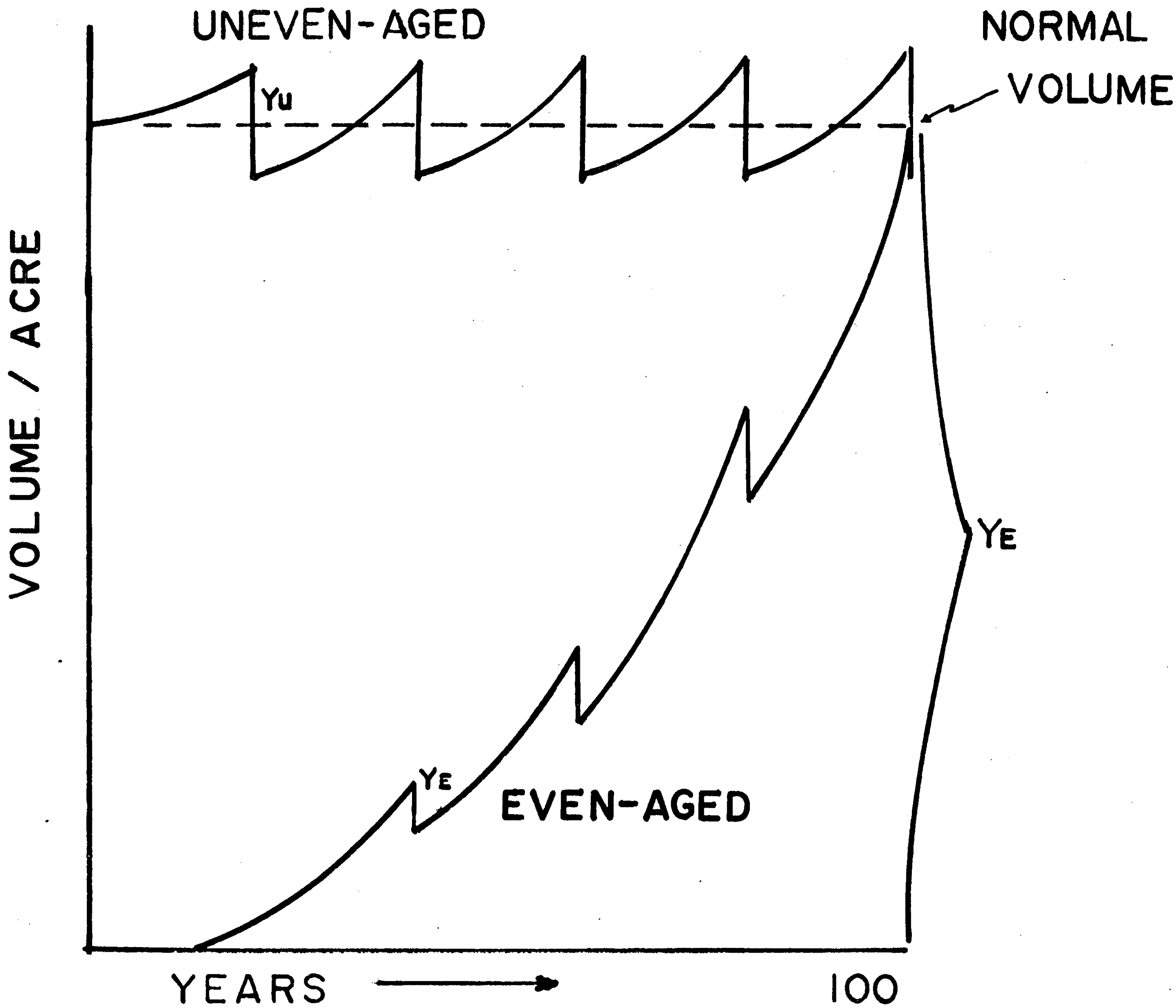

Figure 1.-- A comparison of stand development between even- and uneven-aged stands.
Y = yields

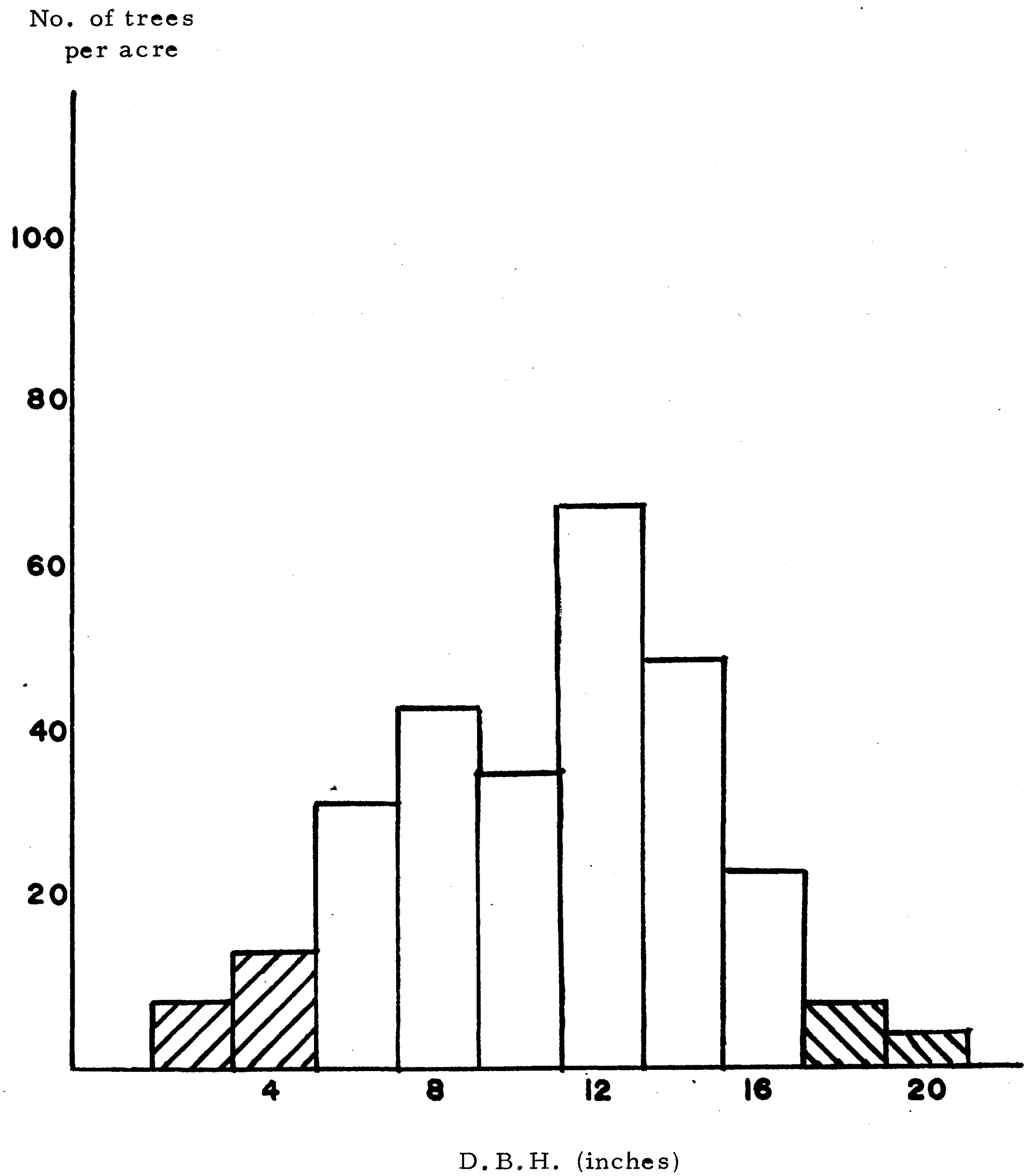

Figure 2.-- A typical diameter distribution on an even-aged upland hardwood stand. Cross-hatched areas often represent other age classes.

trees from an older age class are often residuals from a previous cut. The 2- and 4-inch trees sometimes represent a younger age class. When a single tree selection cut is made, removing the largest trees, the small trees of the same age are released. These trees are generally inferior to the ones removed and rarely respond to the light thinning that has been made. When a second individual tree selection cut is made--say 15 years after the first cut, the better trees are removed again. This is definitely a high grading of the stand. Studies on the Kaskaskia, Vinton Furnace and Fernow Experimental Forests have confirmed this. Most of these studies dealt with variable length cutting cycles. The first cutting, especially if the volume of the stand is near the normal volume of uneven-aged stands, are usually considered operable. Further cuts will gradually liquidate the growing stock to a point where the overhead density is low enough to encourage the reproduction of maple and hickory.

Thus, converting even-aged stands to uneven-aged stands is a slow process involving a change in species composition and possible loss of growth.

In a study on the effects of selection cutting in even-aged stands on species composition changes, Trimble (1965) reports a significant change from intolerant species such as yellow-poplar, red oak, and black cherry to more tolerant species such as sugar maple and beech. Growth losses could be substantial. Table 1 shows average regional growth rates for some selected hardwood species. Those species marked with a minus (--) showed large decreases in composition following selection cutting. The species marked with zero (o) remain about constant and sugar maple becomes more predominant. This is a definite shift from the faster growing species to the slower growing species.

Growth Projection Techniques

The differences between even- and uneven-aged management become more pronounced by comparing growth prediction methods. The methods used for even-aged stands are well known. Growth prediction methods for uneven-aged stands have generally been tied to a forest inventory. Most of H. A. Meyer's (1942) work on method of forest growth determination were based on successive inventories that applied to rather large areas. The benefits of any cultural work applied to the forest during the inventory period should be reflected in the volume of the second inventory. Only recently has research in growth prediction in uneven-aged stands began to consider the biological aspects together with the broader management considerations.

The accuracy and intensity of conventional inventories will not provide the data base to compute reliable q-factors or other structural guides for timber marking on specific tracts. Growth estimates at best are very course. For example, Figure 3 represents an average stand table computed from Schur's (1937) yield tables for even-aged upland hardwood stands. This is a combined

TABLE 1 . A comparison of average diameter-growth rates[1] of selected upland hardwood species and projected average tree diameters at 30, 60, and 90 years (Gingrich, 1967).

Species	Trees bored	10-year diameter growth: Seedlings[2] and saplings	Poles[2]	Sawtimber[2]	Projected average dbh: 30 years	60 years	90 years
	No.	Inches					
--Yellow-poplar	569	2.26	2.40	2.55	6.9	14.3	21.9
Black walnut	409	1.98	2.24	2.06	6.1	12.6	18.8
Scarlet oak	677	1.67	2.00	2.30	5.0	11.0	17.9
--Red oak	400	1.54	1.83	2.32	4.6	10.1	16.8
o White ash	929	1.57	1.77	2.09	4.7	10.0	16.1
Black oak	1,850	1.60	1.78	1.96	4.8	10.1	15.9
++Sugar maple	939	1.29	1.60	1.82	3.9	8.4	13.5
o Beech	609	1.12	1.55	1.63	3.4	7.4	12.1
White oak	2,519	1.20	1.37	1.84	3.6	7.5	11.8
o Hickory	2,123	1.16	1.27	1.42	3.5	7.1	11.0
Chestnut oak	568	0.92	1.32	1.69	2.8	5.8	9.7

[1]Regional average of Forest Survey Resource Reports from Ohio, Indiana, Illinois, Kentucky, Missouri, and Iowa. Central States Forest Experiment Station (Basis--11,592 trees bored.)

[2]Seedlings and saplings--trees less than 5 inches; poles--trees 5 to 11 inches; sawtimber--trees over 11 inches.

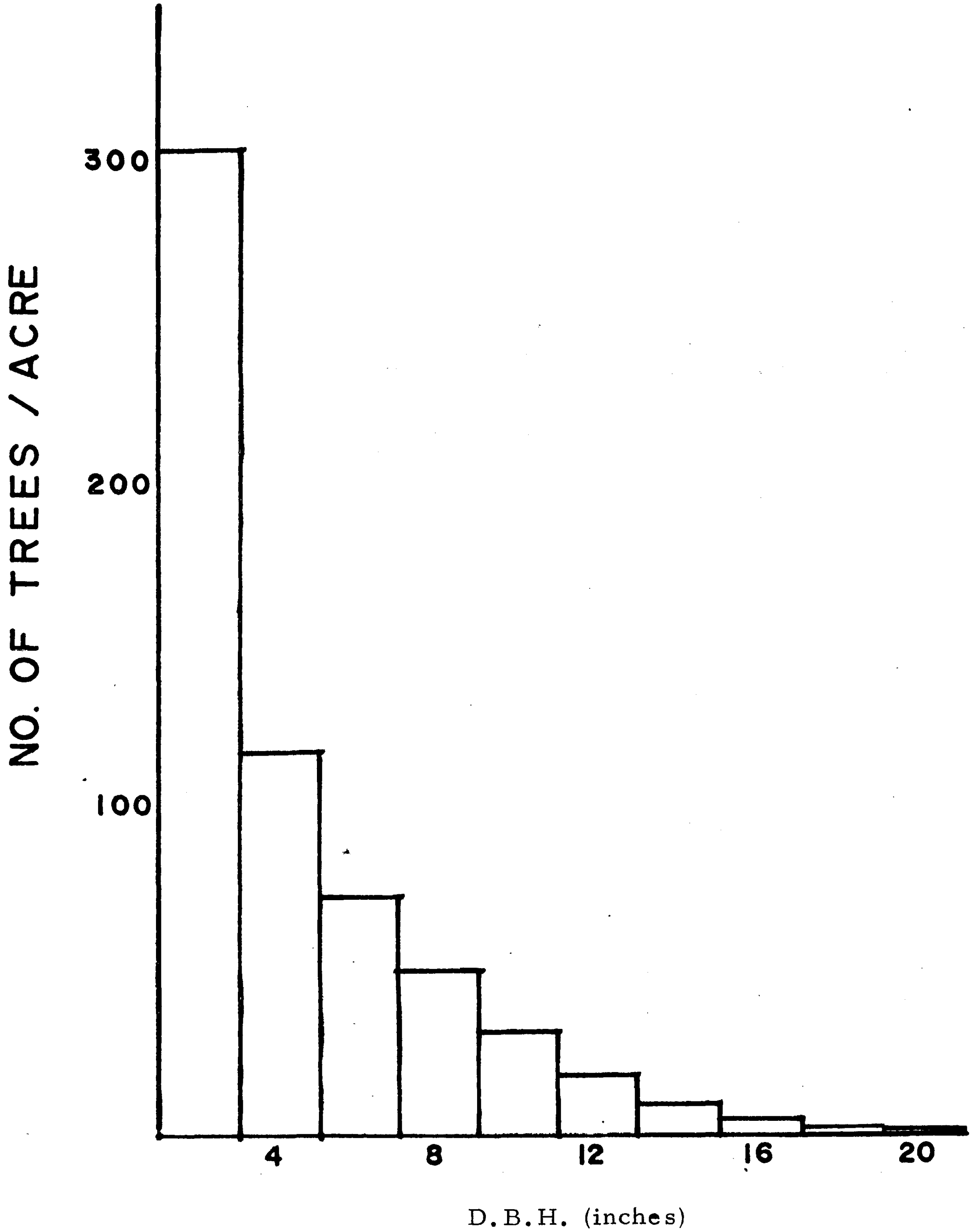

Figure 3. -- Average stand table for upland oak (Schnur) site 70.
All age classes combined (age 10.....100).

stand table for ages 10 to 100 years for site index 70. The stand table has the characteristic J-shape of an uneven-aged forest. The stand is very much like the optimal distribution from Adams' and Ek's (1974) simulation work (Table 2).

Research Needs

The research emphasis in dealing with uneven-aged forests has been on the development of structural goals that will provide periodic harvest of nearly equal volume--that is, forest management. Far less is known about the growth behavior of individual species. Most silvicultural research has been limited to the reproduction that follows harvest cutting. I know of only one study (Gibbs on the Fernow) that deals with individual trees growth in an uneven-aged stand.

The growth losses resulting from converting an even-aged stand composed of poplar, cherry, ash, and red oak, to an uneven-aged stand of maple and beech could be substantial. In the upland hardwood forests of eastern United States, maple is intermediate in growth rate and beech is very low and occupies the more growing space that its common associates.

Tree age of understory trees in uneven-aged stands is rarely known or measured. Studies in even-aged stands have shown that tree age is an important growth variable and it should be even more important in uneven-aged stands. Leak recognizes this in his discussion of the survivorship curve. Tree size is not always a good indicator of tree age (Gibbs 1963).

In addition to age, some measure of growth potential for saplings and poles is needed. Most vigor classes have applied to overstory trees.

Some measure of site quality for uneven-aged stands is needed. The conventional site index for even-aged stands cannot be used for uneven-aged stands. Periodic growth is one possibility when a stand has a balance diameter distribution but some method of site quality appraisal is needed for stands that are not balanced.

Standard forest inventories must be improved to include growth factors such as tree age, growth potential of understory trees, and a measure of site quality.

In summary, there is a need for more research in stand dynamics and development and the effects of cutting on growth and yield.

Is there no alternative to clearcutting than the q-factor and beech-maple?

TABLE 2. A comparison of Adams and Ek's (1974) optimal diameter distributions for uneven-aged stands with an average stand table for even-aged stands (all age classes combined) Schnur.

	Adams and Ek 1/	Schnur Site 70
Diameter Class	No. Trees	No. Trees
6	103.6	73.4
8	43.1	50.5
10	27.6	32.7
12	22.1	18.7
14	6.7	9.2
16	2.3	4.1
18	1.1	1.0
20	---	.2
Total trees	206.5	189.8
Basal area/acre	80.0	82.3

1/ Stocking level constraint = 80 basal area/acre)

Literature Cited

Adams, D. M., and A. R. Ek. 1974. Optimizing the management of uneven-aged forest stands. Can. J. For. Res. 4:274-287.

Gibbs, Carter B. 1963. Tree diameter a poor indicator of age in West Virginia hardwoods. USDA For. Serv. Res. Note NE-11. 4 p. illus. Northeast For. Exp. Sta.

Gingrich, Samuel F. 1967. Measuring and evaluation stocking and stand density in upland hardwood forests in the Central States. For. Sci. 13:38-53.

Meyer, H. A. 1942. Methods of forest growth determination. Bull. 435. Penn. St. Col., School of Agric. 93 p.

Schnur, G. L. 1937. Yield, stand and volume tables for even-aged upland oak forests. U.S. Dept. Agric. Tech. Bull. 560, 88 p.

Trimble, G. R. 1965. Species composition changes under individual tree selection cutting in cove hardwoods. USDA For. Serv. Res. Note NE-30. 6 p., illus. Northeast. For. Exp. Sta.

____________. 1970. 20 years of intensive uneven-aged management. USDA For. Serv. Res. Pap. NE-154. 12 p., illus. Northeast. For. Exp. Sta.

ECONOMICS OF EVEN-AGED AND UNEVEN-AGED SILVICULTURE AND MANAGEMENT IN EASTERN HARDWOODS

by

H. Clay Smith and Paul S. DeBald[1/]

We are going to discuss the state of the art concerning the economics of even-aged and uneven-aged silviculture and management harvest systems as practiced in eastern hardwoods. We will summarize the pertinent literature and present a theoretical comparison of the two systems. For this paper clearcutting will be the form of even-aged silviculture and individual tree selection the form of uneven-aged silviculture.

Economics simply is the art of making a choice. One economic principle sums it all up: You can't have your cake and eat it, too. Notice that we have said nothing about dollars and cents. That is because money matters are unimportant in many dicisions we make and each of us makes many choices each day. That makes each of us an economist.

Consider the biggest choice most of us have ever made--the choice of a wife. Not many of us married our wives for their money. And, as foresters, I doubt that any of our wives married rich. No, each of us had other reasons.

There are many different factors to consider in selecting a wife from an almost infinite supply of possible wives. Obviously, no single standard or simple set of rules of thumb can apply. You can almost say the same for choosing a management system in eastern hardwoods. There is no easy answer. If you are looking for an easy answer, you will not find it here. There are too many types of forest and site conditions for there to be one best way (Smith 1972, 1975). What you will find is a summary of what we have found. We will leave the choice to you.

To our knowledge, in this country, there are no long-term comparisons of the even-aged and uneven-aged systems using actual field data. Where comparisons have been made, they are largely theoretical and are usually case studies. A few papers have been written using actual data for the uneven-aged

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system. More information of this type is needed for both systems. Also most of these studies are aimed at timber production--by foresters for foresters. Usually they do not consider the "other factors" that seem to trouble the general public.

To the general public even-aged practices have been closely associated with the so-called devastation of our forests that occurred around the turn of the century. Today even-aged silviculture and management are widely advocated within the forestry profession. But foresters have suddenly found themselves hard pressed to have this system accepted by the public. Many of the factors that influence the decision to use even-aged management or uneven-aged management rest with society, ownership and management. As Gould (1975) concluded, foresters must consider those factors when deciding which system to use or they will become extinct like dinosaurs.

Literature

We have summarized our literature review in Table 1, listing a number of factors that influence the choice between the even-aged and uneven-aged systems. Many of the studies that we reviewed presented a single point of view--one way or the other. And so we used a + and - rating to show a consensus, factor by factor. For some factors we found no real consensus, and even some question. We rated these, appropriately, with question marks.

Throughout the literature opinions have been reported concerning the attributes of even-aged and uneven-aged systems. As Trimble et al (1974) generalized--even-aged systems are more profitable; within an even-aged system, large clearcuts are more profitable than smaller ones and shorter rotations yield higher rates of return than longer rotations. Within an uneven-aged system a low rate of return is correlated to larger size harvest trees and a high rate of return is correlated with smaller trees.

Species Composition--Reproduction

Perhaps the most unanimous conclusion throughout the literature is that an even-aged harvest system favors a high proportion of faster growing, higher value, light requiring species such as black cherry, black walnut, yellow-poplar, red oak, yellow birch, basswood, paper birch, white ash (Filip 1973; Doolittle 1966; Trimble 1965, 1973; James 1974). Likewise an uneven-aged system results in the slow growing, lower value, tolerant species, primarily sugar maple (high value), beech, hemlock and spruce (Filip 1973; Tubbs 1968; Leak et al 1969; Trimble 1973; Harkin 1972; Metzger and Tubbs 1971).

From an economic view based on the species mixture and high proportion of more valuable species, a form of even-aged silviculture is favored for species development. That supposes, of course, that we intend to manage for high quality sawlogs.

Table 1.--Tabular summary of the even-aged versus the uneven-aged system from and economic view[2].

Factors	Even-aged	Uneven-aged
Species composition	+	-
Growth		
Diameter growth	?	?
Volume growth	+	-
Quality (value) growth	?	?
Regulation		
Harvest cuts	+	-
Pre-harvest activities	?	?
Markets		
Limited products	-	+
Multiple products	+	-
Continuous	+	-
Occasional	-	+
Logging		
Road construction costs	--	--
Road maintenance	?	?
Other logging costs	+	-
Residues	-	+
Tree logging injuries	+	-
Water	+	-
Wildlife	+	-
Aesthetics	-	+
Monetary return	+	-

2/ We use + and - to show a consensus rating. A question mark indicated uncertainty, -- indicates no apparent difference.

Growth

Diameter growth.--There is uncertainty as to the difference in diameter growth for stands managed with even-aged management or uneven-aged management cutting practices. However, nearly all agree that any growth differences as a result of using one system or the other is too small to consider (Smith 1962; Meyer et al 1961).

Volume growth.--Though diameter growth may be uncertain, changes in species composition can affect volume growth. Local volume tables from the Fernow Experimental Forest illustrate this point. International 1/4-inch board foot volumes to an 8.0-inch top d.i.b. for 24-inch d.b.h. trees on a good site were as follows:

Yellow-poplar	662	Beech	445
Black cherry	573	Sugar maple	541
Basswood	535	Red maple	538
White ash	597		

Thus, even though differences in diameter growth may be slight, corresponding differences in volume growth can be quite large.

Quality (value) growth.--No literature exists that compares quality growth change within an even-aged system to that within an uneven-aged system. Yet timber quality is a big key to timber value (Trimble and Mendel 1969; Mendel and Trimble 1969; Grisez and Trimble 1972; Mendel et al 1973). Studies that incorporate timber quality development in even-aged stands need to be undertaken. Such studies in uneven-aged stands on the Fernow Experimental Forest have been reported recently (McCauley and Trimble 1972, 1975).

Regulation

It is more difficult and costlier to regulate stands cut with an uneven-aged cutting practice than an even-aged practice (Smith 1975; James 1974; Roach 1974; Frothingham 1915). However, when considering intensive even-aged stand practices such as cleanings, crop-tree selection, grapevine control, precommercial and commercial thinnings, the administration problem and costs may be significant. The degree of intensity is, of course, important. And because the desired degree of intensity depends on individual stand conditions and management objectives, it is difficult to make comparisons between the two systems.

In harvest cuts, area control is easier to apply than "q", volume control or some other structural control. Therefore even-aged regulation is favored for harvest cuts. But an even-aged stand is harvested only once in each rotation and a series of periodic cuts must precede this harvest. Thus, the problems of regulating even-aged stands between harvest cuts can be as difficult as regulating uneven-aged harvest cuts.

Markets

The expansion and changing of markets to include more species and smaller trees has greatly increased the profitability of even-aged harvest systems (Trimble 1968). And where continuous markets for multiple products are readily available, many of the activities within an even-aged system can be carried out as commercial operations. But in areas where such markets are lacking, some of these activities must be carried out with lower returns or even losses.

Uneven-aged silviculture and management, on the other hand, is adaptable in areas that lack markets for multiple products--say one that lacks a pulpwood market. There, we can adapt our uneven-aged activities to fit sawtimber trees and manage to live with the poletimber. Too, the uneven-aged system provides a holding-reserve that we can dip into to take advantage of occasional market surges and still recover our target tree-size distributions.

Logging

Logging costs vary with given situations. Every logger has problems and situations different than his neighbor. Discussing comparative logging costs boggles the mind.

Frothingham (1915), Harkin (1972), and Gould (1974) reported an increase in logging cost when changing from an even-aged to uneven-aged system. Also with an even-aged system, more effective, labor-saving equipment can be used, the length of time between moves can be extended, and larger volumes per unit area can be removed (Trimble 1968; James 1974). Filip (1967) evaluated the initial harvest cost for selection and commercial clearcutting in unmanaged old-growth northern hardwood stands. Labor costs were uniform for each--4.5 man hours per cunit.

While, in general, the cost per thousand varies, it is our opinion that logging costs per thousand could be slightly less with an uneven-aged system because, in practice, larger stems are usually cut, and relatively fewer marginal smaller trees need to be cut. With an even-aged system and where more smaller trees are to be cut, the situation becomes more acute--logging small logs increases cost (Roach 1956).

Road construction costs.--James (1974) and Gould (1974) state that initial logging road costs for an even-aged system are less than the road costs for an uneven-aged system. This statement needs to be qualified. It obviously presumes the need to meet some specific timber-cut requirements, e.g. the supply requirement for a mill. Because the average cut per acre is higher with an even-aged system, fewer acres would need to be cut. To meet the same mill supply requirement under an uneven-aged system, more acres would need to be cut.

Regarding a particular stand, the above is not necessarily true. Our need is to manage the stand, not to supply a mill per se and in practice, the initial cut is usually a conditioning cut. We plan a road system at that time and begin to build it. In subsequent cuts--either thinnings under even-aged systems or harvest cuts under uneven-aged systems--the same roads can be used. Maintenance costs could be similar. The exception here, of course, would be a stand whose present condition suggests an immediate harvest cut under an even-aged system. Road maintenance may not be as high.

Roads should be planned for the area as a whole and for the type of equipment to be used. Thus, in the long run the type of harvest system should have little influence on the road costs and for similar site conditions the costs/mile for road construction should be similar.

Logging residues.--Martin (1975), Porterfield and von Segel (1975) found that logging residues in Appalachia and Arkansas were higher for clearcutting practices than selection (564 and 441 cubic feet per acre in Appalachia and 338 and 231 cubic feet per acre in Arkansas).

The residue picture depends largely on markets. If only sawlog products are marketable, the residue from clearcuts increases drastically. These problems could be avoided with an uneven-aged system by delaying cutting in the lower diameter classes--though we presently have no data concerning effects of marking or not marking in the 5- to 10-inch d.b.h. class in selection cuts.

Tree logging injuries.--Generally injuries to residual trees are higher for an uneven-aged system (Doolittle 1966). Porterfield and von Segel (1975) examined 20 selection and 14 clearcut areas in Arkansas. They reported much higher residual damage in the selection areas. Others have reported similar results--10 to 12 square feet of basal area per acre for selection and partial cut stands in West Virginia and New York (Trimble et al 1974; Nyland and Gabriel 1971).

Water and Wildlife

Yield and quality from the water standpoint favors the even-aged system (Trimble 1965), but increased yield is only for a short period. However, it is not the cutting practice that influences water quality, it is the road construction and maintenance (Trimble et al 1974). Road problems can be as acute in logging 2,000 M bd. ft. per acre or 20,000 M bd. ft. per acre.

Considering wildlife, the trend is toward an even-aged system (Trimble 1965; Resler 1972). Pengelly (1972) stated that tree monocultures tend to produce animal monocultures with disastrous results. However, technical documentations on the diversity of wildlife use in even-aged and uneven-aged systems are very limited (Trimble et al 1974).

Aesthetics

Aesthetics is the main factor that may force the foresters to modify clearcutting techniques. As a rule, conservation groups and the general public are very much opposed to clearcutting. They will, however, accept uneven-aged practices (Porterfield and von Segel 1975; Echelberger 1975). This is especially true when involved with scenic and heavily populated areas. And this is rather ironic because, through most of an even-aged rotation, the thinnings are not really all that different in appearance from uneven-aged harvest cuts. It is the even-aged harvest cuts that upset people.

Monetary Returns

Only a few studies have been made to compare the monetary returns from the even-aged system with those from uneven-aged systems. And only a couple of those were based on actual stands: Voevoda (1970) and Nekrasov (1972). They reported that in Siberia, after 50 years, an uneven-aged system returned 1.5 to 1.9 times more cash than an even-aged system.

Theoretical approaches, while still few, are more common. Mayer (1969) in Austria compared models of the two systems and reported uneven-aged to be better in terms of labor requirements, costs, and returns. On the other hand, Trimble and Manthy (1966) found that an even-aged system was more profitable in a simulated Appalachian hardwood forest--1.5 to 2 times more profitable depending on the products and application of cutting practices.

Walker (1955) estimated value yields in managed and unmanaged even-aged and uneven-aged forests. His conclusions tended toward the middle of the road. He reported that: Uneven-aged forests have a higher growing stock value than even-aged forests and that uneven-aged forests produce higher annual yields in dollars than even-aged forests. But, he also points out that even-aged forests yield a slightly higher return on investment. Too, he states that market prices make a big difference, i.e., market prices that favor the production of high quality sawlogs or veneer stock:

a. Make long rotations practicable.
b. Favor uneven-aged management over even-aged management.

Market prices that do not reflect positive value increases with tree size increases:

a. Demand short rotations.
b. Favor even-aged management over uneven-aged management.

Several references state that a long-term even-aged system has the potential for growing more and better timber on the same acre of land (Trimble and McClung 1966; Trimble 1968; Frothingham 1915). Doolittle (1966) reported a gross monetary return in stumpage of $15/acre annually for Appalachian cove hardwoods with even-aged management, and $10 per acre with uneven-aged management.

On the short-term side, Filip (1967) reported the initial net returns for selection and commercial clearcutting in a northern hardwood study and showed that profits were about $9 and $13.50 per cunit respectively. However, these results do not reflect long-term costs and returns for various systems of forest management.

Also monetary returns were reported for Appalachian hardwood stands managed with a single system--uneven-aged. After 12 years of selection cutting on two site classes, the stand values increased $76/acre for a fair site (oak site index 60) and $233/acre on a high site (oak site index 80) (McCauley and Trimble 1975). Similar 20-year results from two 60-year-old Appalachian woodlots indicated that the landowner could earn about 6 percent rate of return during stand age 40 to 60 period (McCauley and Trimble 1972).

A Theoretical Comparison of Even-aged and Uneven-aged Management Systems

We have developed a theoretical example, comparing even-aged and uneven-aged management systems in hardwoods. For our example we chose to compare the volume and value yields that we might expect under the two systems. We also chose to make the comparisons as simple as possible.

Our example deals with young and intermediate-aged upland hardwoods. Stands of this kind are widespread and prime possibilities for initiating timber management. Yet, because they contain large numbers of young trees they present some important questions. Should we grow these young trees to maturity as stands or should we grow them to maturity as individual trees? How long will it take either way? Will either give us a bigger volume yield over time? If so, how much bigger? And how about value yield? In short, which seems better--an even-aged or uneven-aged management system?

Gingrich (1971) gives us a lot of clues for answering these questions. He provides schedules of yields per acre from stands managed as even-aged after initiating management at various ages. Roach and Gingrich (1968) state that good sites should produce 24- to 28-inch sawtimber on a 60- to 75-year rotation, if crop tree growth is maintained by regular thinnings.

And so we set up a theoretical mini-forest consisting of seven 1-acre stands, all with an oak site index of 75. Each stand was even-aged with ages ranging from 10 to 70 years. We chose to use a 70-year rotation with thinnings each 10 years. Initially each acre was unmanaged. We used the Weibull distribution (Bailey and Dell 1973) to develop stand tables for each. We then cut and grew each acre through 10 year periods over a 70-year rotation, by making stand table projections and using Gingrich's yield schedule as check points for both cut and growth.

For comparison we set up a second mini-forest. This one was a single acre and uneven-aged--the average of our 7 even-aged stands. Our management goal for this uneven-aged acre was:

Q = 1.4
Maximum diameter = 24 inches
Basal area/acre in sawtimber = 65 square feet

We cut and grew this acre through 10-year periods, again by making stand table projections. We selected cut trees with an eye on our management goal. For growth rates we used, by diameter class, the average diameter growth on our even-aged acres reduced by 25 percent to account for the fact that uneven-aged stands usually carry higher densities than even-aged stands.

In all of our projections we assumed that markets were readily and continuously available for both pulpwood and sawlogs.

Volume yield.--Our first comparison concerned sawtimber development. We summed and averaged the even-aged acres to find (at 10-year intervals) the inventory, cut, and residual board foot volume per acre within the even-aged system. Each 10 years, two of the acres contained no sawtimber volume and one acre was cleared completely. This accounts for much of the difference shown in Table 2.

Note that the cut per acre averages higher for the even-aged stands than it does for the uneven-aged stand; however, the uneven-aged stand carries two to three times the volume. For that reason our uneven-aged stand shows a slightly higher yield per acre per year than does the even-aged stand (Table 3).

Value yield.--Our next comparison involves value yield. Here we assume two value schedules--one high and one low, based on percent of volume by log grade and on dollars per M. These values portray differences in species composition. We applied these value schedules to both management

Table 2.--Volume Yield -- Board feet per acre [3/]

Year	Even-aged stands			Uneven-aged stands		
	Inventory	Cut	Residual	Inventory	Cut	Residual
1975	3,710	1,870	1,840	3,710	263	3,447
1985	3,130	1,537	1,593	6,552	1,655	4,897
1995	3,956	1,753	2,203	7,991	1,943	6,048
2005	5,234	2,284	2,950	9,310	1,939	7,371
2015	6,634	2,749	3,885	10,736	1,842	8,894
2025	7,403	3,157	4,246	12,506	2,219	10,287
2035	7,790	3,544	4,246	14,124	2,693	11,431
Average	5,408	2,413	2,995	9,276	1,793	7,482

3/ International 1/4-inch log rule

Table 3.--Comparison of Volume Yield

(Board feet per acre)

	Year	Board feet
Even-aged:		
Residual stand	2035	4,246
Plus total cut	1975 - 2035	16,894
Total		21,140
Minus the original stand	1975	3,710
		17,430
or 290 board feet per acre per year		
Uneven-aged management:		
Residual stand	2035	11,431
Plus total cut	1975 - 2035	12,554
Total		23,985
Minus the original stand	1975	3,710
		20,275
or 338 board feet per acre per year		

systems. We assumed also that marking cost, overhead cost, and taxes would be similar for each of the two systems in our example. We were treating each acre at equal intervals and even-aged thinnings were for the most part much like the uneven-aged marking.

In terms of total value yield our even-aged system was somewhat better than was the uneven-aged system, using either value schedule. This, despite the fact that each year one or two of the young even-aged acres had to be thinned at a loss (we used a cost of 1 cent per diameter inch for killing small trees).

Comparing the cash flows from our cuts, we find again that the even-aged system has an edge over the uneven-aged system (Table 4).

Note that the returns from the uneven-aged system are steady after the first cut and until late in the time period--we needed to fill in the larger diameters for our reverse J. The jump in uneven-aged value shows that we are almost, but not quite, there. Note, too, that after the first 30 years, returns from the even-aged system pick up considerably. This is where we begin to replace unthinned, unmanaged stands with thinned, managed ones.

Let us look now at one of the old standard economic measures--present net worth. In this calculation of present net worth, we simply discount back to right now the value of each cut and that of the residual stand. In our example, we used a 6 percent rate of compound interest (Table 5).

Table 4.--Cash Flow Per Acre

Year	Low value schedule: Even-aged	Low value schedule: Uneven-aged	High value schedule: Even-aged	High value schedule: Uneven-aged
1975	$19.25	$ 5.37	$ 48.60	$ 11.07
1985	17.98	26.40	42.63	50.32
1995	19.29	30.44	46.47	62.33
2005	28.61	31.37	62.26	77.23
2015	39.95	32.09	118.36	94.88
2025	52.59	39.97	172.19	123.80
2035	63.20	49.39	220.37	157.35
Total	$240.87	$215.03	$710.88	$576.98

Table 5.--Present Net Worth Per Acre[4/]

(Dollars)

	Low Value: Even-aged	Low Value: Uneven-aged	High Value: Even-aged	High Value: Uneven-aged
Cut	$48.94	$41.85	$125.27	$92.76
Residual stand	2.13	6.52	5.02	20.49
Total	51.07	48.37	130.29	113.25

This table tells us a lot: That the value of our cut accounts for most of our present net worth regardless of management system; that the discounted values of our residual stand, while they show relatively big differences between systems, do not add much to present net worth. The differences in residual stand values between the systems, by the way, tend to re-emphasize the fact that the uneven-aged system gives us reserve financial power that we can use at opportune times to take advantage of changes in market prices.

4/ At 6 percent compound interest.

Most important, this table shows us that in our example the differences in monetary returns between the two systems are not all that great. Percentage wise, they range from 5 percent with our low value schedule to 13 percent with our high value schedule.

Granted, we might well find these differences sufficiently attractive and, if we based our choice strictly on monetary factors, we would obviously go with the even-aged system in our example. But outside factors often influence our choices--factors such as those that we discussed earlier. If that is the case, our computations will at least show us how much we would be giving up, financially, if we chose to use the uneven-aged system. The same is true in many real world situations and often economics other than the economics of strictly dollars and cents will help us to make the choice.

In Summary

Choosing a harvesting system is a tough job. In making the choice, we must consider public pressures and priorities as well as stand, site, and environmental conditions. Each of these varies with time and location. Thus, no one harvesting system can be applied across the board.

Rather, the choice of system must be made to fit individual stands and individual situations. In making the choice we need to consider a large number of factors, some of which are dictated by the stand itself and some which are imposed from the outside. One of these factors, and not always the most important, is financial return.

All of the factors that we have discussed here affect the choice of a harvesting system. It is up to us--each in our own mind--to weigh the impact that they have on a given stand and make our choice as we see fit. And so, it is possible that each of us viewing things differently could make a different choice for a given stand.

That's what makes choosing a harvesting system an economic problem: An economic problem is finding the answer to the question, "how can I best do the thing that I need to do, using the things that I have to do them with?" The answer is not always in terms of dollars and cents. Often it is in terms of common sense.

Literature References

Bailey, Robert L., and T. R. Dell. 1973. Quantifying diameter distributions with the Weibull function. For. Sci. 19:97-104.

Doolittle, W. T. 1966. Some implications of even-aged management and the production of Appalachian hardwoods. For. Prod. J. 16:25-28.

Echelberger, Herbert E. 1975. Public reaction to different timber harvesting practices. Proc. Logging Residue Conf., Morgantown, VW., June 4-6, 1975. (In press).

Filip, Stanley M. 1967. Harvesting costs and returns under four cutting methods in mature beech--birch--maple stands in New England. USDA For. Serv. Res. Pap. NE-87; 14 p.

____________. 1973. Culturing and culture methods for managing northern hardwoods in the Northeastern United States. USDA For. Serv. Gen. Tech. Rep. NE-5; 5 p.

Frothingham, E. H. 1915. The northern hardwood forest--its composition, growth and management. USDA Agr. Bull. 285; 80 p.

Gingrich, Samuel F. 1971. Management of young and intermediate stands of upland hardwoods. USDA For. Serv. Res. Pap. NE-195; 26 p., illus.

Gould, Ernst M. 1974. Clearcutting and economics. <u>In</u> Clearcutting--a view from the top. p. 156-167. Horwitz, Eleanor C. J., 1974. Acropolis Book Ltd., Washington, D.C. 179 p.

____________. 1975. Aesthetics and land use. Proc. Logging Residue Conf., Morgantown, WV., June 4-6, 1975. (In press).

Grisez, Ted J., and Joseph J. Mendel. 1972. The rate of value increase for black cherry, red maple, and white ash. USDA For. Serv. Res. Pap. NE-231; 26 p.

Harkin, D. A. 1972. Clearcut or selection. What kind of cost? J. For. 70:420-21.

James, Lee M. 1974. Clearcutting in the public forests of the North Central region. <u>In</u> Clearcutting--a view from the top. Horwitz, Eleanor C. J. 1974. p. 45-46. Acropolis Book Ltd., Washington, D.C.

Kochenderfer, J. N. 1975. The percentage of area in roads and landings on logged areas in the Central Appalachians. USDA NEFES. Final Report on file, Timber and Watershed Laboratory, Parsons, EV.

Leak, W. B., and S. M. Filip. 197_. Uneven-aged management of northern hardwoods in New England. U npublished manuscript.

_____________, Dale S. Solomon, and Stanley M. Filip. 1969. Silvicultural guide for northern hardwoods in the Northeast. USDA For. Serv. Res. Pap. NE-143; 34 p.

Martin, A. Jeff. 1975. Volume of logging residue available for harvest in Appalachia. Proc. Logging Residue Conf., Morgantown, WV., June 4-6, 1975. (In press).

Matics, H. E. 1975. Economics of harvesting total trees and residue materials. Proc. Logging Residue Conf., Morgantown, WV., June 4-6, 1975. (In press).

Mayer, H. 1969. Long term rationalization of forest enterprises by way of silviculture. Allg. Forstzeitschr 1968. 23:40-45+. In For. Abstract-1969. 30:339 Abs. No. 2893.

Mendel, Joseph J., and George R. Trimble, Jr. 1969. The rate of value increase for yellow-poplar and beech. USDA For. Serv. Res. Pap. NE-140, 27 p.

_____________, Ted J. Grisez, and G. R. Trimble, Jr. 1973. The rate of value increase for sugar maple. USDA For. Serv. Res. Pap. NE-250; 19 p.

Metzger, Frederick T., and Carl H. Tubbs. 1971. The influence of cutting method on regeneration of second-growth northern hardwoods. J. For. 69:559-564.

Meyer, H. Arthur, Arthur B. Recknagel, Donald D. Stevenson, and Ronald A. Bartoo. 1961. Forest Management. Second Edition; 282 p. The Ronald Press Co., New York.

McCauley, Orris D., and George R. Trimble, Jr. 1972. Forestry returns evaluated for uneven-aged management in two Appalachian woodlots. USDA For. Serv. Res. Pap. NE-244; 12 p., illus.

_____________, and George R. Trimble, Jr. 1975. Site quality in Appalachian hardwoods: the biological and economic response under selection silviculture. USDA For. Serv. Res. Pap. NE-312; 22 p., illus.

Nekrasov, M. 1972. Comparison of the economic effectiveness of principal felling. Lesnaya Promyphlennost. Forestry Abs. 1973. 34:78. Abs. #880.

Nyland, Ralph U., and William J. Gabriel. 1971. Logging damage to partially cut hardwood stands in New York State. AFRI Res. Pap. 5; 38 p.

Pengelly, W. L. 1972. Clearcutting: detrimental aspects for wildlife resources. J. Soil and Water Conserv. 27:255-258.

Porterfield, Richard L., and William W. Von Segel. 1975. Utilization efficiency during harvesting and primary manufacturing in Arkansas. Final Report. General Forestry Association Project. Wood Utilization Survey--Arkansas. SE Area, State & Private Forestry, USFS, Atlanta, GA. 53 p.

Resler, Rexford A. 1972. Clearcutting. Beneficial aspects for wildlife resources. J. Soil and Water Conserv. 27:250-254.

Roach, B. A., and Gingrich, S. F. 1968. Even-aged silviculture for upland central hardwoods. USDA, Agr. Handbook 355; 39 p.

____________. 1956. Logging costs for central hardwoods. South. Lumberman 193:53-54.

____________. 1965. Is even-aged management practical for small woodlands in the Central States? Rep. from Proc. SAF. Detroit, MI., 151-154.

____________. 1974. Selection cutting in group selection. St. Univ. NY, Coll. of Env. Sci. and For. AFRI Misc. Pap. #5; 9 p.

Smith, David M. 1962. The practice of silviculture. 578 p. John Wiley and Sons, Inc., New York.

____________. 1972. Clearcutting, selection cutting, and some pathways between. Conn. Woodlands 36:3-7.

____________. 1975. Dangers in over-simplification of forestry. North. Logger and Timber Proc. 23:12, 13, 28.

Trimble, G. R., Jr. 1965. Species composition changes under individual tree selection cutting in cove hardwoods. USFS Res. Note NE-30; 6 p.

____________. 1968. Research findings on even-aged management in hardwoods in the Appalachian area of the Central States. Monongahela N. F. Timber Management Conf. Proc. 15 p.

Trimble, G. R., Jr. 1973. The regeneration of central Appalachian hardwoods with emphasis on the effects of site quality and harvesting practice. USDA For. Serv. Res. Pap. NE-282; 14 p.

____________, and Robert S Manthy. 1966. Implications of even-aged management on timber. In Trends from Selection Cutting to Even-aged Management. Soc. Am. For., Allegheny Sect. Proc. 1965: 62-75.

____________, and Joseph J. Mendel. 1969. The rate of value increase for northern red oak, white oak, and chestnut oak. USDA For. Serv. Res. Pap. NE-129; 29 p.

____________, and Lester McClung. 1966. Clearcutting profitable. WV. Conserv. 30:2-4.

____________, Joseph J. Mendel, and Richard A. Kennell. 1974. A procedure for selection marking in hardwoods combining silvicultural considerations with economic guidelines. USDA For. Serv. Res. Pap. NE-292; 13 p., illus.

____________, James H. Patric, John D. Gill, George H. Moeller, and James N. Kochenderfer. 1974. Some options for managing forest land in the central Appalachians. USDA For. Serv. Gen. Tech. Rep. NE-12; 42 p., illus.

Tubbs, Carl H. 1968. Natural regeneration. USDA For. Serv. NCFES. Sugar Maple Conf. Proc. 75-81. St. Paul, MN.

Voevoda, I. N. 1970. Evaluating the effectiveness of felling, taking account of the time factor. Lesn. Prom. 1970(2), (26-9). In For. Abs. #7009, 1970. 31:830.

Walker, Nathaniel. 1955. Volumes and values of normal growing stock and yields in managed and unmanaged even- and uneven-aged forests. Penn. State Univ. School of Forestry. Unpublished Thesis. 113 p.

REGULATION OF CUT

by

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Introduction

Regulation of cut is a secondary term for yield determination in the multilingual Forestry Terminology Series, No. 1, Society of American Foresters. It is . . . "the amount of forest produce that may be harvested, annually or periodically, from a specified area over a stated period, in accordance with the objects of management." In the SAF Forestry Terminology, 3rd edition, 1958, regulation is defined as the technical aspects of organizing and maintaining a forest for sustained yield. We normally think more in terms of the latter definition when we think of regulation.

Our objective in regulation is to determine and control the yield of forest products for a future period of time. I feel rather pessimistic about trying to meet this objective in a narrow sense of concentrating on yield. As D. M. Matthews states in his old management textbook, "emphasis too often is on regulation of yield rather than on regulation of the growing stock." To put it briefly, the core of my thesis is that if we leave the proper residual growing stock in uneven-aged management and control the area which we examine and treat each year, the yield will take care of itself.

In the following discussion, I'm concerned primarily with uneven-aged management of stands of tolerant species. The silvicultural system is single-tree selection. The best example is the sugar maple-dominated Lake States hardwood type.

With species mixtures of tolerants and intolerants and varying economic and pathologic rotation ages or sizes, we have a new situation. This will require more guidance from Research if we wish to maintain such mixed stands under uneven-aged management. I don't think we can apply uneven-aged silviculture operationally now. If group selection rather than single-tree selection is the answer for these less tolerant species mixes we have a far more difficult regulation problem. The vast area of mixed hardwoods south of the northern border fringe characterizes this condition.

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In expanding on the above, I want to examine regulation of large private ownerships and public lands where we attempt to optimize the production of timber within the restraints imposed by other uses of the forest and without damage to the environment. This restricts the area to which the discussion applies, but I don't believe we can generalize about small private owners with their widely varying objectives of management.

Most small private owners are not going to be concerned with "even-flow" for their property. However, sustained yield, on a marketing area basis, is achieved regardless of the silviculture involved, if, in total, there is an adequate timber supply for the marketing area. If insufficient wood is offered for sale, the buyers will raise their prices and aggressively go out and convince some owners they should allow their woods to be cut. If wood is offered in volumes greater than the mills' needs, they simply will not buy. Therefore, regulation occurs through the market mechanism of supply and demand. Each individual owner, however, may not regulate his property at all. Where mill capacity exceeds the forest's productive capacity, this balance is less likely to be achieved. Here there is real danger of depletion of the market area wood supply.

Because of the relatively large areas and volumes involved, regulation becomes significant for National Forest lands. Even here, we can only limit the volume sold. We cannot increase the volume sold or cut above what the market will take and we cannot completely control when the timber is cut, after it is sold. Private lands that are owned by processors of the stumpage can be in a better situation. I say <u>can</u> because this situation is a mixed blessing.

Mother nature helps determine what we will market. In fact, I believe our carefully laid plans are more subject to the whims of nature than we care to admit. For example, virtually the entire Fiscal Year 1975 Sale Program on the Allegheny National Forest was storm damaged timber, concentrated on a small part of the Forest. The areas being harvested have no relation to the planned harvest for the year. Similarly, Dutch elm mortality is causing significant changes in the areas harvested and in the stocking and structure of residual stands on the Nicolet National Forest.

One further generalization. To really do a quality job of management, permanent access and good roads over all portions of the property are a must.

Area Classification

The first step in regulation of any property is to classify the area to be managed. As an example I present the Forest Service classification (FSM 2412.1, Exhibit 1). Among the various land classes, we ultimately get down to "regulated commercial forest land." This is divided into standard, special and marginal components. Within each of these, the area of each timber

EXHIBIT 1

Standard Land Classification
for Timber Management (M acres)

Total Land Ownership		498.9
Water	8.4	
Land		490.5
Nonforest	8.0	
Forest		482.5
Unproductive	1.0	
Productive		481.5
Reserved or Deferred	47.0	
Commercial Forest Land		434.5
Unregulated		
Experimental Forests & Plots	5.4	
Recreation Sites	1.3	
Special Interest Areas	.2	
Isolated Tracts	14.	8.3
Regulated		426.2
Marginal		
Uneconomic now	7.6	
Special Logging Needed	1.2	
Environmental Constraint	18.9	
Special		
Travel Zone	29.6	
Water Zone	29.1	
Other	26.4	112.8
Standard		313.4

type or type group will be determined. For example, we may regulate the northern hardwood type group together. The northern hardwood type treated under the same silvicultural system is a "working group." There could be three working groups of northern hardwoods if the silvicultural systems differed among the standard, special and marginal components of regulated commercial forest land. Each working group is regulated separately. The sum of yields calculated for all the working groups is the yield for the forest.

I mention area classification because it is extremely important to know the area that will be regulated. The tendency generally is to overestimate the area from which regulated yields can be obtained. I believe the basic control must be area treated. The regulated area divided by the cutting cycle sets the target area to be treated each year.

Difference Between Even- and Uneven-aged Management

How does regulation of uneven-aged working groups differ from that of even-aged groups? Even-aged stands have a beginning and an end; and there is a considerable body of data regarding growth and yield. Calculations of yield under various regimes of management are straightforward; and fairly firm yields can be predicted (barring catastrophes). Area control with a volume estimate is relatively simple.

Uneven-aged stands, in contrast, have no beginning and no end. There is sparse data on growth and yield. Stand structure, stocking and species composition affect growth and yield. We do have a supply of very limited empirical data to calculate some mean yields. These could be used to check on calculated yields. However, I question whether we have yet demonstrated the application of the selection system over a long enough time to verify the theory.

A whole body of literature has developed over many years to guide the regulation of even-aged timber, but the direction for uneven-aged regulation is scarce.

Rotation Age - Is it a Usable Concept?

In a word - no! Rotation has no bearing on how regulation will be accomplished. Tree size is the important factor. Management must set tree size and stand structure goals for residual stands. Stand structure is far more important than a theoretical rotation. Structure will determine the proportion of volume harvested in the various size classes. Certainly age is important in its effect on tree size, vigor, quality, and pathology but not in the regulatory aspect.

Cutting Cycle - How Long - Why?

The cutting cycle is related to residual volumes, growth capacity, diameter increment, access, markets, logging technology, the management needs of adjacent even-aged stands, and on public lands, multiple-use needs. Cycles could vary from 5 to 20 years depending on the interaction of all the above factors. Cutting cycles are usually established for an entire property. However, the ultimate refinement would be to abandon cutting cycles and treat each stand according to its own needs. This would require on-site examinations of the stands at frequent intervals - perhaps every five years. A prescription would include a schedule of the year of treatment. The prescriptions would be tabulated by year of treatment and priority of need. An operating plan would be prepared from the tabulation to keep a steady program. In this way, each stand would be treated as needed and cutting would be scattered all over the forest every year. A complete, permanent road system would be needed for successful application. The method would maximize wood yield, but very likely not financial yield.

In the Eastern Region we have a 10-year re-entry schedule for each compartment. After the field examination and a multidisciplinary review of the prescription, all needed treatments are scheduled. These would include thinnings and regeneration cuts in even-aged stands, and selection cuts in the uneven-aged stands or immature even-aged stands that we wish to convert to all-aged condition. The treatments themselves are on a nominal 10-year schedule, but there are wide variations.

In hardwoods on the National Forests we may be too optimistic in our 10-year treatment schedule. A cycle of 15 years, might be better from a workload and logging economics standpoint. However, we are now on a compartment entry basis and short-lived timber types and multiple-use needs on most of our forests make a cycle shorter than 15 years more desirable. With the 10-year re-entry, we will often prescribe "no-cut" to a stand that had a scheduled selection cut in the previous 10-year period; so in essence, we created a 20-year cycle for some stands. At each field examination, we now prescribe either a treatment or another examination. After any treatment, another examination is scheduled. Thus, each stand will have a history of its own and will be kept producing to its highest potential. This provides us with the data to go to individual stand management in the near future.

Potential Yield Determination (Allowable Cut)

"The potential yield for a 10-year period is the maximum harvest that could be planned to achieve the optimum perpetual sustained-yield harvesting level attainable with intensive forestry on regulated areas, considering the productivity of the land ---" (FSM 2415.41). "Potential yield calculations should employ a form of tabular scheduling through time by stand condition, size, or age, reflecting a high level of intensive management. A tabular format similar to an area-volume check or timber RAM report is appropriate. Calculations should summarize periodic timber outputs for at least 1-1/2 rotations to ensure compliance with policy in FSM 2410.3" (FSM 2415.43). These quotes from the Forest Service Manual describe the allowable cut and how to calculate it. The definition can apply to all lands but the method is peculiar to National Forest land.

The difficulty of regulating yield is in proportion to the time horizon involved. Regulation is difficult for the time span of 1-1/2 rotations through which even-flow, or at least smooth changes in harvest should occur on the National Forests. I don't think we now have the yield data to work on this basis.

Bob Schirck has been struggling with this problem in the Monongahela National Forest Timber Management Plan. He believes a whole set of yield tables is needed for each of several site-class and stand structure combinations. These would characterize present irregular stand conditions and show the development to optimum conditions. Below is an example of what might be developed, (Exhibit 2). As time went on, the need for all these tables would decrease until we had only number 16, a yield table for a stand of desired structure for each productivity class.

I agree with Bob on the need for a mammoth amount of yield data to meet Forest Service requirements for regulation with uneven-aged silviculture. I can't get too concerned about a time horizon of 100 to 150 years. Neither can I get concerned with strict even-flow for these lands, especially for uneven-aged management. We foresters tend to leave the real world when we talk about regulation. Even 10 years is a long time horizon for most individuals and with all the uncertainties of life we would do well to accomplish 10-year goals and be satisfied to set broad objectives beyond that time span.

Eventually, as foresters continue treating stands of different condition, they will develop more uniform conditions all over, and they will accumulate empirical yield data. For now, I would think that an estimated yield for the next 10 years should be based on field examination and prescriptions for stands. I think foresters know enough about growth to judge whether a cut will be desirable within 10 years and the approximate volume to cut.

Prescriptions for cutting can only be made if the desired residual stand conditions are known beforehand. This is information the silviculturist must provide the stand examiners. Here is a key point in the whole process of regulation - the proper prescription for each stand. I think we have this for tolerant northern hardwoods. If we are to apply single-tree selection to other less tolerant species combinations, more silvicultural research guidance is needed.

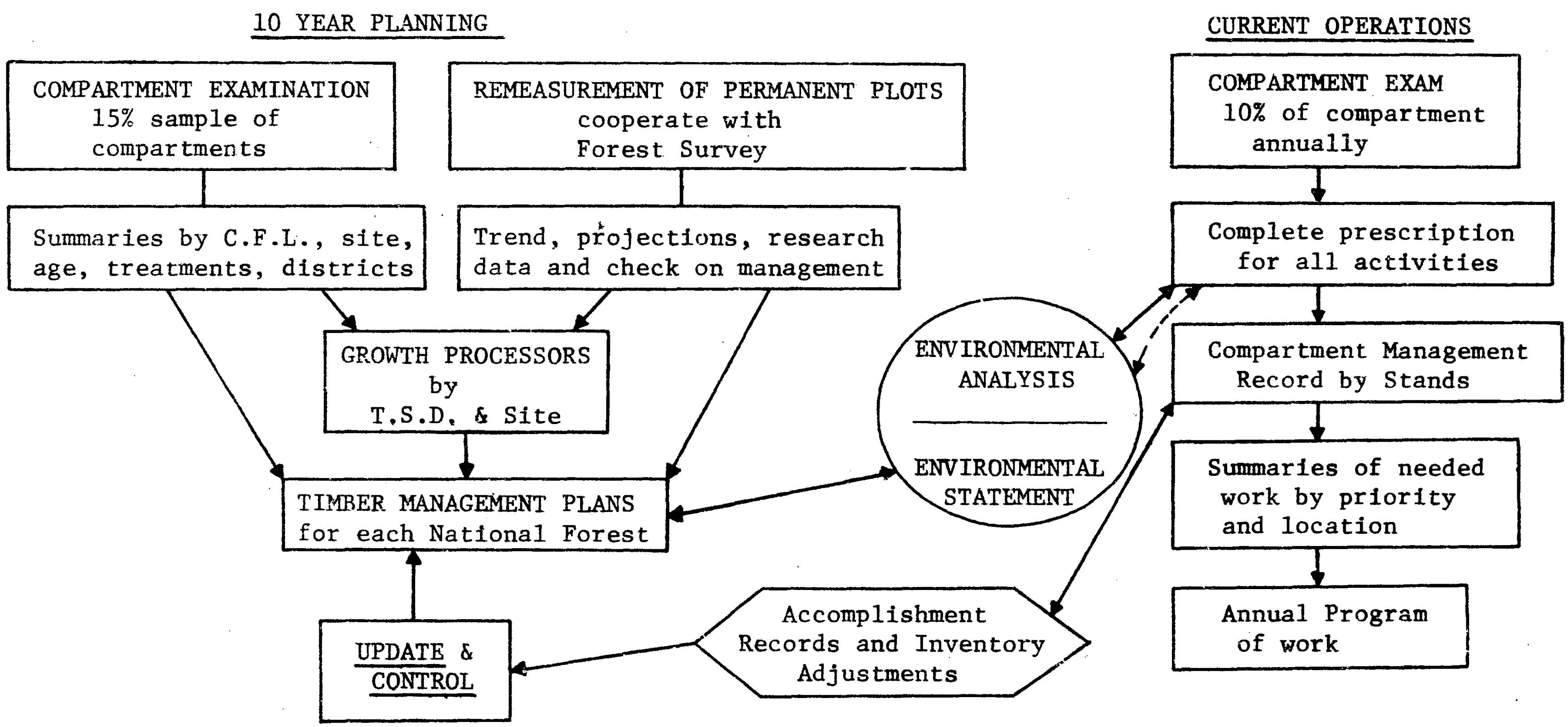
EXHIBIT 2. STAND STRUCTURE FOR WHICH YIELD TABLES ARE NEEDED

Yield Table	STAND CONDITION		
	Heavy Stocking	Medium Stocking	Light Stocking
1	Sawtimber (ST)	Poles (P)	Seed & Saps (SS)
2	ST	SS	P
3	P	ST	SS
4	P	SS	ST
5	SS	ST	P
6	SS	P	ST
7	ST	-	-
8	P	-	-
9	SS	-	-
10	-	ST	-
11	-	P	-
12	-	SS	-
13	-	-	ST
14	-	-	P
15	-	-	SS
16	-		
	desired structure		

DeWilton Smith prepared a chart (Exhibit 3) showing the process of determining and controlling the rate of harvest on National Forest lands in this Region. This applies to all the working groups including those to be managed under the uneven-aged system. This is the process by which we hope to regulate the harvest in the Eastern Region.

The National Forest System provides for the remeasurement of sample plots to obtain growth for planning purposes. I think another important use is to reassure our own people we're not over-cutting the forest. The plots also provide statistical evidence to outsiders just what is happening on the National Forest. It is nice to know what growth was or is, but I still question its direct value in preparing a 10-year cutting budget. Rather, the plots provide the raw material that I believe research might use to define optimum stand structures, to build up empirical yield tables, to make economic analyses, and to develop equations for growth processors.

EXHIBIT 3


10 YEAR PLANNING
CURRENT OPERATIONS
COMPARTMENT EXAMINATION 15% sample of compartments
REMEASUREMENT OF PERMANENT PLOTS cooperate with Forest Survey
Summaries by C.F.L., site, age, treatments, districts
Trend, projections, research data and check on management
GROWTH PROCESSORS by T.S.D. & Site
TIMBER MANAGEMENT PLANS for each National Forest
UPDATE & CONTROL
COMPARTMENT EXAM 10% of compartment annually
Complete prescription for all activities
Compartment Management Record by Stands
Summaries of needed work by priority and location
Annual Program of work
ENVIRONMENTAL ANALYSIS
ENVIRONMENTAL STATEMENT
Accomplishment Records and Inventory Adjustments

Control of Growing Stock

The classic example of the "all-aged" forest structure cannot be expected to be found on small plots; but only for "larger areas." (Cover enough area and you will invariably get a nice "all-aged" curve even though all the individual stands are even-aged). One generally envisions about an acre to provide the complete all-aged structure under the selection system. But, I don't believe we have to continually strive to obtain the theoretical diameter distribution on every acre. The present northern hardwood guides give desired structure by three broad size classes. As far as I can see, these are sufficiently fine objectives to reach over an entire stand or perhaps even "larger" area. The marker with the paint gun should not give first concern to structure in any one spot so much as to obtaining a uniform distribution of desirable residual growing stock at recommended stocking densities. Structure must always be in the background of the marker's mind, however. This is particularly true when marking in an even-aged stand where an attempt is being made to convert it to an uneven-aged stand. A flexible economic size limit is needed too, to provide guidance for the markers. The foregoing is at some variance with classic theory, but I personally cannot accept carrying junk trees for years just to maintain stand structure. When stem quality is high for all trees the structure guides become more important in the marking.

By concentrating on leaving the proper residual stand, we will theoretically never deplete the growing stock or face a reduced yield; unless we cut over the area in the working group in a period of time that is less than the planned cutting cycle. Area control is simple to apply, so there need be no concern about depletion if we follow the plan. A further check is found in the periodic inventory plots that will show the gross long-range trend of forest changes. Of course, this optimistic picture is based on the premise that regeneration will occur and provide the recruits to enter into the stand structure.

When I speak of application of the single-tree selection method of marking I want to emphasize that I include marking within all three of the broad size classes given in the northern hardwood guide. At each entry we are making a regeneration cut and doing cultural work in the smaller size classes.

I must mention some other factors we too often fail to consider when talking about silvicultural systems. The timber marker becomes a key man in successfully carrying out the silvicultural direction for uneven-aged stands. We can talk of doing all these good things but will they be done on the ground? Unfortunately, I'm afraid application could be our weakest link and could sink the system. Marking guides for the selection system (single-tree or group) are more complex than for any other kind of marking and it simply may not be done right. Control over the actual cutting and removal of the marked timber are also major factors in successful application. Let's face the facts; unmarked, premium trees can simply disappear unless an administrator is constantly on the scene. Damage to residual growing stock is also an extremely important factor. Improper marking, cutting unmarked trees, and damaging residual trees can combine to destroy the stand structure and deplete the growing stock, thus wrecking the system even if the silvicultural theory is sound.

In uneven-aged management, I think the management objective should be to place every acre into the desired condition as quickly as market conditions permit. The landowner should respond as quickly as he can to market conditions; offering more timber when demand is high and less when it is low. The key to control is again to leave adequate growing stock with reasonably good structure on the cut area. We have made a start in this direction on the National Forests by accumulating an inventory of prepared sales that are ready for the market if demand arises. I think this is an extremely desirable development.

The previous two sections concerned with allowable cut determination and control of growing stock have been discussed with the assumption that single-tree selection is a silviculturally feasible system. This may not be a valid assumption for the vast area of eastern hardwoods that are not composed of tolerant species. However, a proposed solution to this dilemma is to reduce the size of clearcut (even-aged) openings down below the size where they can be recorded and controlled as separate stands. We then have the group selection variant of uneven-aged management. Unfortunately, I don't believe it is that simple. I think it is an acceptable regeneration method, it is a difficult silvicultural method, and it is an impossible regulatory or management method. This is not to say it should not be used. However, the yields should not be regulated and its use should be restricted to relatively minor portions of large properties where we are forced to compromise technical knowledge with public relations pressures. It seems to me it is also valid on small properties where the manager can mentally grasp the picture of the entire area and can apply a lot of time and effort to intensive management. I am indebted to Ben Roach for his paper, "Selection Cutting and Group Selection" for the last thoughts expressed here.

Size of Sustained-Yield Unit

The logical sustained-yield unit for economic purposes would be a market area or "timber shed." Large private holdings would naturally adopt such units. It could be a ranger district or a combination of several forests in the National Forest System. The National Forest is generally the sustained-yield unit or working circle. I would not like to see it smaller because there is an adverse effect on yield and flexibility. However, the current trend in multiple-use planning indicates that the "unit plan" area within the National Forest will essentially be a sustained-yield unit. Unit plans cover areas from 5,000 to 50,000 acres of similar bio-geo-socio-economic conditions. Land planning by these units is still not completely systematized and timber yield regulation has yet to be fitted into this system of planning.

RESEARCH GAPS AND RESEARCH NEEDS[1/]

by

Robert E. Phares[2/]

A number of important conclusions regarding the applicability of uneven-aged silviculture and management in the eastern forest regions were surfaced by the individual work groups at this workshop. In general, there was almost total agreement that uneven-aged silviculture and management can be used in more situations than it is at present. However, the work groups also found that much additional research is needed to provide the scientific knowledge for uneven-aged silviculture and management to equal that now available for even-aged systems. By summarizing some of these key points in this Proceedings, it is hoped that forest managers will have a better understanding of some of the complexities and uncertainties of uneven-aged silviculture and management, and that forest researchers will have a stronger basis for initiating new research to fill in some of the gaps in our knowledge.

Regeneration

While we have not yet reached glittering perfection, regeneration one way or another is not a great problem with most hardwood types. However, particularly in those many types not considered in the workshop, we have much to learn if uneven-aged management is to be on a firm footing. This would involve the composition and timing of regeneration under various overstories, effect of opening size using group selection, etc.

We need to know much more about the requirements for establishment and development of natural regeneration. This involves the biological response to the spectrum of conditions in managed stands for each timber type and species involved.

More research emphasis should be placed on light, temperature, moisture, and nutrients and how they vary over a range of residual stocking levels or stand densities with varying structure. If one or more of these factors is limiting, can it be overcome? Are openings required? Is there seed production?

1/ Condensed from Work Group reports by Barton Blum, Charles McGee, Martin Dale, Jack Stubbs, Albert Stage, and LaMont Engle.

2/ Research Forester, Timber Management Research, Forest Service, USDA, Washington, DC.

How does reproduction develop under a range of stocking levels? Does length of time reproduction is suppressed affect its ability to respond to release. Are there related pathological or insect problems? Regeneration growth should be studied through the sapling stage.

What are the inherent site conditions that affect reproduction establishment and growth? This involves the physical and chemical properties of the soil, soil fauna and flora--mycorrhizae may be important. What is the effect of animal populations, physiography, microclimate?

Are special cultural treatments necessary to enhance or ensure reproduction of the species wanted? This involves control of competition from undesirable vegetation, drainage of wet sites, irrigation, seedbed preparation, fertilization, and underplanting. Underplanting should include effects of stock size. Are special protection or cultural measures necessary?

We need to know how to control species composition of the reproduction. Is there a real need to control unwanted species at this stage or can they be removed later?

Should cutting be tried with reference to phenological events? Good seed years? It may be significant for certain species but little probably can be done about timing of cuttings.

Regeneration stocking guides need to be developed for different timber types and species. How much reproduction is enough? How much is too much? Regeneration goals that include numbers of stems and distribution, both areally and by species should be stressed. Guides should cover seedlings and saplings.

What is the role of stump sprouts, in regenerating uneven-aged stands? Are they a significant component for some forest types and/or species? Is there significant conversion from seedlings to seedling sprouts for some species?

What are the economics of regenerating uneven-aged stands? What are the costs and returns in terms of physical inputs and outputs?

Stand Structure and Composition

A J-shaped structure should not be a hard and fast goal because the structure of balanced stands can vary. The size of the area being managed itself has an effect on structure.

Changes in species composition may reflect structural changes. There is some question as to whether a certain pre-selected species composition can ever be a realistic goal in uneven-aged silviculture.

Cutting must be carried out in all size classes to achieve orderly and desirable stand development in intensive management under uneven-aged systems.

Important research needs related to stand structure include:

- -- Effect of stand structure on species composition and vice versa.
- -- Effect of different management-silvicultural systems on species composition in each timber type.
- -- A system of site evaluation and the relationship of various sites and types to several systems of management.
- -- Methods to achieve specified stand structures.
- -- Costs related to maintaining certain species compositions and stand structures.
- -- What are the desired "q" values for different management objectives?

Growth and Yield

Single tree selection is probably not suitable in some types, like upland oak. Small openings created by individual tree harvesting do not create the environmental conditions needed to insure growth and development of upland oak reproduction. Group selection, which creates larger openings, may provide the needed environmental conditions to maintain the oak component in the stand. There may be some difficulties in regulation, but nevertheless, group selection is believed feasible from the silvicultural viewpoint. Marking and logging difficulties were especially noted, as well as the need to manage the entire stand and not the individual groups. There is need to determine growth and yield trade-offs between individual tree selection and group selection. It is most important to know what the trade-offs are in timber quantity, quality, and values when switching from even-aged to uneven-aged systems.

Uneven-aged management of the bulk of the eastern and southern hardwood types will probably demand systems other than single tree selection. Unpalatable as it seems to be in regulation, for regeneration these other types may demand group cuttings of some sort. There may be some special problems regarding uneven-aged silviculture and management of southern hardwoods. These stands are generally uneven-aged and are often cut selectively already. However, the cutting is done to fill a special order and hence the selection is often on individual species. We do not know what effect selection cutting by species will have on future growth and productivity of the southern hardwoods.

Our terminology is often a point of confusion. Researchers must be particularly careful to use correct terms and thus avoid confusion or misunderstanding. Some terms commonly associated with even-aged stands, such as site index, may not apply directly to uneven-aged stands.

Switching from even-aged to uneven-aged stands will probably result in loss of volume production. Even-aged stands tend to favor the faster-growing intolerant species while in uneven-aged stands the slower-growing tolerant species are favored. The change in species composition is believed the major source of any volume loss. Where the same species can be grown in either even-aged or uneven-aged stands, volume production may be little affected, although there does not appear to be enough evidence to reach a consensus opinion.

Uneven-aged stands may show better volume production because of better utilization of space both vertically and horizontally. However, there is not enough growth data available from uneven-aged stands to make valid comparisons.

Most growth data for uneven-aged stands are obtained by cruise of continuous forest inventory (CFI). Present inventory systems are usually inadequate for growth estimation for uneven-aged management because the inventory does not measure variables shown by research to be critical for growth projections.

The problem of regulation as noted with group selection in the upland oak type, as well as the marking and logging problems associated with group selection, are believed to be more a management problem than a research problem. However, the lack of adequate growth and yield data in terms of quantity, quality, and value appear to be clearly a researchable problem. More research should be conducted on stand dynamics based on individual tree growth studies.

There is an overall lack of adequate growth and yield information for uneven-aged stands. Several approaches can be taken with new growth studies, including both individual tree and total stand approaches. One possible way to obtain growth and yield of uneven-aged stands is to reconstruct the stand based on past performance. This would involve a great deal of field work to obtain borings or felled tree measurements to develop and reconstruct past growth patterns of trees. Other approaches may involve development of growth and yield under different "q" values or different structures and also for different basal area levels.

Other key problems that need to be researched include the following:

- How do young trees differ from older trees in their response to release?
- Do the younger poorly-formed understory trees develop into acceptable overstory trees, both from the standpoint of form and growth rate?
- Do we need to reduce stand density to low levels to obtain a better growth rate of the smaller understory trees?
- Do we need as many small trees as the "q" values indicate or will fewer numbers of these small trees suffice?
- What is the growth response of residual trees following a regeneration cut?

Quality trees should not be neglected. We need to know what the quality changes are in response to various silvicultural practices not only in uneven-aged stands but from other silvicultural systems as well.

Regulation

Regulation includes the specification of growing stock distribution, and this is a vital part of uneven-aged management. Silviculturists need to be able to tell the forest manager whether the desired stand structure is biologically feasible. There may be some question whether "q" factors or other geometric progressions of diameter distribution are either necessary or indeed desirable in more intensively managed stands. These distributions have often been formulated from judiciously selected virgin stands; many other stands do not fit the pattern and seem to have done just as well.

Forest classification based on ecologically equivalent units of the landscape has only received sporadic interest in the United States. As a result one often wonders whether silvical and management information will apply "over yonder" on another 40 acres. As management intensifies so does the need for a holistic forest land classification using landforms, soils, species composition, and other important environmental and biological factors, to serve as a frame of reference for forestry recommendations. There are many possible approaches and factor combinations, some more useful than others on a provincial scale. No one method will be all-encompassing.

A major obstacle in uneven-aged regulation is our inability to make fairly long-ranged growth projections comparable to what can be done in certain forest types with even-aged management. There is a critical need for growth and yield information for both pure and mixed hardwood stands, especially the latter. No one yet has figured out how to make accurate long-range growth projections for mixed stands. Degrees of management intensity are a further complication. Research to acquire this mensurational information deserves top priority. We have the computer software programs but lack the necessary biological data. There is some value in resurrecting and maintaining some of the older experimental plots related to uneven-aged silviculture for use as demonstration areas and leads to new research. However, the realities of limited personnel and funding will sharply limit what can be done in this line.

Group selection regulation may simply amount to area control with a multitude of small patches, and there is no inherent reason it could not be done with an intensive record system.

We also need to know under what circumstances--ownership category, size of forest land ownership, market environment, etc.--regulation is important. How much, if any, regulation is minimally needed for each class? (With National Forests for instance, "even flow" regulation for 1 1/2 rotation ages seems as unnecessary as it is unattainable). Again, with these ownership classes, what will be the probable yield losses? Losses will be generally inevitable because as a rule the tolerant species grow less rapidly than do less tolerant associates. Will these losses vary by size and/or class of ownership?

Short-term site quality classification for uneven-aged stands is a knotty problem, but a necessity for even mildly accurate regulation. Eventually of course, the yields approximately answer this but something is needed in the interim.

What criteria should guide the evaluation of trade-offs between size of regulation area and amplitude of yield fluctuations?

Almost everyone's network of primary and secondary forest roads seems to proliferate in a near random fashion. Some systems analysis would be welcome to determine more optimum road networks for a range of management intensities.

And finally, we need more detailed economic analysis to determine the administrative and conversion costs involved with various degrees of uneven-aged management intensity. These ought to be compared with even-aged management alternatives. Economic and systems research would especially benefit by input from administration. Most of the problem items could well be cooperative ventures.

THE WORKSHOP IN RETROSPECT

by

Warren T. Doolittle[1/]

I believe most of the questions about the selection system of silviculture and uneven-aged management have been covered in the reports of the four work groups. However, there are several points that I want to emphasize.

On the first day, I outlined for you the objectives of this meeting. Let me summarize these objectives once more. Forestry practices in the future will make more use of an array of silvicultural systems--including the selection system. In Research we need to make sure that we include the selection system in our studies and in the options we offer in our silviculture and management guides. The papers presented here at this workshop were aimed at helping us outline the state of the art for the selection system of silviculture and for uneven-aged management. Even more importantly, this workshop was supposed to help us pinpoint some of the gaps and goals in research for the near future. And from where I sit these objectives have been at least partially achieved here at this meeting.

It appears obvious to me, as I am sure it does to most of you, that we need to tighten up on our terminology. We need to do this so we understand what we are talking about. I recommend that we use the terms as they are defined in the glossary found in the back pages of the USDA Handbook No. 445, "Silvicultural Systems of the United States." This glossary describes the silvicultural systems very well, and we need only to add a couple more definitions for even-aged and uneven-aged management, and we are covered.

We need to be thinking more about ways to improve the program for our western workshop scheduled in October 1976. And I also urge each Station to begin scheduling regional workshops--including other disciplines and the user groups--with emphasis on the selection system of silviculture and uneven-aged management.

1/ Director of Timber Management Research, Forest Service, USDA, Washington, D.C.

We need to dust off some of the old work we have on selection cutting and see if there is something there that can be built on or used in preparing management guides. Actually, we have a lot more old study areas and records available to us than most people realize. We have some study areas with over 40 years of records! That is over half a rotation in many forest types.

I believe I can see where "Q" or some other stand structure control of age or size classes will continue to be a useful and necessary marking guide for the selection system. Yet, we need to guard against slavish structure for every clump of trees or for each small area. Structure control must always be in the marker's thinking--but always a guide and not overriding. And in areas where financial maturity figures are available, they can be used in marking trees to be cut. Perhaps some combination of financial maturity and stand structure would be better than either one alone?

There is a need for better and more frequent inventories of stands under the selection system. We need better measures of quality in both large and small trees. There is a great need for "managed stand" yield tables or equations for stands under both even-aged and uneven-aged management. As you probably know the Forest Service has a National Growth Processor Committee which Al Stage chairs. This committee has a representative from each of most of the Stations. And by the end of this year we hope to have all Stations included. This committee was formed originally to help meet the needs of the latest Timber Requirements. Now the committee assumes even greater importance and stature because of the requirements of the Resource Planning Act of 1974 and because of the surge of intensive management on both National Forests and private lands. In keeping with this importance and need, WO-TMR is setting up a new position at Fort Collins to adapt yield tables and equations to the computer. The person in this position will be working with the committee, getting yield tables and equations from the Stations; he will be under the supervision of the Chairman, Al Stage. I hope all of you will support this effort.

GPO 897-650