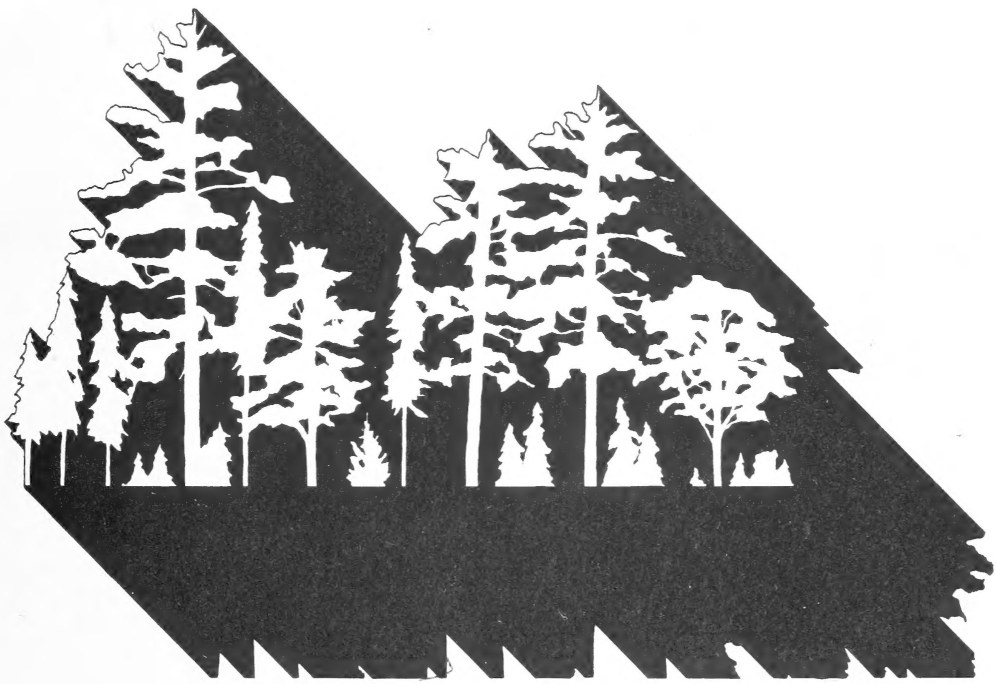
Uneven-Aged Silviculture & Management in the United States



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UNEVEN-AGED

SILVICULTURE AND MANAGEMENT

IN THE UNITED STATES

Combined Proceedings of two In-Service Workshops held in
Morgantown, West Virginia, July 15-17, 1975,
and in
Redding, California, October 19-21, 1976.

Timber Management Research, Forest Service
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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 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 clearcutting, however, it has become more and more evident that forest researchers must be able to provide technically reliable information on all silvicultural and management systems.

The state-of-the-art knowledge about the applicability of uneven-aged silviculture and management was recently reviewed in two separate Forest Service workshops. The first workshop was held in Morgantown, West Virginia, July 15-17, 1975, for the eastern forest regions; the second workshop was held in Redding, California, October 19-21, 1976, for the western forest regions. Participants were primarily In-Service, with representatives from Research, National Forest System, and State and Private Forestry. One major objective of these workshops was to develop a much better mutual understanding of the definitions of uneven-aged and even-aged silviculture and management, and the differences between them. A number of research gaps and research needs were also identified, and many of these needs are now being addressed in program planning for several research work units in the four eastern and four western Experiment Stations. The papers presented at these two workshops have been consolidated into these Proceedings so as to 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 and Western United States until more of the needed research can be completed.

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HISTORY AND PHILOSOPHY OF SILVICULTURE MANAGEMENT SYSTEMS IN USE TODAY

by

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In trying to trace the history of silviculture, more particularly the development of forest culture systems, we can readily, if not quickly arrive at four 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);

4. Public opinion, political expediency, and/or individual personalities often dictate the form and substance of cultural practices irrespective of silvicultural requirements, site conditions, and often contrary, if not conflicting, objectives.

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. Most 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 look - 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 rivival 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. Whether it was the seemingly preoccupation of this early management advice with the economics of cutting methods, the incongruities and apparent paradoxes in the above-mentioned NFS direction, or other factors, a number of well-known foresters began to question the silviculture being advocated and applied in the United States. Acknowledging the validity of the fundamental principles of silviculture demonstrated in European practice, they pointed out that the European methods were not always applicable to the types and situations in this country.

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 toward 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 clear-cutting, 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.

Diameter limits were relied on heavily in the western National Forests from the start and vestiges of them have remained with us until recent years in spite of ". . . the policy of the Forest Service to work away from a diameter limit just as fast as the men can be trained to appreciate its failings and to apply remedies." (Carter 1908). It is interesting to find that even in the early years of the Forest Service, some people acted independently of the word or ignored it, and reflection in later years proved they were right. One account of such independent thought and action is revealed in comments on a sale of yellow pine in the Southwest. It apparently had taken 2 months correspondence with the WO to determine a diameter limit for the sale. When it was finally decided, the man in charge of the sale is reported to have already completed the marking and in so doing had "very wisely ignored completely any diameter limit at all but had based the marking wholly on the condition of each individual tree when considered in relation with the diversity of the stand and the abundance or absence of reproduction." (Carter 1908).

About the same time Greeley prescribed for forest lands in the western Sierras a simple system of cutting adapted to the logging methods of that day that would conserve timber values and at the same time begin improving the forest. He said, "Without attempting any exact calculation of sustained yield, the forest should be logged under a rough selection system, by groups or single trees, with a cutting interval of 40 or 50 years." Sugar pine and yellow pine were to be favored, and fir and cedar were to be cut to as low a diameter as they were merchantable, which at the time averaged about 19 inches d.b.h. Interestingly, Greeley went on to say, "The irregularity of the virgin Sierra forests will, of course, make it possible for us to realize the ideals of this system of cutting but seldom . . . . The improvement feature of the cutting must be put first, every possible sacrifice being made in the interest of second growth and the permanent value and productiveness of the stand." (Greeley 1907).

For the dense stands of Douglas-fir and hemlock in the Northwest, the recommended treatment was to cut everything that would make a merchantable log except carefully selected seed trees. In those stands where due to the absence of fire for several centuries the Douglas-fir had been displaced by other more tolerant species, it was noted that the best silvicultural proposition would be to clearcut and plant, but such a practice was out of the question at the time (Carter 1908).

Clearcutting was still considered the most feasible method for harvesting Douglas-fir and believed to produce the best results from a silvicultural standpoint until the 30's. Following the advent of the crawler tractor in the Douglas-fir region about 1931 which permitted the logger to make a light cut of the better trees and leave trees that showed a negative conversion value, a form of partial cutting popularly called selective logging developed on private lands. It was more properly referred to as zero-margin tree selection or loggers selection--taking the best, sometimes expecting to come back for the rest later, but sometimes not (Hofman 1924, Munger 1950). That philosophy appears to have influenced, with some exceptions, timber management practices in the West for many years. In 1934, the net return per acre under economic "selective" cutting in ponderosa pine was reported to be greater than from clearcutting, carrying an implied recommendation of the selective cutting which was an economic selection of pine only (Anderson 1934).

Apparently quite a bit of interest and controversy developed in the 30's over the merits of partial cutting vs. clearcutting, but the practice spread and the Regional Forester in the Northwest Region at that time told the Forest Supervisors that "clearcutting practices on National Forest lands should be abandoned if possible and systems of selective logging devised and substituted." Although foresters on the ground had varying opinions, they loyally and skillfully tried out the prescribed method. Munger reported in 1950:

> "During the past 15 years, foresters of the Douglas-fir region have made a silvicultural detour in their cutting practices in the virgin forests of western Washington and Oregon. They departed from the time-honored path of clearcutting and explored the labyrinth of partial cutting, and now are back again at practically their point of departure."

The Chief's report in 1947 stated that the partial logging practiced up to that time in Douglas-fir had "failed to accomplish the objective of converting static forests to growing forests." Munger reported that clearcutting was employed again as of old, in practically all new National Forest sales except in mixed, uneven-aged stands in southwestern Oregon and in certain other thrifty mature stands.

I think it worth mentioning that Munger also commented that within the experiment station ". . . those and its staff who were silviculturally minded were suspicious of partial cutting in typical old-growth Douglas-fir, while the economists thought it the great hope of profitable forestry."

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 on the 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 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, Stuart's predecessor 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 . . .
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> 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.

In the East, where from the beginning we have been dealing mainly with second-growth stands, we suddenly woke up to the fact that within our own lifetime those stands were reaching maturity and we had to start thinking about regeneration methods as well as stand improvement. 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 have been preoccupied largely with extending the old growth, both for the "next cut" and for non-timber purposes. We're really just getting into second-growth management and the regeneration of managed stands. In both situations, we have found ourselves without an applicable silvicultural system or without the on-the-ground knowledge, understanding, or capability of applying the appropriate system of management. There are examples, however, 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.

Now, I recognize there are exceptions and considerable progress has been made in the development of silvicultural systems. Yet I remind you of the frantic scramble just recently to conjure up new systems or adapt the classical systems to the harvest of only dead, mature, and large growth trees. Or, take a look at some of the infamous examples of selective cutting in certain special management zones or areas still being prescribed--and I use the word "prescribed" advisedly! In such situations, we find that we do not know, are unable to evaluate, or do not consider the alternative consequences of the treatments prescribed or applied in the name of silviculture. We have not had, except for possibly one or two short-lived species, the benefit or the personal satisfaction of seeing through a silviculture system practiced diligently and consistently from regeneration to maturity to regeneration again in any of our major timber types. Although desirable, that should not be necessary to get on top of some of the silviculture problems besetting us.

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!

For what it's worth and your own determination of its relevancy to what we are about today in forest management, I quote one statement by a western researcher several years ago:

> "Silviculture is an art that should base its practices on the proven findings of many sciences. It must be practiced consistently over a long term of years. It should not be managed by considerations of passing expediency or popular appeal. Let foresters keep to their science of silvics. And let us keep research ahead of practice, so that untested innovations will not get ahead and get off the trail of nature's silvicultural laws." (Munger 1950)

I promised I would not try to define silviculture, but maybe we need 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.

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

by

Carter B. Gibbs[1/]

During the fifteen months between the eastern and western workshops on uneven-aged silviculture we saw the final evolvement of the "Monongahela decision;" and the development of a National Forest Management Act. Discussions of uneven-aged silviculture, what it means, how, and where it can be applied, and how it differs from even-aged were an integral part of both events. The unknowns and misconceptions that were surfaced by these discussions present us with unparalleled challenges and opportunities in silvicultural research.

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 textbooks and bulletins for definitions of management and silvicultural systems. The result, as I'm sure most of you have experienced, was disappointment and frustration. I soon came to the conclusion that most existing definitions, particularly those that explain the terms rather than the processes or systems involved, do not reflect the degree

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of knowledge we have achieved through research and practice. I further came to realize that, with 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.

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 some that reflect my personal biases after several years of attempting to apply uneven-aged silviculture in both hardwoods and conifers.

Before going further, I want to discuss the differences between silviculture and management. 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 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.

The omission of group selection as a silvicultural system obviously requires some explanation. 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 silvicultural 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 the 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.

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 the 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 need 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 silviculture, 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 size class distribution 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 the most important factor in the application of uneven-aged silviculture. To control or maintain an uneven-aged structure it is 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 very largest trees are removed. This misconception must be corrected because removing only the largest trees at each harvest can result in reduction of sustained yields and the development of either an irregular or even-aged structure.

Tree Quality

Both even-aged and uneven-aged systems properly applied will produce quality timber.

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. However, 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 situation. In even-aged structures, competition is mostly horizontal between codominants. The differences in root competition between the two systems are unknown, but undoubtedly there 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 either system, however, the question often arises as to which system will produce the most 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 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. Two 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 factors 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 utilized 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 structure will take care of itself and that we can use the same stand 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 crop trees. As management intensity increases we will need more efficient and economical methods for monitoring growth, particularly in regeneration, saplings, and poles.

Three, uneven-aged stands that are not developing as they should because of deficiencies in individual tree growth or excessive removals in some size classes may still appear to have a balanced uneven-aged structure. In short, mistakes in uneven-aged management are not as easily recognized as they are in even-aged. If mistakes are not recognized and corrected quickly the result may be loss of sustained yield regulation and reduced harvestable volumes.

In summary, I would like to emphasize two points: One, 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 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. Two, 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 is one 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 ideas of many, but particularly those of Dick Trimble, Bill Leak, and Ben Roach in the eastern United States, and Bob Alexander and Bud Twombly in the West.

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 of inadequate regulation. It was a common occurrence to concentrate cutting in the large size classes with little or no thought given to development of a balanced diameter distribution that could be maintained over a long period of time. The only control used was on the total volume. As a result, the first several cuts simply removed most of the good timber present in the original stand. Although growth and yield may have been good during this period, lack of a balanced distribution of trees in smaller sizes eventually led to greatly reduced ingrowth into the sawtimber classes.

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To put it simply, we ran out of large trees to cut after several of these so-called selection cuts had depleted the original stand (Roach 1974). Many of these early attempts at selection cutting were abandoned at this point, rather than waiting the comparatively long time that would be required for the remaining small stems and new reproduction to grow to merchantable size.

Actually, if continued as before, these early selectively-cut stands would eventually have achieved some sort of balanced distribution. But, the interval between cutting would have had to have been longer, and the long term yields less than indicated by the first few cuts.

This falldown in yields during the adjustment period could have been minimized if more effort had been devoted to the development of a balanced diameter distribution during the early cuttings. The lesson we have learned (hopefully) is that regulation of single-tree selection cutting requires control over both the diameter distribution and the residual volume (stocking level). 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. Many current guidelines for selection cutting provide general recommendations for residual stocking level. For example, 80 square feet of residual basal area is recommended for stands 10 inches d.b.h. and larger in a variety of central and southern Rocky Mountain types (Alexander 1974, Myers 1974), 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. More refined guides have been developed in some forest types for control of stocking under even-aged management, and these are equally useful for selection cutting.

Most of you are probably familiar with the type of stocking guide developed originally by Sam Gingrich for the oak type in the eastern United States (Gingrich 1967) which shows the normal, full, or A level stocking for stands for varying basal area, numbers of trees, and average diameter (figure 1). These guides are by far the most useful means available to evaluate stocking. The data required for their use are easily collected and the evaluation can be readily made in the field. The A level on these stocking charts represents the normal stocking level of fully stocked stands. The B level is the minimum stocking at which the residual trees fully occupy the site. Total stand growth is about equal anywhere between the A and B levels, but individual tree growth is best at the B level. Stands are normally thinned or selectively cut to leave a residual stand at the B level. In stands below B level, trees are too widely spaced to utilize all the growing space, so the stand is understocked. Stands at the C level will normally grow to B level in 10 years. Thus, the C level is used as an indicator of stands that are so far understocked that they will not be considered for replacement. 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 hardwood (Roach 1975), and some western types.

I have reworked a chart that Bud Twombly sent me for ponderosa pine to place it in this same format, and to make it easier to read basal area (figure 2). Consider an example using Bud's chart. A stand with an average diameter of 10 inches would normally contain about 98 square feet of basal area at full stocking, and could be cut back to 69 square feet without losing any total growth. A younger stand with an average diameter of 6 inches would normally contain only 69 square feet of basal area at full stocking, and it could be cut back to 48 square feet without losing total growth. Thus, the desired residual of these two stands varies by 21 square feet because of a difference in size or age.

In mixed hardwood stands of the East, Ben Roach (1975) has found that the various species present have markedly different growing space requirements, so that species composition must be considered in the evaluation of stocking. 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 (figure 3). Black cherry, white ash, and yellow-poplar require much less growing space than sugar maple, beech and other associated species. Thus, full stocking

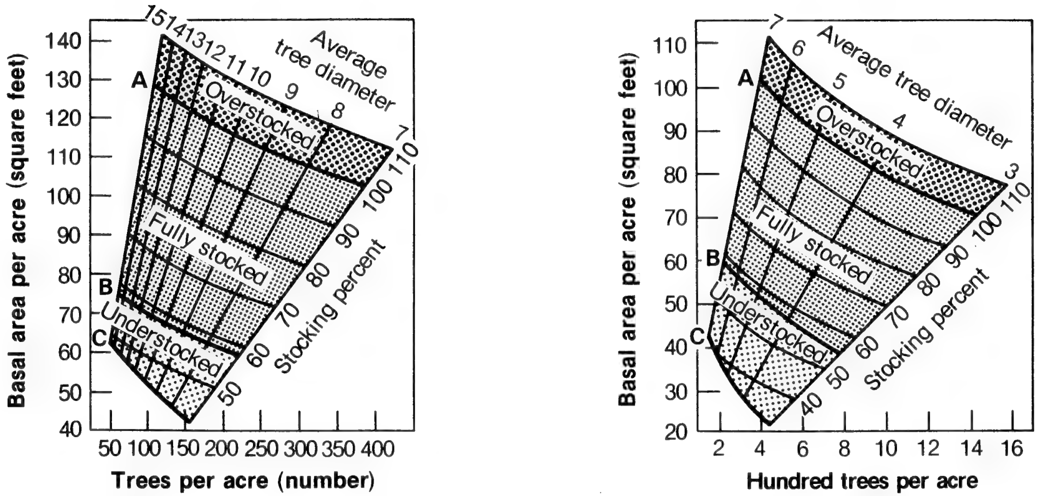

Figure 1.--Relation of basal area, number of trees, and average tree diameter to stocking percent for upland hardwood forests of average uniformity. Tree-diameter range 7-15 (left), 3-7 (right). The area between curves A and B indicates the range of stocking where trees can fully utilize the growing 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).

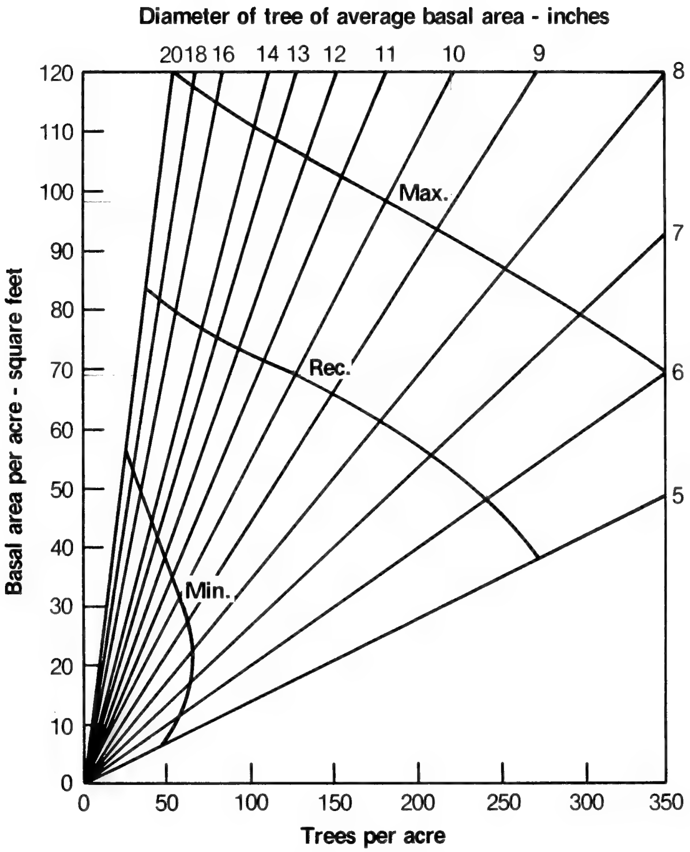

Figure 2.—Ponderosa pine high and medium site

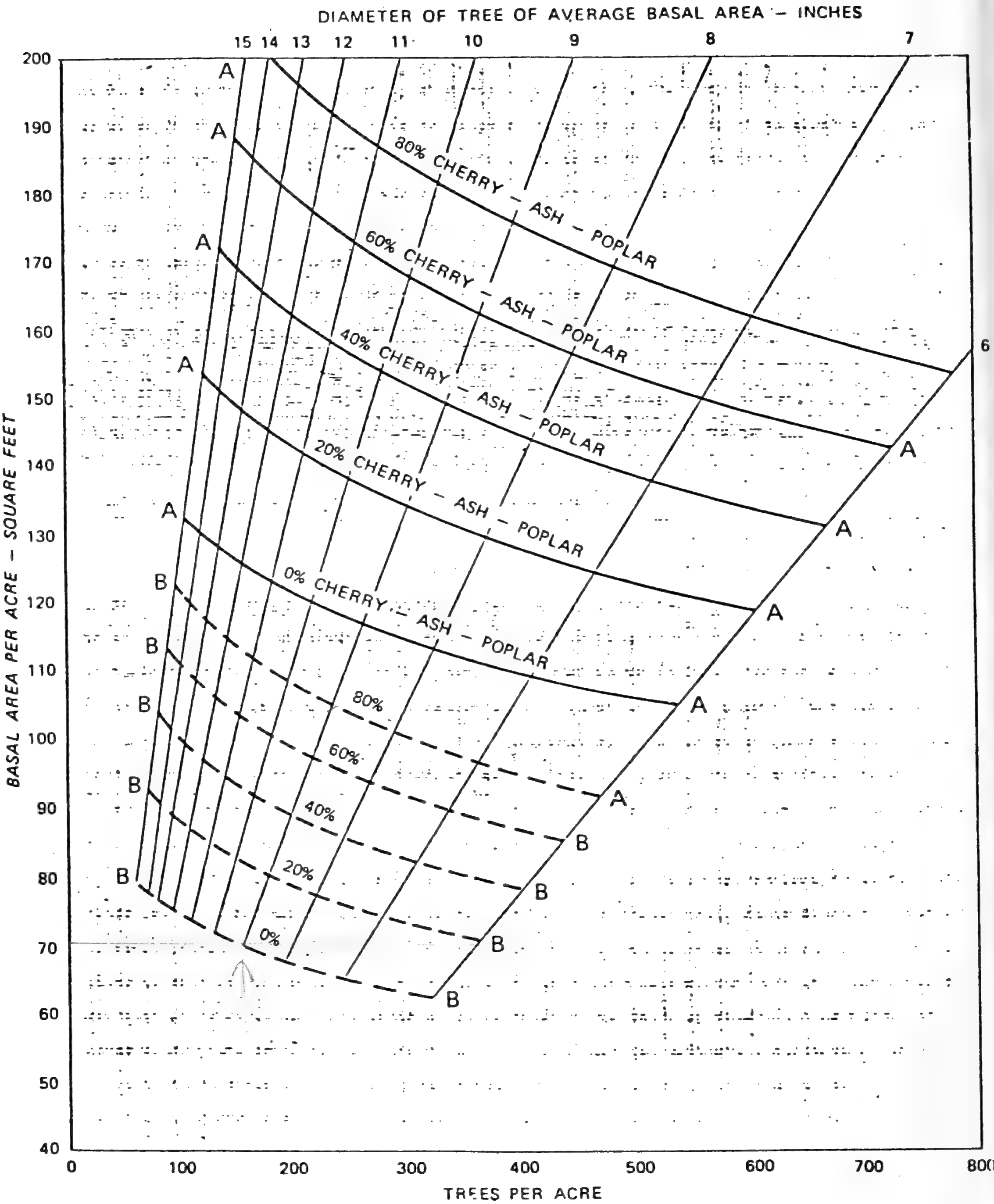

Figure 3. -- Stocking guide for Allegheny hardwoods for stands 6 to 15 inches in diameter (Roach 1975).

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 as a factor affecting stocking. But I suggest that the same concept will eventually be extended to other types, especially those containing a mixture of species with widely different tolerance levels and growth rates. Some of the western mixed conifers are likely candidates for this treatment; and 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 do vary widely. Furthermore, even in fully-regulated stands, average diameter, and therefore stocking levels, will vary with the diameter distribution being maintained.

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.

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.-
1.14 (1.3)	10.0	73	9.0	71
1.18 (1.4)	8.4	69	7.8	68
1.22 (1.5)	7.2	66	6.9	66
1.26 (1.6)	6.3	64	6.2	64
1.34 (1.8)	5.2	61	5.1	61
1.41 (2.0)	4.5	58	4.4	58

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

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 most widely 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. There is recent evidence that distributions other than q may be advantageous under certain circumstances, but these distributions have not been fully evaluated as yet. So, I shall limit my discussion to the quotient q.

Meyer and others have shown that q 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 shape (figure 4). Or, if plotted on semi-log paper, the distribution follows a straight line (figure 5). 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.

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 obtained from financial maturity data. Rate of return information of this sort is available for many eastern hardwoods--

Table 2.--Distribution of trees by 1-inch 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

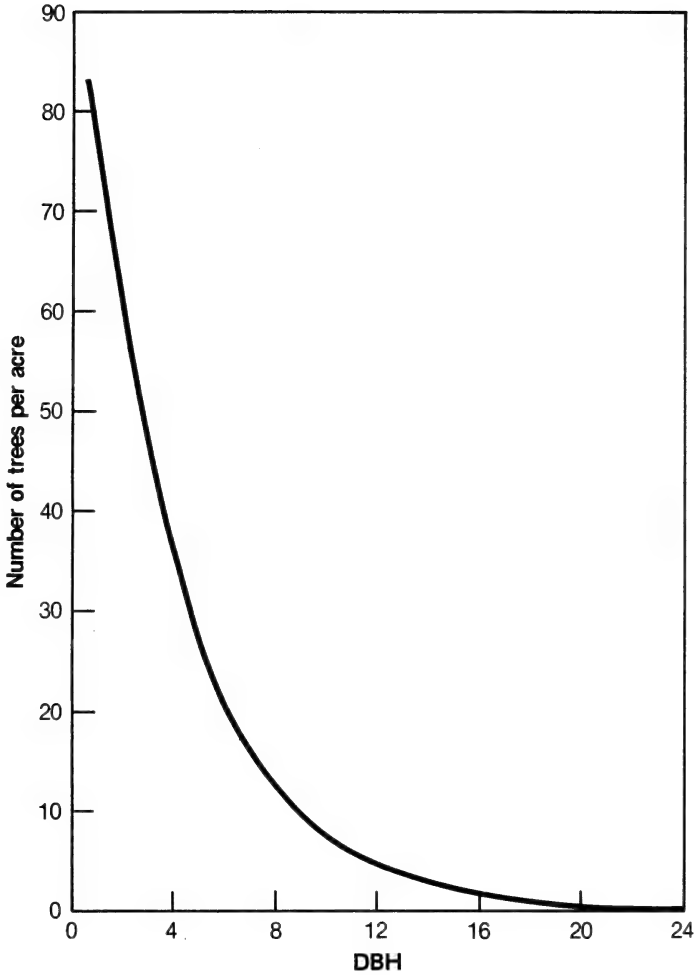

Figure 4.—Diameter distribution for a "q" of 1.3 (1.69), maximum tree size of 24 inches, and residual stocking level of 62 sq. ft. per acre.

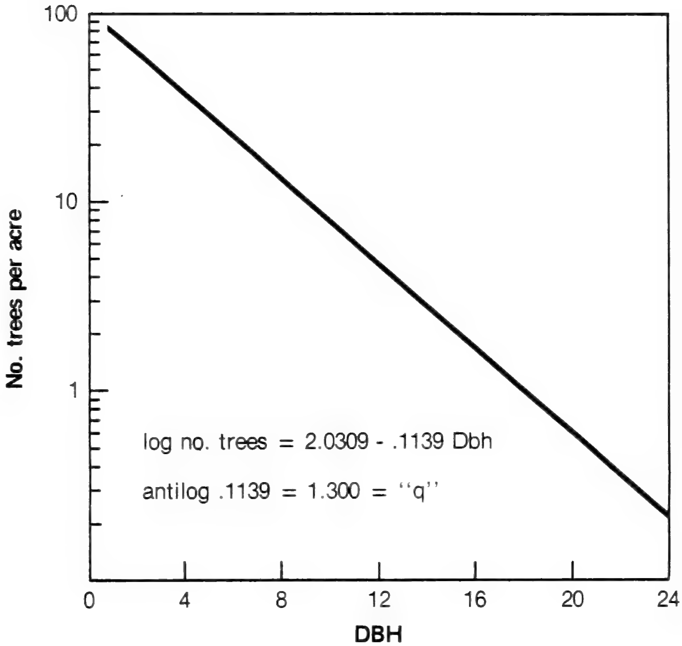

Figure 5.—Diameter distribution for a ''q'' of 1.3 (1.69), maximum tree size of 24 inches, and residual stocking level of 62 sq. ft. per acre.

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). In my limited search, I could not find similar data for western species, but it may well be available. If not, it might be approximated from data on volume growth as a function of d.b.h., plus data on value.

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 execess 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.

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 markets and money available for cultural work in small trees. The prelogging "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 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

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

Species	2 percent			4 percent			6 percent		
	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		
	1.14 (1.3)	1.26 (1.6)	1.41 (2.0)
	Average stand diameter		
D.b.h. 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 d.b.h.

during the period when a stand is first being brought under management, and to gradually work toward a smaller "q" in successive cuts. Or, it is quite possible to use a low "q" level in the sawtimber size classes, and a higher "q" in the smaller size classes of the same stand.

As a very general recommendation, "q" levels of between 1.5 and 1.8 (for 2-inch classes, or 1.20 and 1.35 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. It can be handled nicely by computer or programmable calculator, but 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 one 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 1½-inch classes. Broader size classes are usually used. But the calculations are best made by small classes for accuracy, and then combined where necessary for field use.

What About the Small Trees

You'll notice that I've made the calculations all the way down to the 1-inch d.b.h. class. One reason for this is that there are often large numbers of these small stems in tolerant forest types 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

Table 5.--Calculation of stand structure goals for quotient of 1.3 (1-inch classes) using 24 inches as maximum d.b.h., and residual stocking of 62 sq. ft.

	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	

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

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

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 field inventories is infinitesimally small.

Although there is little reason to ignore these small trees in recordkeeping, it may not always be possible to regulate their numbers. Trees less than pulpwood or sawtimber size may be uneconomical to cut and remove in many locations. Therefore, regulation of trees below commercial size would require some investment in cultural work.

If such cultural work is not performed, trees below the merchantable size are unregulated. This creates a hump in the diameter distribution in the small sizes, and means that cutting must usually 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 intended 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 may be 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.

Bill Leak (1975) has suggested that use of a double q factor (or other special distribution) may provide a useful compromise. Under this scheme, a low q factor is applied in the sawtimber sizes, with a higher q in the small sizes. This minimizes cutting of small trees while retaining regulation there, and at the same time it maintains a moderately high proportion of the growing stock in large sawtimber trees.

Until more complete information is available, the only appropriate recommendation would have to be that cutting be carried down to the smallest diameter classes feasible without incurring large expenditures for cultural treatment.

Stand Examination

Having discussed all of 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 be 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 foot, 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 (or high) 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 6).

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 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.

Figure 5

Allegheny	SM-BE	7/1/75
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									

Finally, subtract the residual stand data from the original stand data to obtain figures for the cut stand (figure 7).

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 one 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 one 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.

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 high quality logs, 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.

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. If the marking crew normally tallies each tree as it is marked, 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.

To overcome this problem, it is desirable to have 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. Periodically, dividing the

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					

total for each size class by the number of prism points sampled up to that time provides data that can be 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 (figure 8).

Regardless of the exact procedure, periodic checks on the marking are 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 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 or by stand growth simulation techniques. However, where data to permit this are not available, average figures of growth by size class can often be used to make rough projections.

Some simple growth figures of the type required, are presented in table 6. To be useful, this sort of data must have come from stands of similar species composition and average diameter as the stands in question.

Table 6.--Distribution of growth by diameter groups[1/]

D.b.h. group - inches -	BA growth - sq. ft./year/sq. ft. original BA -
1-5	.020
6-10	.030
11-16	.034
17-24	.036

1/ for maple stands 6 inches d.b.h. at 60 percent stocking.

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					

These growth figures can be used to project growth to the end of the cutting cycle. Simply multiply the growth figures by the basal area in that size class, multiply by the number of years in the cutting cycle, and add to the current basal area for each size 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).

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.

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

D.b.h.	Residual Stand	Future Stand	Good	Cut	Cut[1/]	
	- Square feet of basal area per acre -				cu.ft/ac.	MBF/ac.
1-5	12.1	16.9	11	0	0	0
6-10	23.5	37.6	22	15.6	312	0
11-16	20.7	34.8	19	15.8	395	1.9
17-24	9.6	16.5	10	6.9	172	.8
Total	65.9	105.8	62	38.3	880	2.7

1/ Conversions used:

20 cu. ft. = 1 sq. ft. poletimber
25 cu. ft. = 1 sq. ft. sawtimber
120 bd. ft. = 1 sq. ft. sawtimber

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

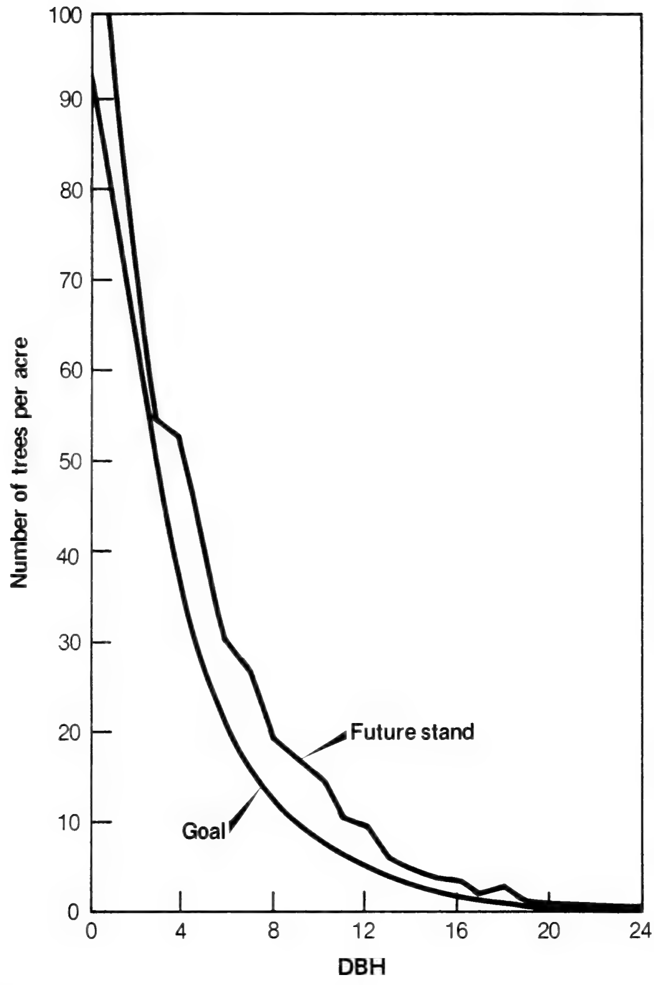

Figure 9.—Calculated allowable cut; the difference between the future stand and stand structure goal.

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. As a general rule, cutting cycles of 15 to 25 years will be appropriate for many forest types.

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 regulation or uneven-aged silviculture with even-aged regulation. Let's look at some of the options.

Single-tree selection consists of the removal of trees throughout several or 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 intolerants are removed and replaced by more tolerant species (U.S. Forest Service, 1973; Trimble 1970, Trimble 1965). Complete conversion may take 50 to several hundred years, but true single-tree selection cutting will eventually produce stands dominated by the most tolerant species that are capable of growing on the site.

The species best adapted to single-tree selection include sugar maple, beech, hemlock, red spruce and balsam fir in the eastern United States, and western hemlock, western redcedar, Pacific silver fir, grand fir, red fir, white fir, subalpine fir, incense cedar, and Engelmann spruce in the western United States. In some types, and under certain stand conditions less tolerant species such as Rocky Mountain Douglas-fir and redwood may also respond to single-tree selection. If reproduction of one or more of these species cannot be expected in the stand in question, single-tree selection cutting is a poor choice. In general, this means that single-tree selection cutting is likely to be most useful in the western mixed conifer types such as: the mixed conifers of southwest Oregon, the true fir--mountain hemlock, the red fir--white fir, the Engelmann spruce--subalpine fir, and the southwestern mixed conifer types, and 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 (U.S. Forest Service, 1973).

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 are 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. We really should not use the same terminology for these quite different cutting methods.

The larger group selection openings are really very small clearcuttings and have the same effect on regeneration, wildlife habitat, and other resources as small area clearcutting. But so long as the opening 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 opening to be a group (patch) selection cutting under even-aged management rather than a small clearcutting under even-aged management. The method of regulation is the deciding factor here.

Group (patch) selection cutting 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 (regulation).

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 to control diameter distribution when cutting must be restricted to fairly large openings and all trees in that opening 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 openings gets larger, and should certainly be considered anytime openings 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 silviculturally suitable for use in most forest types. Although it may be considerably less efficient for timber production than even-aged management, it would at least permit perpetuation of the present types where 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 95 percent of western forests would receive group selection if a choice had to be made between single-tree and group selection (U.S. Forest Service, 1975).

Group selection cutting has special advantages in some situations. This cutting method is well matched to ecological requirements for regeneration of certain open, uneven-aged stands such as those found in dry southwestern ponderosa pine types. Large group selection openings also have special value for water yield increases in some high elevation Rocky Mountain types where streamflow comes primarily from snowmelt.

Diameter-Limit Cutting

Diameter-limit cutting can be used as another bastard method employing the opposite combination of silviculture and regulation 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, desired residual stocking, etc.

Although diameter-limit cutting has usually been associated with exploitive logging, it does not necessarily have to be that. 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. The diameter limit would have to be flexible within the stand so that a uniform residual is maintained. This would provide conditions suitable for regeneration of intermediate and perhaps intolerant species, forming a new age class to replace the one 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 regulation.

Actually, much of the early cutting done in many stands was diameter limit cutting of this general sort. Although it was done with little or no thought given to either regeneration or regulation, and although no attempt was made to retain a uniform residual stand, results of these early cuttings 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 as well or better than group selection cutting. It would appear that the possibilities of this type of cutting need to be explored more fully.

Insects, Disease, and Climatic Factors Affect Choice of Cutting Methods

A variety of insects, diseases, and climatic conditions may affect the choice of uneven-aged cutting methods. Partial cuttings such as those used in single-tree selection and diameter limit cuttings may be entirely precluded where dwarf mistletoe infestations occur. Insects, such as the western budworm may present similar situations. Likewise, danger of windthrow is especially severe after partial cuttings on high elevation, exposed sites where trees are shallow rooted. Group selection, or even-aged clearcuttings may be the only feasible alternatives in such situations. General overmaturity and decadence of many old-growth stands may also dictate even-aged methods (Alexander 1954, 1973, Hatch 1967, Issac 1956).

Although it is much less common, insect and disease infestations are sometimes minimized by partial cuttings rather than clearcutting. Examples include lodgepole pine stands infested with the mountain pine beetle, or Rocky Mountain Douglas-fir stands infested with Douglas-fir beetle.

Frost is a special problem in some high elevation western types, such as the true fir--mountain hemlock type and the mixed conifer type of southwest Oregon. In these situations, partial cutting provides a protective canopy that reduces frost damage to regeneration. Group selection openings probably provide the greatest danger from frost, even more so than larger clearcuts.

Drought may also interfere with regeneration in some types such as the mixed conifer type of southwest Oregon and the Pacific and southwestern ponderosa pine types. In these areas, partial cuttings or very small group openings provide better conditions for regeneration than larger group selection cuttings or clearcuttings.

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 priority values, 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 roadside 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 something 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 during thinnings 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 25 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 other areas.

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 somewhere 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.

Maximum skidding distances are greater with aerial skidding than with ground skidding, and therefore the number and cost of roads required to harvest a given area is considerably less. Although there is some effort now being devoted to the development of aerial equipment suitable for partial cuttings, such equipment is not in common use at present.

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 appears to be greater potential to reduce skidding injuries than felling injuries. Most of the serious skidding injuries were concentrated near the major skid roads, suggesting that efforts to control damage be 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.

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, if groups are at least 1½ times as wide as the height of the larger trees in the stand.

Protection of advance seedlings is also of great concern in many coniferous forest types under uneven-aged management. Directional felling, careful layout of skid trails to minimize their number, and close supervision during logging are some of the major ways in which advance seedlings can be protected. This is much less of a problem in hardwoods where sprouting occurs after seedlings are damaged.

Some slash disposal will be needed after most partial cuts in western conifers. To minimize damage to residual trees, slash disposal should generally be confined to concentrations, should generally be done by hand rather than machine. In many cases, it will be preferеble to lop and scatter rather than burn. However, some hand piling and burning may be desirable in small openings. Group selection probably provides the least difficulty with slash disposal since conventional techniques can often be used in these openings.

Uneven-aged silviculture and management techniques are most useful in tolerant forest types, and can be adapted to many other types. In general, timber yields and values are a little lower and costs a little higher under uneven-aged systems, but this may be 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 and advance regeneration during logging and slash disposal.

Of the several cutting methods available, single-tree selection is likely to be useful in the northern hardwood and mixed conifer types, while group selection and diameter-limit cutting should be possible 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.

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PART II

UNEVEN-AGED SILVICULTURE AND MANAGEMENT IN THE EASTERN UNITED STATES

CONSTRAINTS ON FOREST MANAGEMENT IN THE EASTERN HARDWOOD REGION

by

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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

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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 sweet-gum 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, stell, 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 materials 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

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

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 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, seed tree, shelterwood, and selection. There is no one method of cutting that applies to all

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, DC.

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.

However, during the past 25 years, both research and application of clearcutting, 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.

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.

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

by

Barton M. Blum[1/]

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 in some places." (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 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."

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,

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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 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 and Filip 1963, Sander and 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 accessibility, 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 judgment 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 grey 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 mixed wood stands once predominated. If fire followed the cutting, aspen--grey 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 high-gradings. 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, Winckler, 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 and 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 and 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 and Frank 1968, Marquis and 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 and Solomon 1975, Trimble 1973, Sander and 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 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 1 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 and 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.

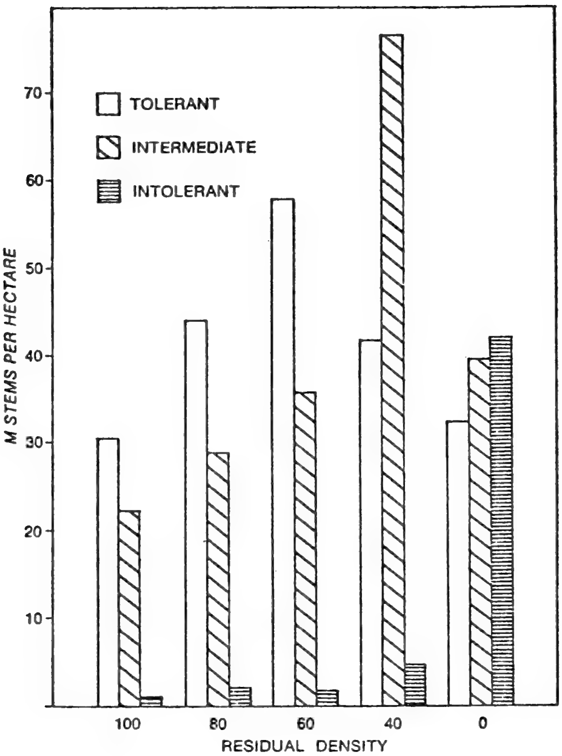

Figure 1.--Average numbers of stems (in thousands per hectare) of commercial timber species by residual basal area and tolerance group: tolerant (beech, sugar maple, hemlock, red spruce, balsam--fir), intermediate (yellow birch, red maple, white ash), and intolerant (paper birch). Numbers under zero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

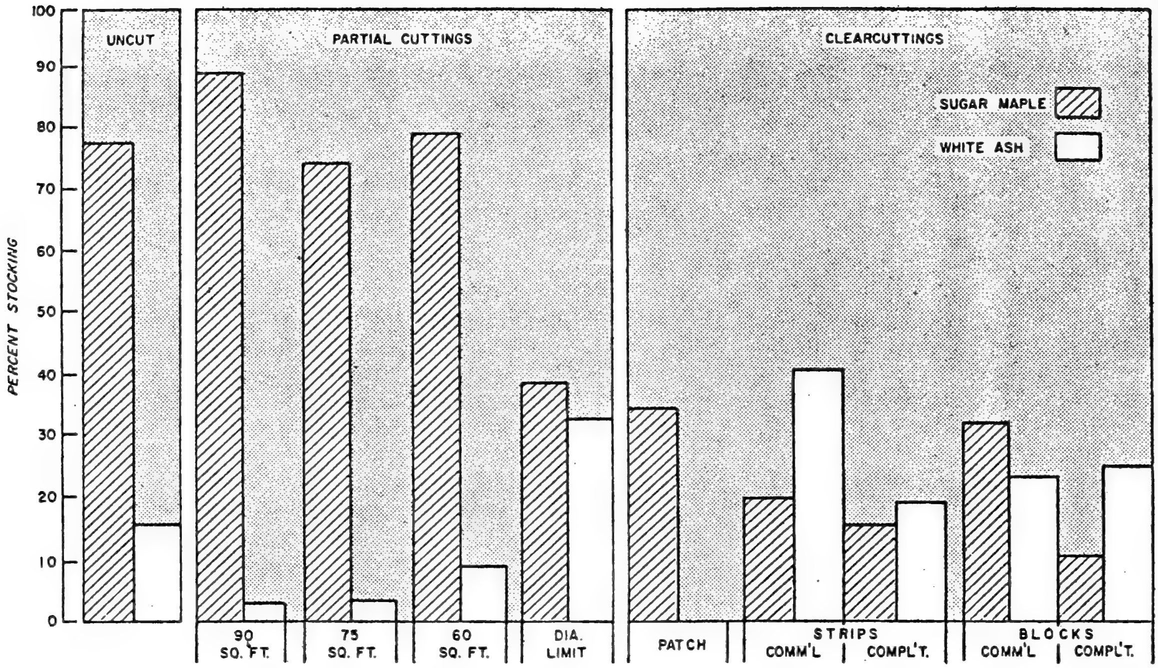

Figure 2.--Influence of cutting methods upon stocking of dominant sugar maple and white ash seedlings after 15 years (Metzger and Tubbs 1971).

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 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 and 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 and 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 and 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.

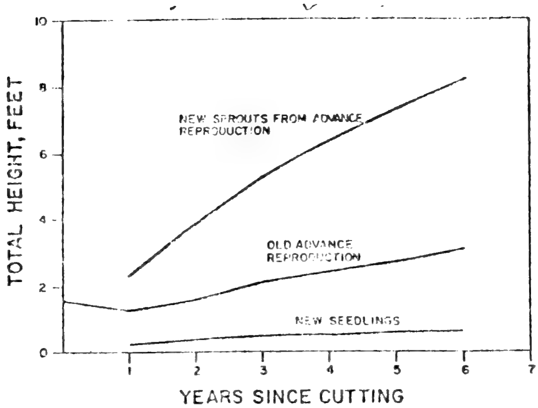

Figure 3. -- Height growth of different kinds of oak reproduction after partial cutting in Illinois (Sander & Clark 1971).

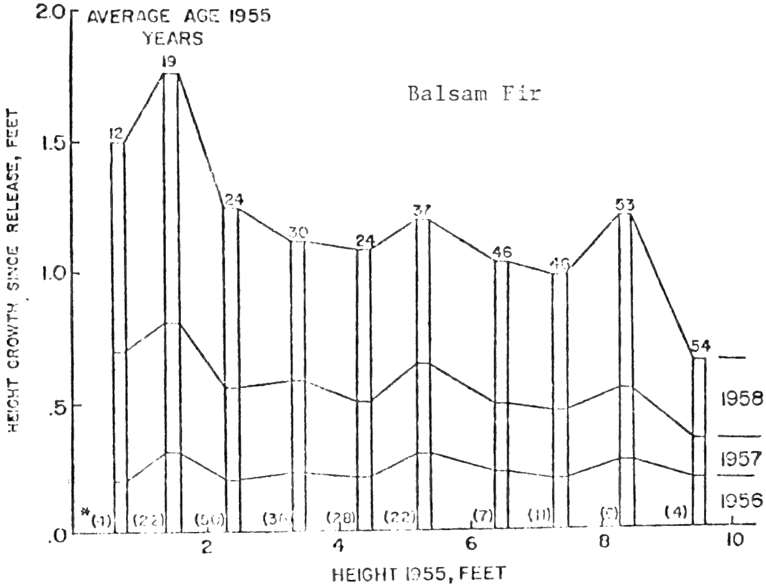

Figure 4. -- Relationship of height growth after logging to height prior to logging, Lake Edward (Hatcher 1967).

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 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.

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.

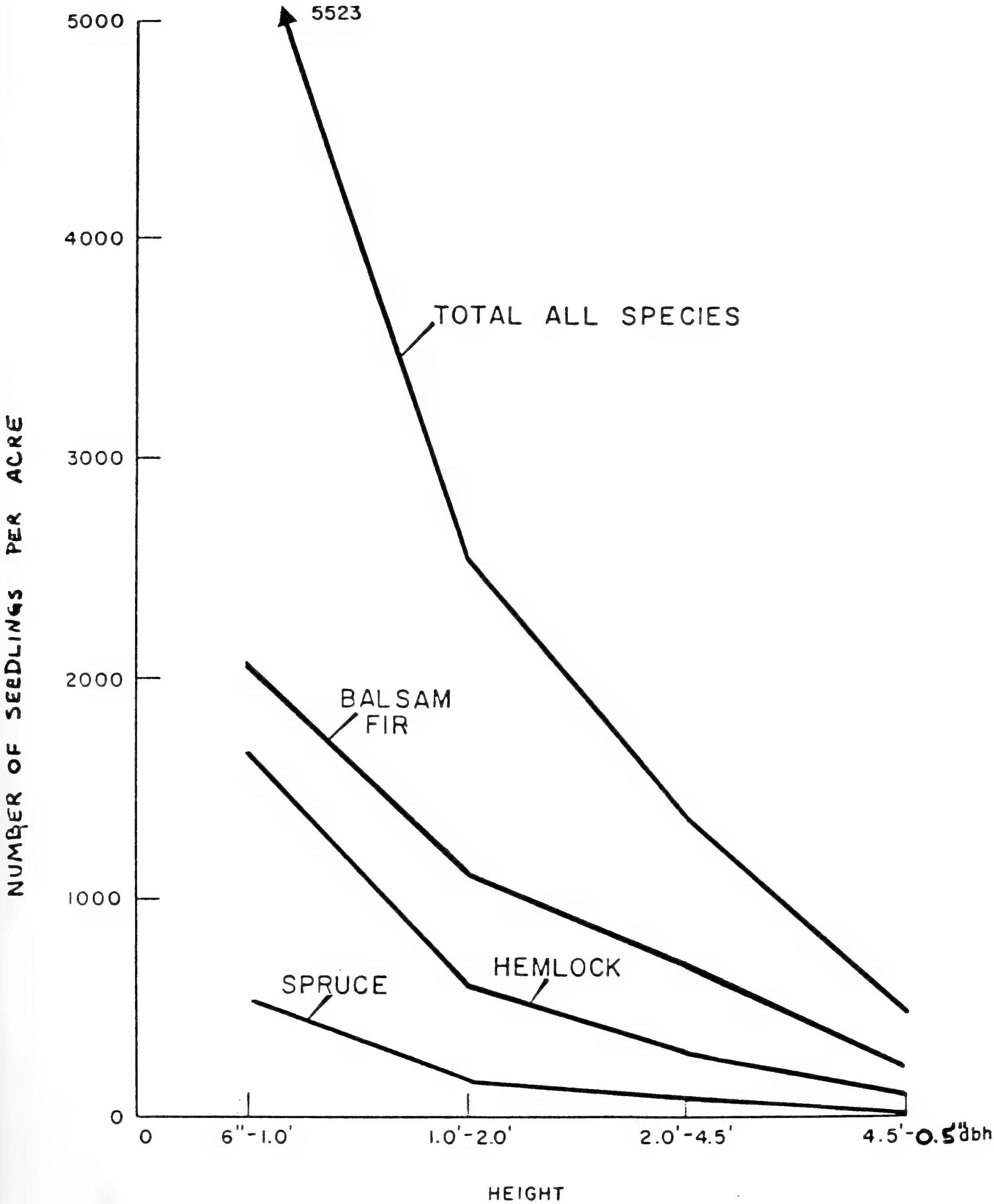

Figure 5. -- Regeneration data from four intensive selection compartments.

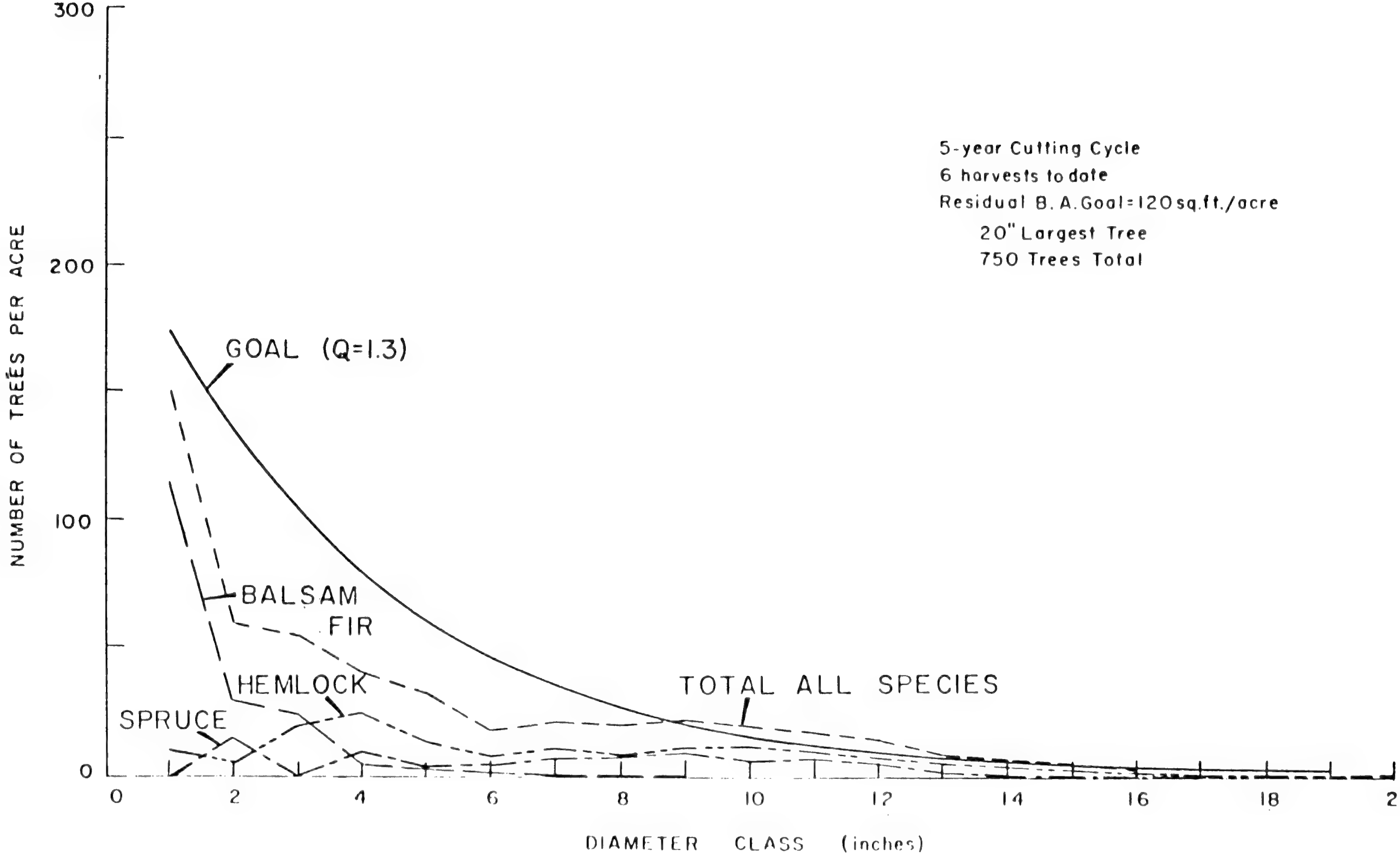

Figure 6. -- Mid-intensive selection - current stand diameter distribution.

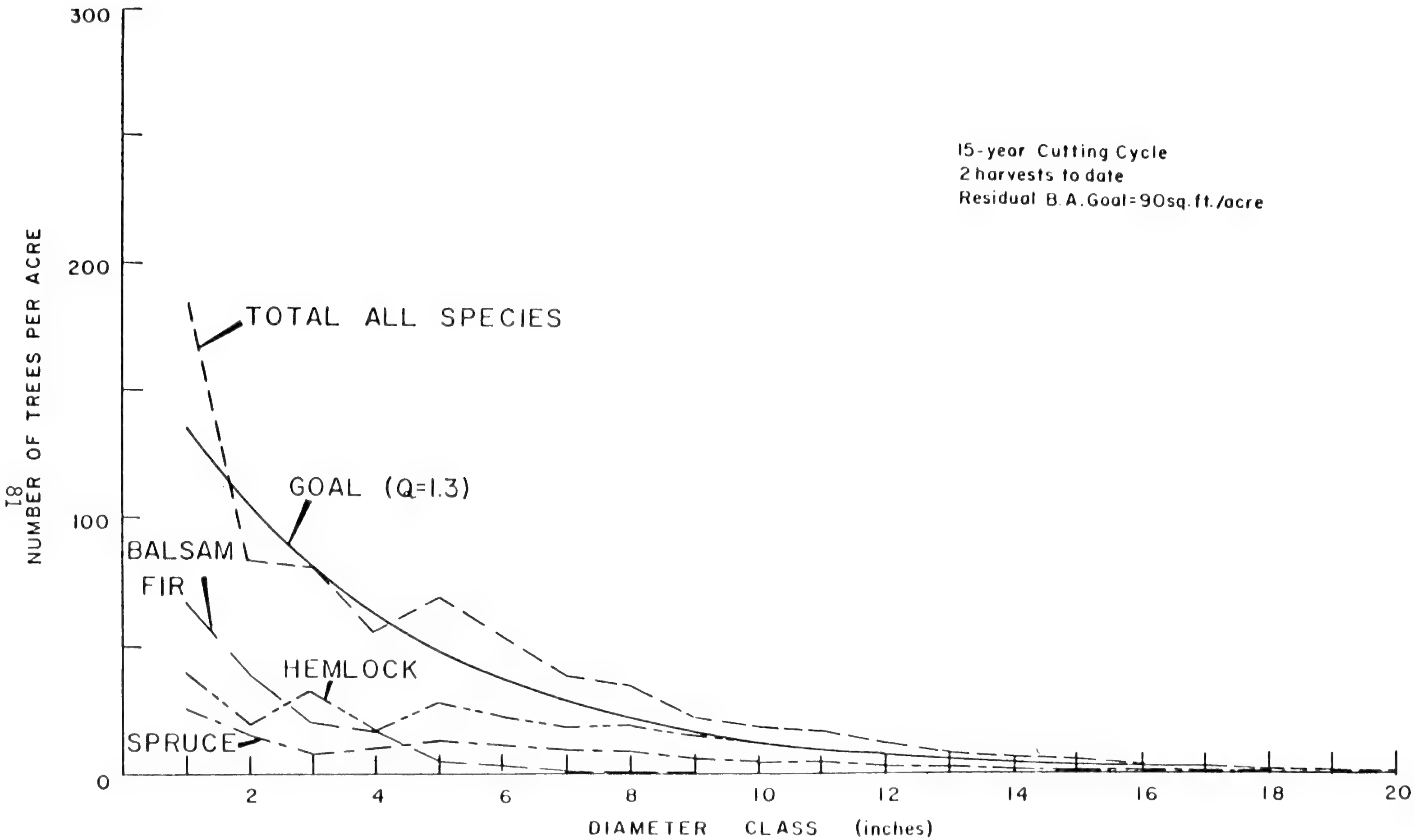

Figure 7. -- Mid-extensive selection - current stand diameter distribution.

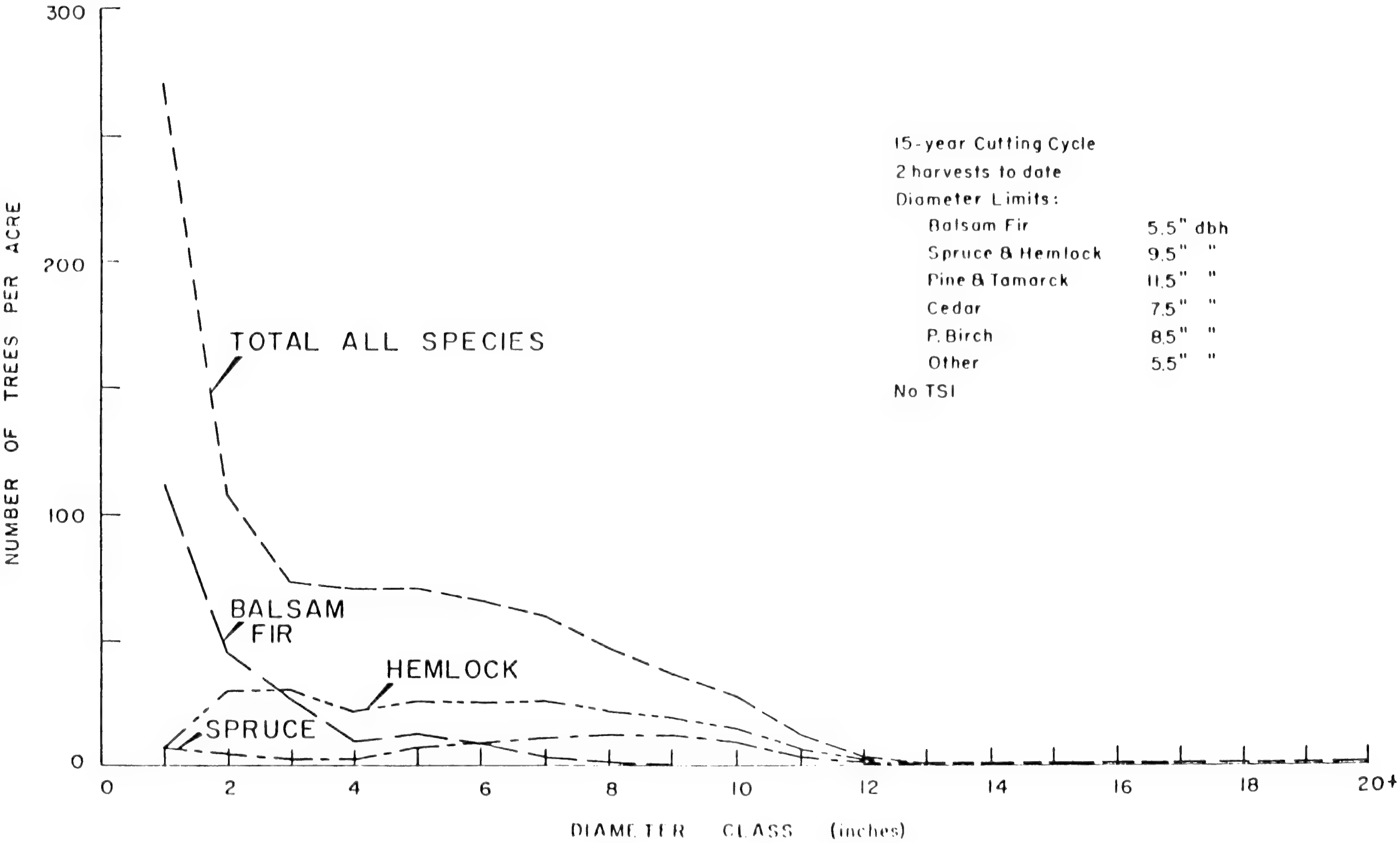

Figure 8. -- Mid-diameter limit - current stand diameter distribution.

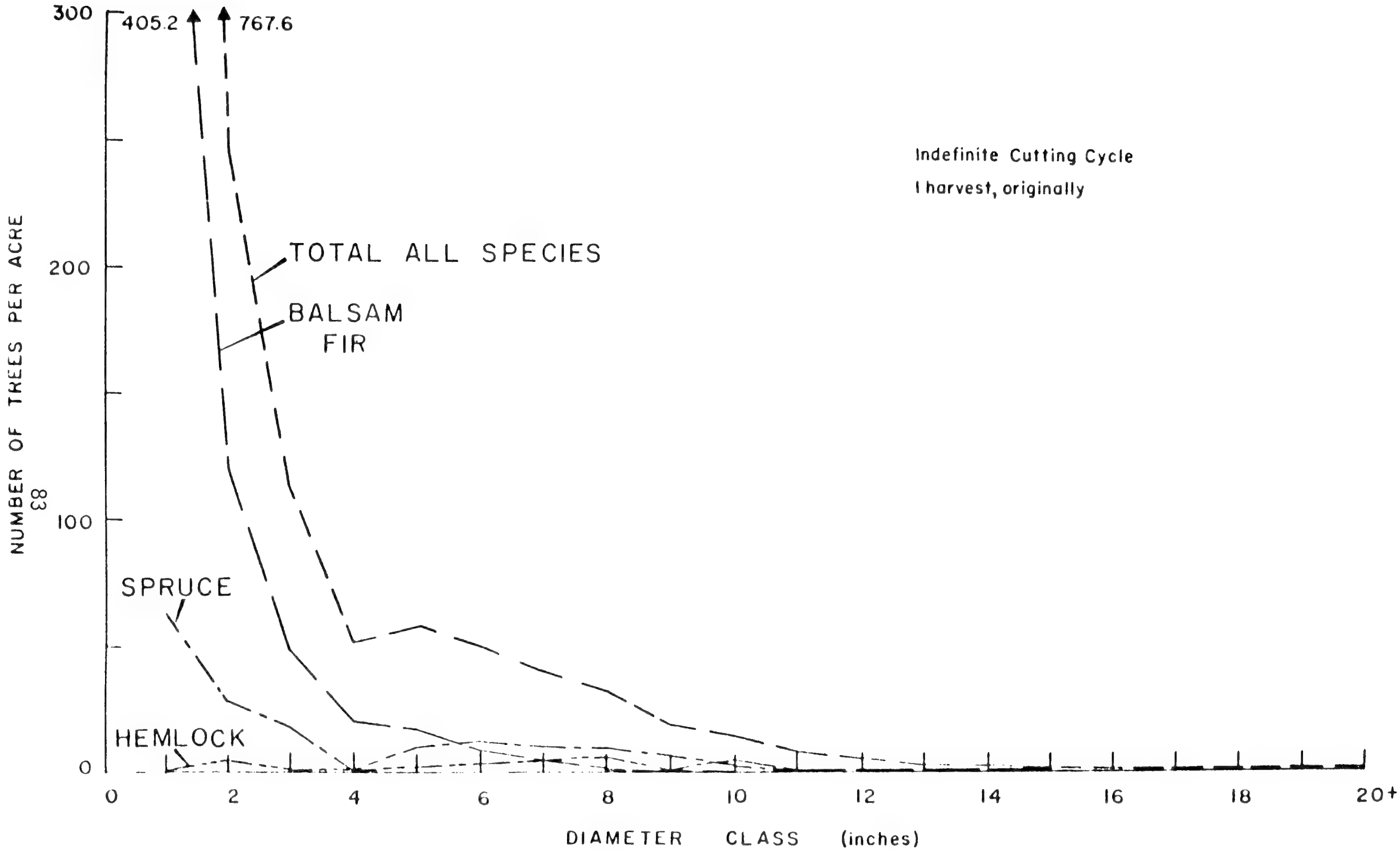

Figure 9. -- Mid-commercial clearcut - current stand diameter distribution.

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

Competition to regeneration from grape vines can be serious in central Applachian 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 unique instances, 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.

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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 pricipitation 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.

The tree species which comprise the various cover types vary genetically also. Sugar maple (*Acer saccharum*) (Kriebel and Gabriel 1969) and red maple (*Acer rubrum* L.) (Perry and Wang 1960) contain physiological races as does yellow birch (*Betula alleghaniensis*). "Tolerance" also may change (Spurr and Barnes 1973) from one region to another. Impact of disease may vary, too. The beech scale nectria disease is a serious problem in beech stands

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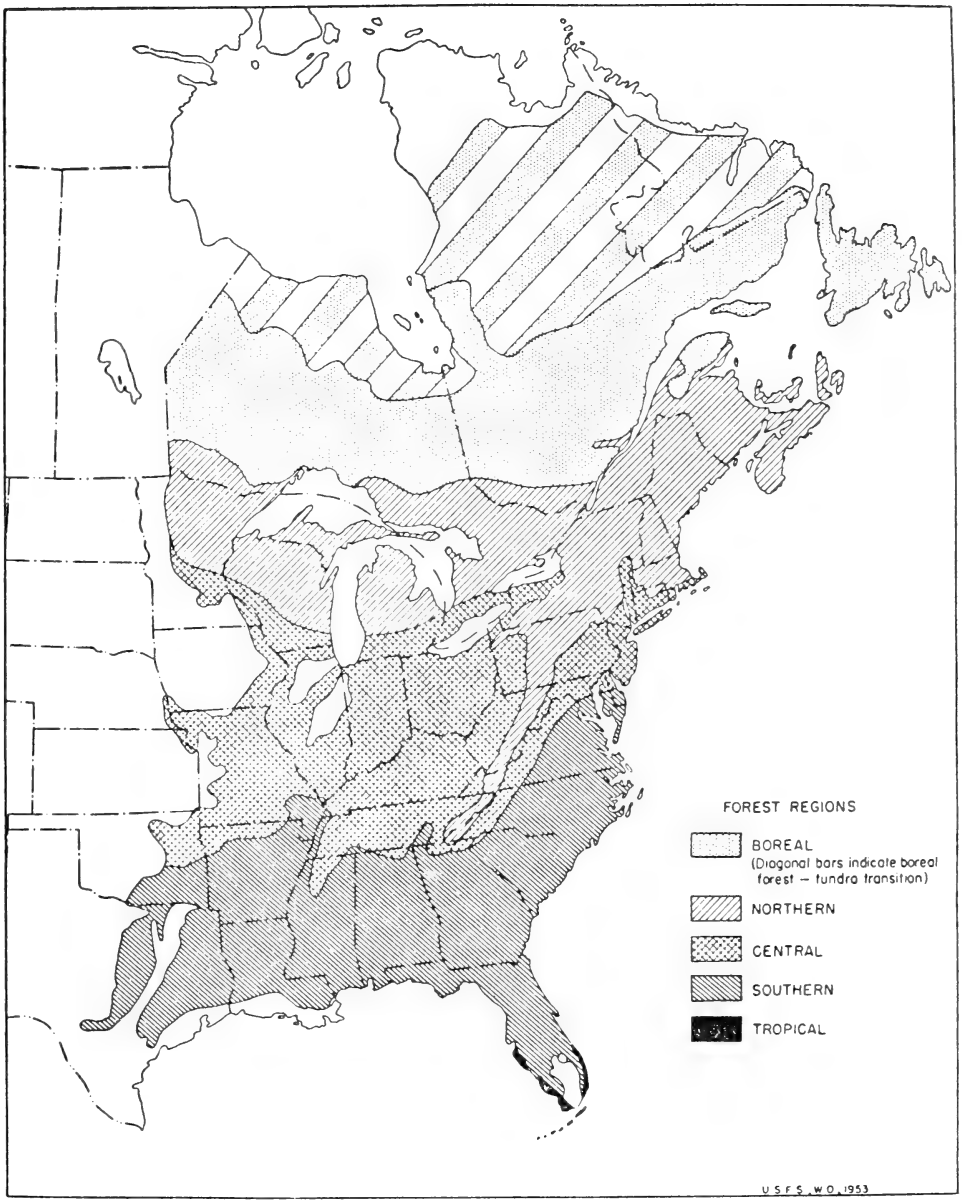
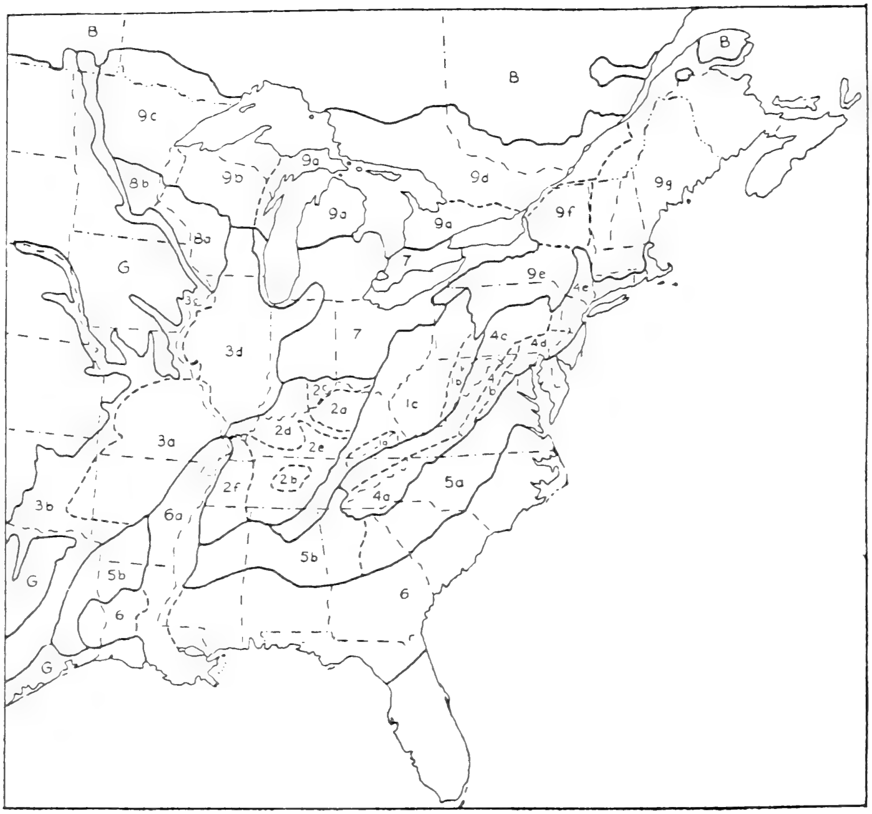


Figure 1. -- Forest regions of eastern North America.



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 RE(

   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 formatio (Braun 1964).

of the East (USDA Forest Service 1973) 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 (USDA Forest Service 1973). The same tree species found in the Lake States are severely damaged by deer in Pennsylvania and New York (USDA Forest Service 1973). 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 sawlog 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 (USDA Forest Service 1973); an uneven-aged stand is one which contains trees of different ages or sizes which intermingle singly or in groups. The older Forestry Terminology (SAF 1950) says that more than three age classes must exist in the stand while a textbook (Smith 1962) 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 nor 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 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.

	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. group selectio[n]
Red pine		Yes	Shrubs		Yes	Even-age, clearcut plant	Shelterwood wi[th] site preparati[on]
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 selectio[n]
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 tre[e] 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

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.

Maintenance of Composition

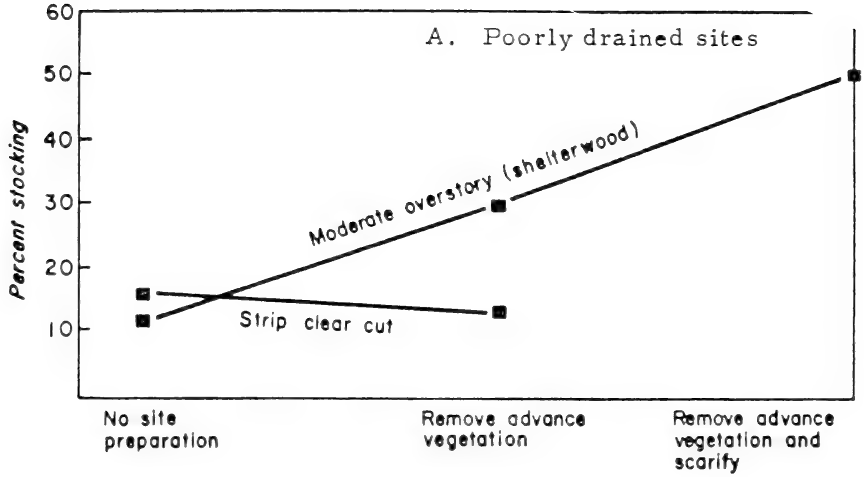
Maintenance of composition appears to be less of a problem when small even-aged or all-aged stands compose the forest, than getting desirable regeneration in the first place. Exceptions occur, however. In the Lake States, yellow birch is likely to fall out of the stand at an early age unless thinned at regular intervals.

Once established, maintenance of yellow birch requires periodic thinnings especially where sugar maple is the main competitor (Northeastern Forest Experiment Station 1969). 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 even-aged 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. Sawlog-sized trees are the fast growing elm and basswood.

This may cause problems in succeeding rotations or cutting cycles where 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. 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 some 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 require special attention. Moderately tolerant and tolerant species growth rates are similar in all-aged stands (Table 1) under a variety of conditions.

2/ Number of years after release of regeneration



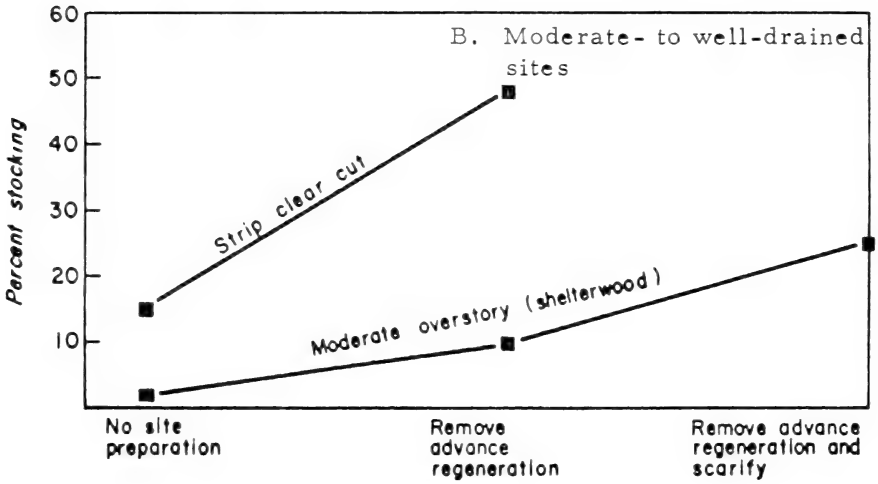


Figure 4. -- Influence of cutting method and site treatment on percent of sample quadrats dominated by yellow birch on: A. Poorly drained sites; B. Moderate- to well-drained sites.

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									

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 (Trimble 1961) but beech in northeast northern hardwood stands may require non-commercial operations for effective control (Leak, Solomon, Filip 1969). 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 sawlogs. 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 recordkeeping 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.

On the other hand, planting northern hardwood species in openings has met with limited success (Michigan Technological Univ. 1969). 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 (Hart 1964, Eyre and Zillgitt 1953, Trimble 1961). 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 sawlogs or those composed of large sawlogs.

Schemes developed on the basis of De Liocourt's (Meyer, Recknagel, Stevenson 1952) 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 (Michigan Technological Univ. 1969). 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.

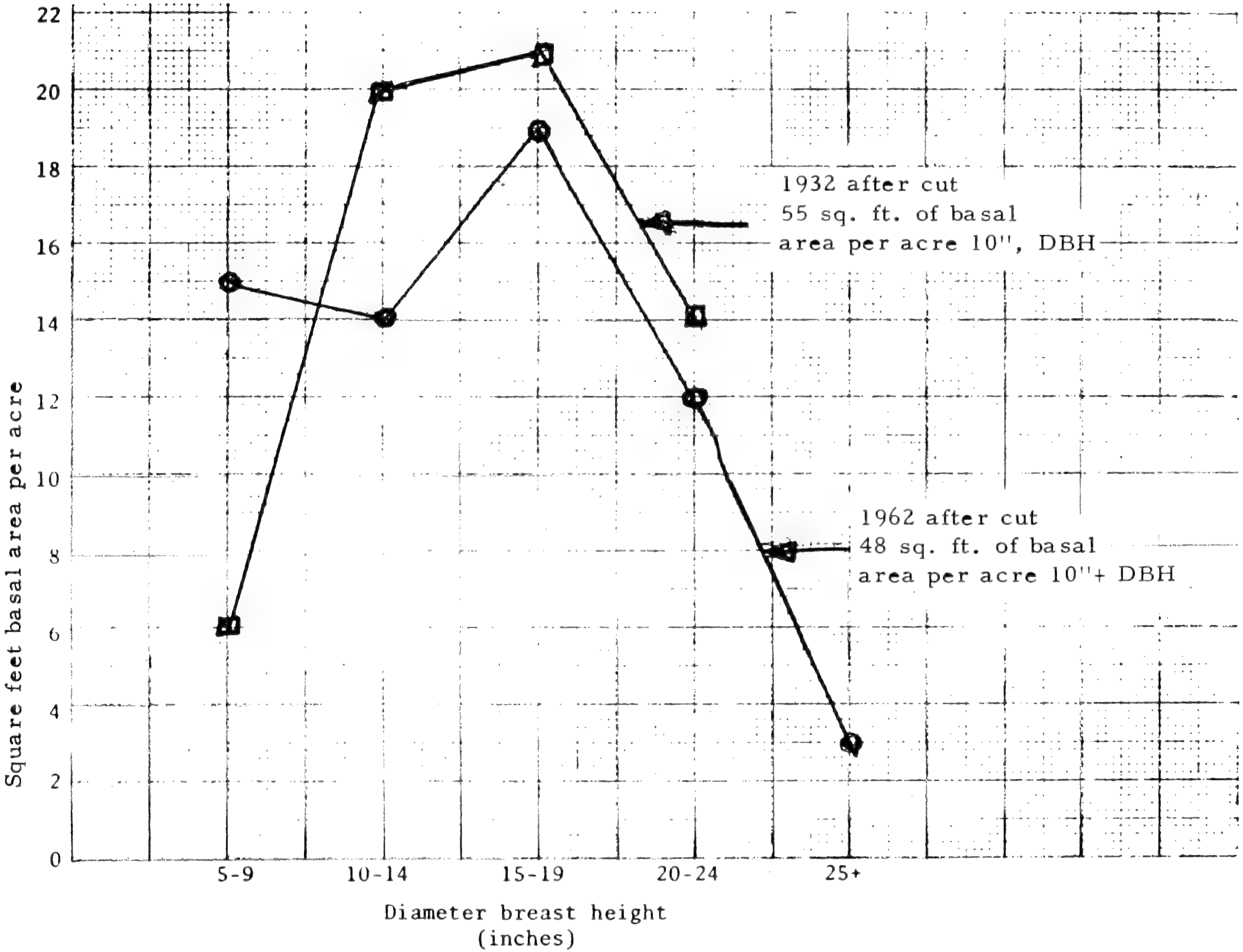


Figure 5. -- Stocking by size class maple--birch--beech stand Upper Peninsula Experimental Forest overmature and defective #2.

More apparent effects of size class deficiencies are found in stands which are deficient in the sawlog class. Usually these stands (second-growth) have no or very defective sawlog overstories and yields are reduced through the time it takes for the larger poles to attain the desired sawlog sizes. Stand density controls ingrowth into the sawlog class in these stands, too. The common practice of cutting most marketable sawlogs and leaving the pole class untouched tends to perpetuate a stand composed of poles and a few sawlogs; 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 (Trimble 1961). 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 (1973) which predicts with reasonable accuracy movement of trees through the various size classes for rotation length periods.

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.

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STAND STRUCTURE

by

W. B. Leak[1]

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.

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

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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 porportion 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 Experimental Forest (Table 3). I'll assume that markets for 6- and 8-inch

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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.

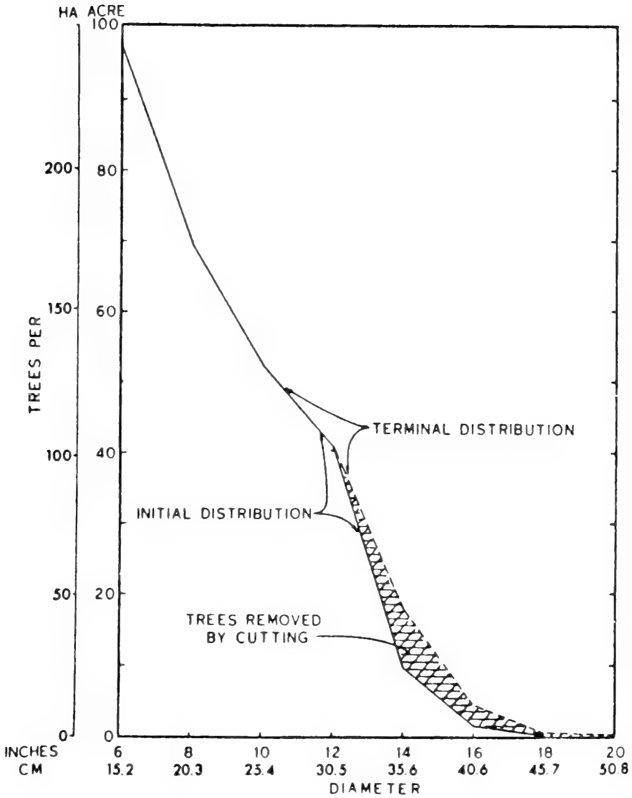

Figure 1.--Example of sustainable diameter distribution. Difference between initial (solid line) and terminal (dashed line) distributions removed by harvest (cross-hatched area). (Adams and Ek 1974).

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

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

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, silvicultural 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/] plus any poletimber removals that could be well justified as a cultural

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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.

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 the 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 ball carriers, 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.

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.

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GROWTH AND YIELD

by

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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 crosswalks 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 managing uneven-aged stands by some structural goals is to provide a balanced 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

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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 balanced diameter distribution. Once the ideal level of stocking is reached the volume removed at each cutting cycle will equal the periodic gorwth 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 trees from an older age class are often residuals from a previous

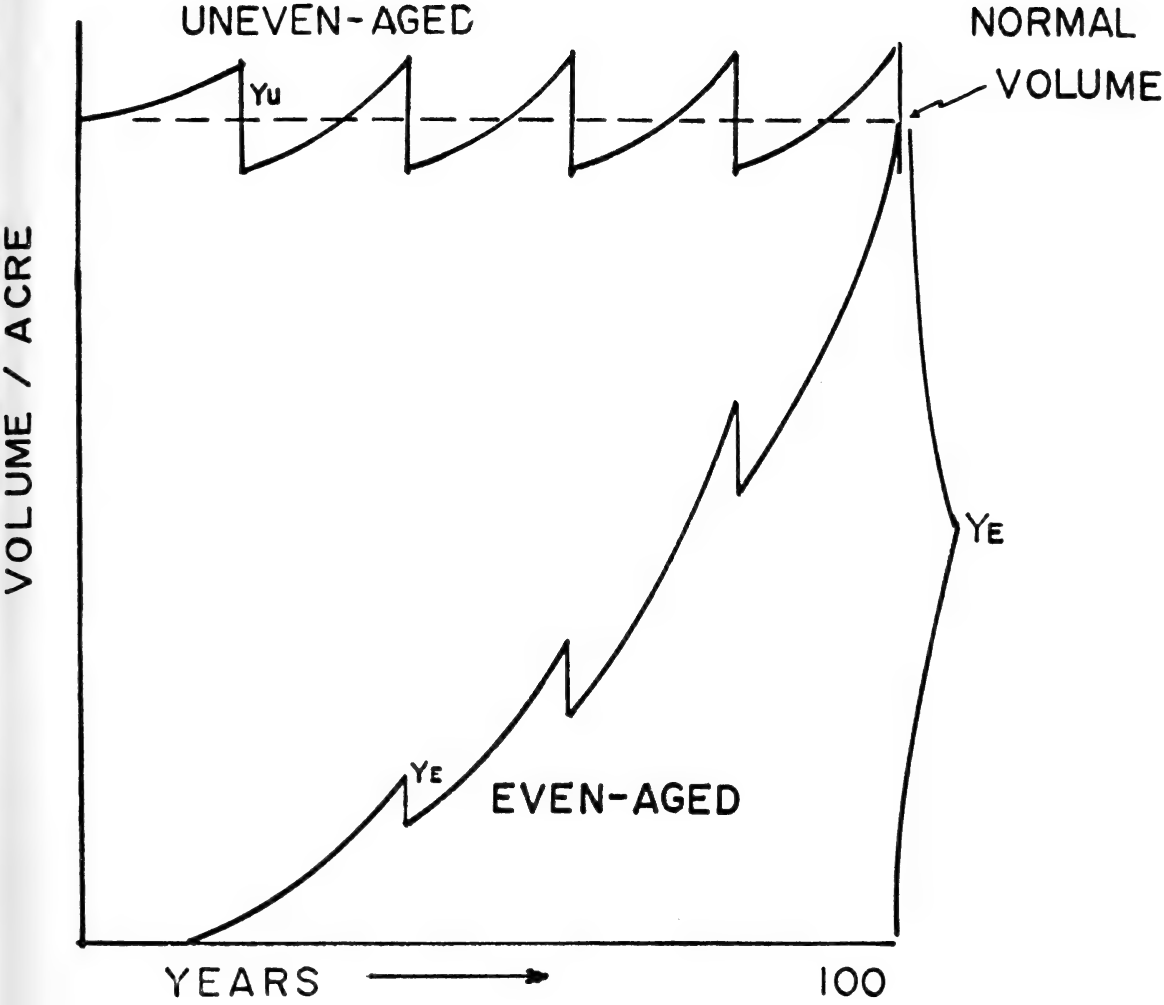

Figure 1. -- A comparison of stand development between even- and uneven-aged stands.
Y = yields

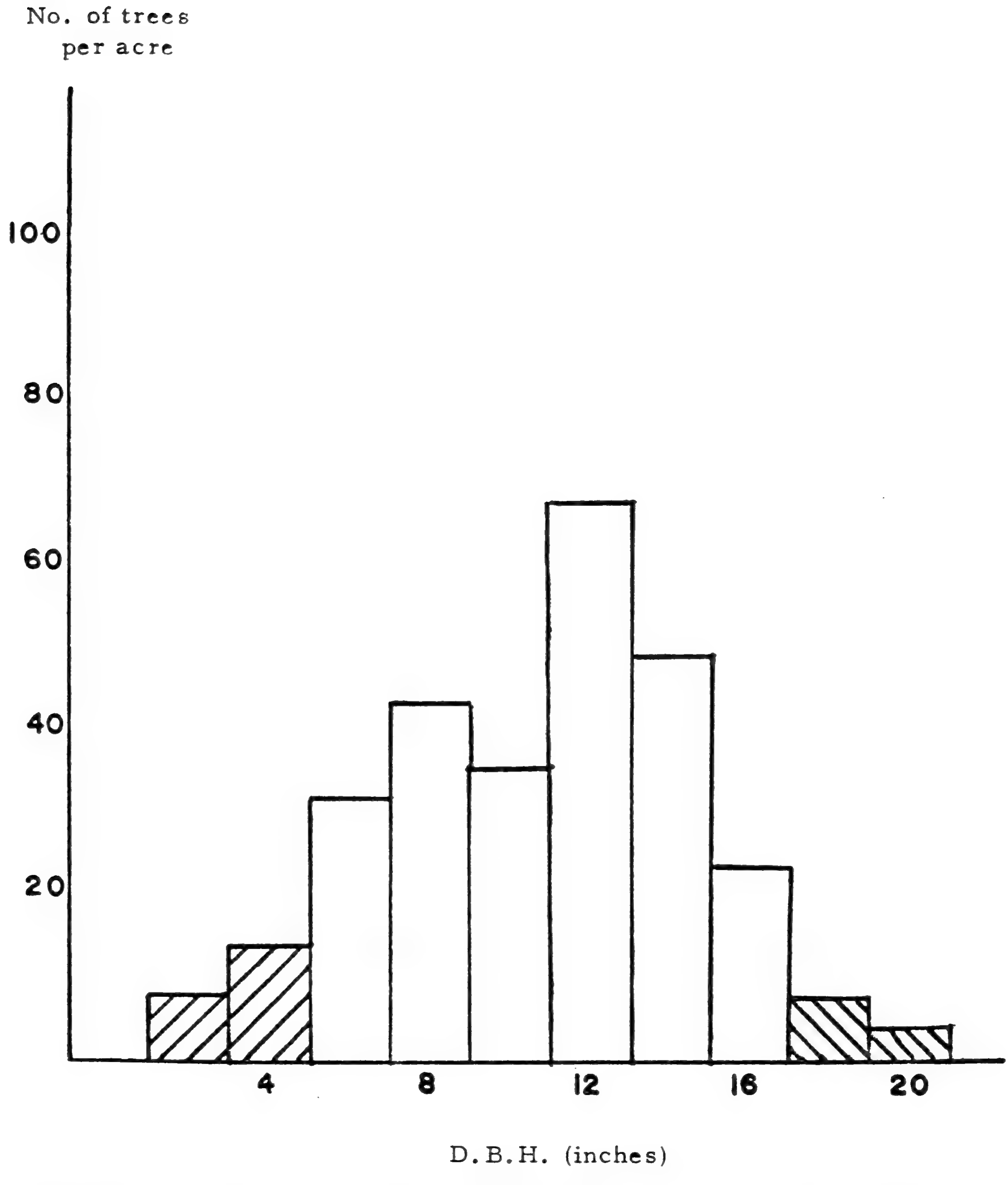

Figure 2. -- A typical diameter distribution on an even-aged upland hardwood stand. Cross-hatched areas often represent other age classes.

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 begun 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 coarse. For example, Figure 3 represents an average stand table computed from Schnur's

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.

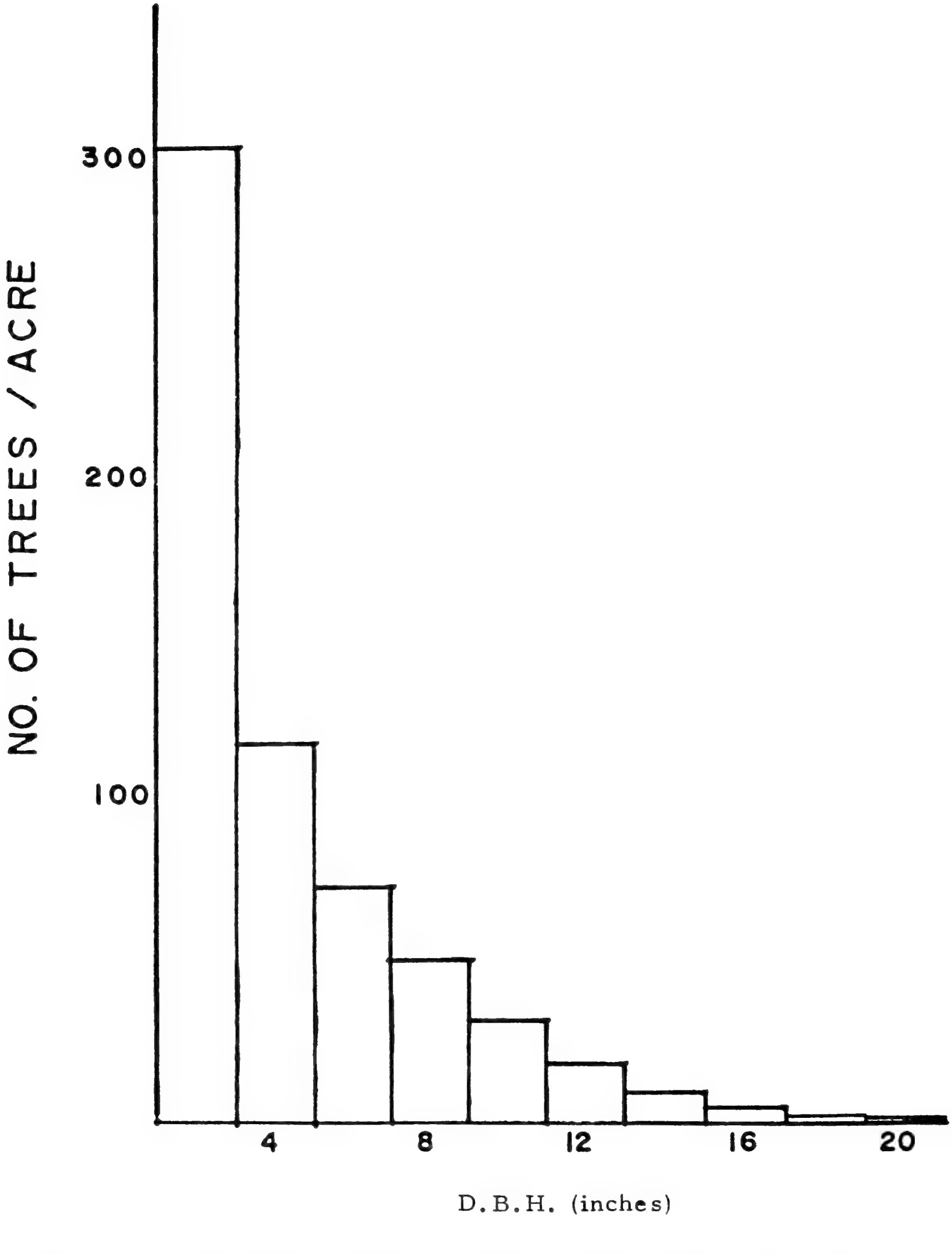

Figure 3. -- Average stand table for upland oak (Schnur) site 70.
All age classes combined (age 10.....100).

(1937) yield tables for even-aged upland hardwood stands. This is a combined 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 more growing space than 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 this 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 balanced 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)

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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 decisions 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, we 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 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.

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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 these factors when deciding which system to use or they will become extinct like dinosaurs.

Literature Review

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 in 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, and 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[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 are 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 ¼-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 Mendel 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 from 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 cost/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 MBF per acre or 20,000 MBF 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/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).

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

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 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.

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		

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-shaped curve. 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

	Low value schedule		High value schedule	
Year	Even-aged	Uneven-aged	Even-aged	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		High Value	
	Even-aged	Uneven-aged	Even-aged	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

4/ At 6 percent compound interest

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.

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 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.

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.

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REGULATION OF CUT

by

LaMont G. Engle[1/]

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 confidently apply uneven-aged silviculture in these mixtures now. If group selection rather than single-tree selection is the answer for these less tolerant species mixes we have a more difficult regulation problem. The vast area of mixed hardwoods south of the northern border fringe characterizes this condition.

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

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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. Industries that process stumpage from their own lands can more closely control and regulate their harvests.

Mother nature helps determine what we will harvest. 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 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 intensive management, good permanent 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. Exhibit 1 illustrates the classification used by the Forest Service for National Forest lands. 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 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

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	1.4	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

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 the 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). 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 have a limited supply of empirical data to calculate some mean yields. However, I question whether we have yet demonstrated the application of the selection system over a long enough time to have dependable yield data. 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 still scarce.

Rotation Age - Is it a Usable Concept?

Rotation age has no direct 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, and on public lands, multiple-use needs. Cycles could vary from 5 to 20 years depending on the interaction of all the above factors. One cutting cycle is 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 onsite 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 should maximize wood 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 and in even-aged stands that we wish to convert to all-aged condition.

We may be too optimistic in our 10-year treatment schedule of hardwoods on the National Forests. 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 other 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 may 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 the next 10 years 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 1½ rotations to ensure compliance with policy in FSM 2410.3" (FSM 2415.43). These quotes from the Forest Service Manual describe the potential yield 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 1½ rotations through which evenflow, 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 large amount of predictive yield data to meet Forest Service requirements for regulation because of the tremendous variation in structure, stocking, and quality among present stands. I can't get too concerned about a time horizon of 100 to 150 years. Neither can I get concerned during the period of transition to regulated conditions. 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 structure, they will develop stands of more uniform conditions, 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 sample 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 prescription that will result in the desired residual stand conditions after the timber harvest. 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.

DeWilton Smith of the Timber Management Staff Group, Eastern Region, prepared a chart (Exhibit 3) showing the process we hope to use in 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.

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

EXHIBIT 2

Stand Structures for Which Yield Tables are Needed

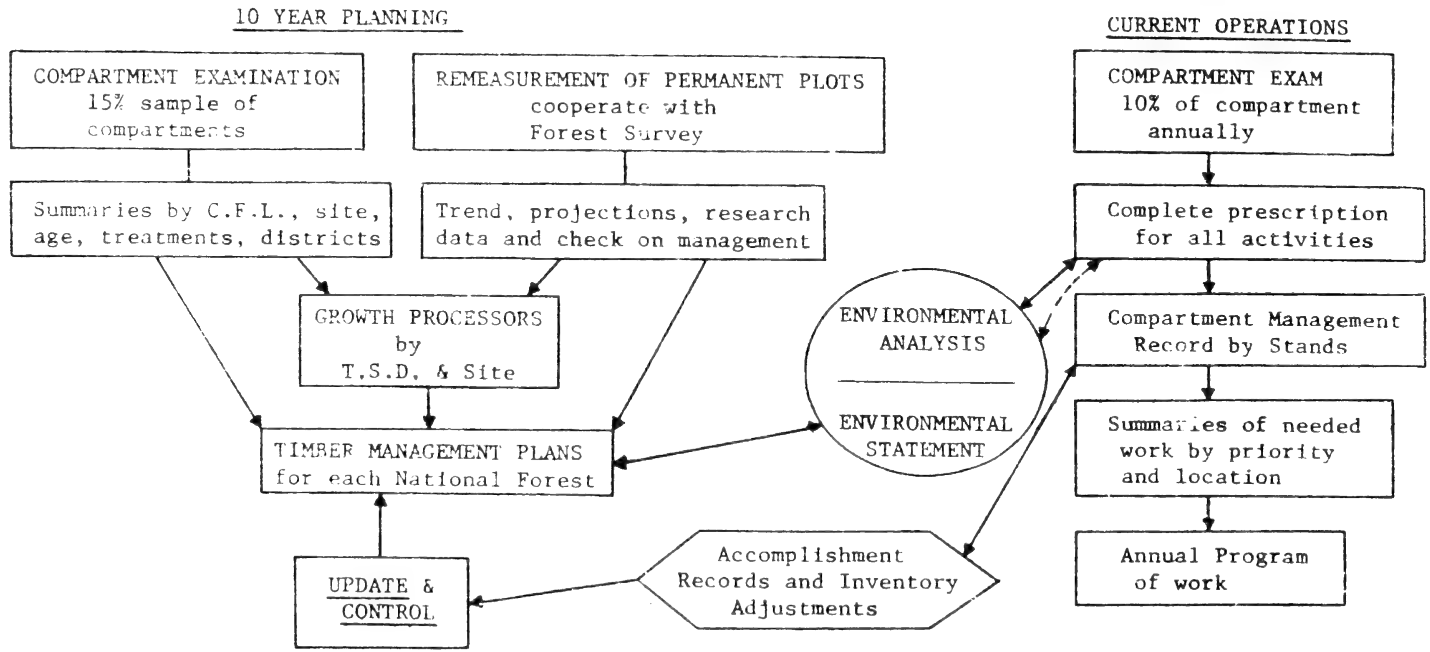
Yield Table	STAND CONDITION		
	Heavy Stocking	Medium Stocking	Light Stocking
1	Sawtimber (ST)	Poles (P)	Seed & Saps (SS)
2	ST	SS	P
3	P	ST	SS
4	P	SS	ST
5	SS	ST	P
6	SS	P	ST
7	ST	-	-
8	P	-	-
9	SS	-	-
10	-	ST	-
11	-	P	-
12	-	SS	-
13	-	-	ST
14	-	-	P
15	-	-	SS
16	-	-	-
	desired structure		

the National Forest. 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.

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, seedlings and saplings, poletimber, and sawtimber. As far as I can see, these are sufficiently fine objectives to reach over an entire stand. The marker with the paint gun

EXHIBIT 3


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

should not give first concern to structure in any one spot as much as 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 may be 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 far 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.

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 is also a major factor 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. The selection system requires more skill and care than do even-aged systems if it is to be applied successfully.

The previous two sections concerned with potential yield 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. A proposed solution to this dilemma is to reduce the size of clearcut 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 a valid method 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 FOR THE EASTERN FOREST REGIONS[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 the eastern 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/ Principal Research Silviculturist, 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 1½ 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.

PART III

UNEVEN-AGED SILVICULTURE AND MANAGEMENT IN THE WESTERN UNITED STATES

REGENERATION

by

Donald T. Gordon[1]

While putting together some of the suggested topics for this session, I became impressed by the detailed knowledge of regeneration already in print. Let me go on record as recommending study of two publications as excellent summaries: "Silvicultural systems for the major forest types of the United States" (USDA 1973), and "Silvics of forest trees of the United States" (Fowells 1965). The recent series of "status" Research Papers (Numbers 120 to 123, 1974) by scientists in the Rocky Mountain Station is an example for other stations to emulate. Many other relevant papers exist.

Within the literature are strong indications that some kind of uneven-aged management could be imposed on most major forest types, involving at least 22 relatively important species in the Rocky Mountains and westward to the Pacific. In some cases, extraordinary planning, costly initial field work, and some cost for maintenance of appropriate growth conditions would be necessary to create and hold uneven-aged stands. In mixed species forests, planning and execution would more often than not have to begin with acknowledgement that the most tolerant species would predominate. And in the West, the most tolerant species are, unfortunately, often the least desirable from the standpoint of general usefulness to man.

As I reviewed the literature, I became unhappy with what I was doing--not because of a dearth of information, but because I felt that all of you are aware of the same kinds of sources I was using. I know there is a lot of current concern with the lack of field application of information we already have, so I propose to summarize what are mostly well-known requirements for insuring establishment of regeneration, then try to relate these tidbits to a number of interactions which would be experienced by people at the operational level.

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History of Regeneration Cutting Practices

The first thing to be understood by anyone studying the Forest Service's stewardship of timber on the National Forests is that, since the beginning, both successes and mistakes have been attained by well-meaning people. In the West, there was a great practicing of various kinds of "selection systems." Some of these based on tree maturity classes succeed in removing all overmature trees from two-storied stands, and from park-like areas lacking understory. Some of the early logging was done so well that excellent released young groups remained. Some of the larger clearcut parks never regenerated. In California mixed-conifer areas, much of the new regeneration was of tolerant species, particularly white fir (Dunning 1923). Some early heavy cuttings in Arizona produced grass, and I expect most of these haven't improved much from the standpoint of ponderosa pine stocking. Many similar results have occurred with both heavy cuttings and single-tree salvage cuttings in the interior ponderosa pine type of northeastern California. There, the infrequent seed crops make planned natural regeneration all but impossible.

Differing cutting systems gave differing regeneration results in the coastal Douglas-fir region. Some large clearcuttings became stocked first with alder. Selection or selective cuttings favored hemlock regeneration, as well as exposing stands to often-severe wind damage. I can sympathize with foresters in coastal Oregon and Washington because of the rapid invasion of jungle-like undergrowth in all sizes of openings. But one problem the Pacific Northwest foresters and loggers seem to have whipped: the energy shortage. A drive up Interstate Highway 5 plainly reveals that they have thoughtfully provided residents with a fine source of madrone firewood!

Because of problems with natural regeneration, foresters turned to artificial regeneration. Most successful has been planting with bare root stock. Artificial seeding has a few adherents, but they are on the wane. The currently increasing practice is the use of so-called container stock, and particularly the use of plugs.

Two recent developments can be cited for interest in the regeneration area: reduction in size of clearcuts in several species, and attempted use of stand structure as a control in applying silvicultural treatments. We can hope for and work toward better application of relatively assured methods of getting natural regeneration.

The Place of Artificial Regeneration

I fail to see how artificial regeneration can be used successfully in areas under uneven-aged management. The exception to that flat statement might exist when numerous closely-spaced small openings are created at each entry into the stand. The principle involved is that where travel time between planting areas constitutes a small percentage of planter's time, the work might be economical.

Genetically superior stock might be introduced, but keeping track of it might be difficult. Although we have all inferred from pictures in texts that many small areas are planted, and interplanted, in Europe, it's my understanding that current economics prevent some of these past practices. I have not seen a report on artificial regeneration of conifers for an uneven-aged timber stand in Western States.

Basic Principles in Getting Natural Regeneration

By this time the Forest Service should have acquired expertise in natural regeneration methods concerning both what to do and what not to do. We have operated for decades as if we expected to get natural regeneration as a result of our cutting practices. We have found some conditions and places where we couldn't miss, and others where cattlemen have been happy with the results through several decades. But we have acquired a lot of expertise in regeneration, and this enlightened assemblage is more aware of it than most other layers within the Service. Perhaps meetings like this serve a useful purpose, but ways must be found soon to bring the expertise represented here to bear directly on resource management. In my opinion, evidence on the ground indicates that the influence of groups such as this is less than we'd like to think it is. I have been cheered by the principles in the silviculture certification program, but saddened by the sight of some recent timber marking by a relatively untrained person.

The following list of principles for getting natural regeneration is fairly extensive, but I believe strongly that these items must be considered by anyone entrusted with a plan or a paint gun:

a. Prevent the destruction of all healthy seedlings which are established.

b. Seed source--consider quality and quantity of individual trees to be left and their relationship to areas requiring regeneration with respect to wind and shade patterns, and dispersal characteristics of desired seed.

c. Seed crop frequency, factors affecting soundness of seed crop, and time lag in securing regeneration.

d. Size of area to be regenerated:

   (1) influence of wanted or unwanted tree species;

   (2) influence on potential development of low-growing competitive plants;

   (3) effect of nearby large trees on growth rate of desired reproduction;

   (4) influence of stand opening on subsequent damage from wind and other factors;

   (5) spatial relations influencing possible spread of pathogens like dwarfmistletoe.

e. Seedbed requirements for wanted species, including:

   (1) special soil problems like compaction or excessive looseness, deterioration of fertility;

   (2) necessary or desirable slash treatment, including disposal of large pieces of cull material.

f. Competitive plants and trees--possible utilization, control, or elimination.

g. Dependence on unusual meteorological patterns for successful establishment:

   (1) critical timing of rain;

   (2) absence of severe frosts during growing season;

   (3) absence of excessive isolation.

h. Relationships of wild and domestic animals--possible needs for total or partial control methods.

i. Growing space requirements for proper development of new reproduction within reasonable time periods:

(1) thinning needs of small trees;

(2) removal of large nearby trees through harvesting.

j. Relationships to topography, aspect, erosion, and the total transportation system.

Interaction of Special Problems, Natural Regeneration, and Uneven-aged Management

The title of this section may cause you to visualize a basket category like that infamous file heading "Miscellaneous." But the section may prove to be more like a sieve than a basket, and serve as a starting point for a discussion to follow. I think we will find that problems will be solved validly through biology and economics, and not by politics.

One of the problems perhaps can be called "What the heck are we going to do here?" For a whole sale area there's a broad decision like "indulge in multiple-use." But breakdowns often occur for travel zones, stream zones, distant viewing, and so on. And we can still decide to grow trees in many places for people's consumption. Therefore, decisions often must be reached for fractions of hectares. To produce trees primarily for harvesting, I urge more emphasis on even-aged management than on uneven-aged management. For purposes of near-viewing, for campground screening, for protecting streams for riparian life, for special protection of sensitive soils and slopes, I think there's a good chance to derive special benefits from uneven-aged management--even for the single tree selection system. As professional foresters we must reach one agreement regardless of hierarchy: "no more regeneration cutting where we can't assure regeneration."

A special problem associated with all aspects of uneven-aged management is the cost of administering or supervising activities. I fail to see how such costs can avoid exceeding costs of even-aged management. Who will define these costs and accept them?

On-the-ground work for Forest Service personnel, and loggers and other contractors, would have to be more sophisticated for uneven-aged management compared to even-aged management. The Service is consciously trying to up-grade its performance. Encouraging the private sector to undertake a comprehensive training program for its woods-going personnel by some direct means also would be beneficial. I can't avoid the feeling that the proliferation of specifications in Forest Service contracts, and various State forest practice laws, is trying to tell us something, so to see a few beneficial changes in forest work practices is disappointing.

These remarks may seem tangential to my assignment of "regeneration," but I see more regeneration problem areas than necessary being created in the woods--places too small to plant, in areas which probably will not regenerate naturally or areas which the manager will forget because he either judges them to be too small to worry about or has no established inventory system. The frequent entries required by uneven-aged management could produce an increasing loss of productive area unless these problems are solved.

How do you administer the regeneration phase of production in uneven-aged stands? Somehow you must transform theories and estimates of a management plan into adequate quantities of desired species of seedlings where and when they are needed on the ground. A true individual tree selection system would deal with units of area so small that they could scarcely be mapped, especially by any of the computer-oriented mapping systems. Accurate information on stand regeneration could be gained in such a system only by repeated and expensive walking by a person qualified to make silvicultural, mensurational, and management judgments and decisions. That person's problem would then become one of communicating locations and work orders to his associates. The neatest way to avoid this pickle is to grin and be happy with whatever seedlings from natural seedfall you happen to get. And don't lose your grin if you learn you're converting to the most tolerant species, and maybe wearing out the ground in some places, or even getting some unstocked areas.

As soon as you move away from individual tree selection, you get into group-selection and semantics. David Smith's (1962) silviculture textbook offers some suggestions on how large a group may be, but the Society of American Foresters (Ford-Robertson 1971) didn't expose its neck that far. There seems to be no debate about the fact that groups are even-aged units. Artificiality enters our definitions as soon as we create a size limitation to separate a selection system group from an even-aged system group. I get the unhappy feeling that either I lack understanding, or we may be perpetuating some historical sloppy thinking. Can we eliminate confusion between "group selection" and "clearcutting?" The Forest Service is working on the characteristics of different methods of logging, and I hope more emphasis is placed on it soon. Knowledge of logging systems by managers should help to improve woods practices. I recently saw some tractor logging on private ground so steep I

I wondered what was holding the road up. The operation appeared to be destructive in several ways. But I will confess that I know so little about cable systems that I couldn't begin to recommend anything better, except to stay out.

Attaining and maintaining a desired species mix is a good trick. Proper distribution of age and size classes in uneven-aged stands presents other problems. And once you get spacing into the picture, in some circumstances you begin to get new regeneration--frequently the most tolerant and undesirable species. In some places aggressive hardwood sprouts take over. I have just recited some of the early problems encountered by the University of California Department of Forestry and Conservation at its Blodgett Experimental Forest during early phases of a study to test uneven-aged versus even-aged management in a high site central-Sierra Nevada location (personal communication from Rudolph F. Grah). So far the study is concerned with silviculture and mensuration. Limited financing has prevented a study of costs under each system of management.

We know that large trees--even poles--either as individuals, or constituting edges adjacent to groups of small trees, affect growth rates of nearby small trees. On an absolute basis, this effect appears adversely greatest on poor sites. So we need to know much more about the interaction of regeneration requirements with respect to space released for seedling establishment, and the effect of tree spacing and size of groups as they relate to seedling species, numbers, and progressive growth rates. Just getting a lot of the right kind of regeneration quickly may seem like quite an accomplishment to most of us, but that isn't good enough. We also need acceptable seedling growth.

As far as I know, the relative values of uneven-aged and even-aged management of western forest lands are still matters of opinion. If this isn't true, I would appreciate someone's telling me so.

And in case I appear to be out of step, I would like to introduce a fellow who seems to agree with my obvious bias. In this case my man is T. R. Peace (1961), who was Chief Research Officer of the British Forestry Commission when he delivered a paper entitled "The dangerous concept of the natural forest." I hope you'll enjoy this choice bit of literature as I have. Here are some of his ideas.

> Relative to agriculture, forestry is still a very young science. Long after man had started to cultivate food

crops on an artificial basis, he was still getting the timber he required from the exploitation of natural forests. Today, especially in Europe, forests are being continued or created on a large scale by artificial or semi-artificial means, but nevertheless the bulk of the World's timber still comes from natural, rather than artificial, forests. Thus, while the agriculturist has no experience of the days when man gathered berries in the woods or edible leaves and grains in the prairies, and naturally tends to regard the few primitive peoples who may subsist in this way as incredibly backward, the forester can still see the magnificence of some of the natural forests untouched by man, and tends to use them as a measure against which to assess the success or failure of his own efforts. The contrast shows nowhere more clearly than in the field of selection and breeding. In agriculture, man has for centuries been selecting and breeding both his animals and his plants for increased production and better quality. Only in the last thirty years has the forester realized that the same could be done for forest trees. . . .

It is clear that the natural forest is worthy of considerable study, since it provides an example of trees and their accompanying organisms established in a relatively stable and balanced environment. As such it may well give information of value for managed forestry. It becomes dangerous only when it is elevated to the level of a concept of desirability, as an example which foresters should endeavor to copy. Used in this way it can lead, and has led, to the adoption of practices, not because they will give enhanced and sustained production, but merely because they appear relevant to this unthinking ideal. . . .

There has always been a tendency in a growing and imperfectly understood science, such as forestry, to enunciate at an early stage general principles, which it is hoped may serve as signposts through the fogs of ignorance. Biologically at any rate, such a procedure is almost invariably dangerous. The interactions of organisms with one another and with their environment are so complex that what appears at an early stage to be rules, may merely be coincidences. At present we lack the necessary basis for any embracing simplifications. If we are to make progress in the acquisition of the knowledge that is so necessary for a proper understanding of forest processes, it is dangerous to limit ourselves at this stage by enunciation of general principles, even if they appear to have a moderately sound foundation. To burden ourselves with a concept as vague and ill-founded as the inherent desirability of the natural forest is doubly dangerous.

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EFFECTS OF UNEVEN-AGED MANAGEMENT ON SPECIES COMPOSITION

by

Jerry F. Franklin[1/]

My assignment is to consider our knowledge of relationships between uneven-aged management and stand composition. Will selection forestry lead to undesirable shifts in the species composition of our forest stands? Is uneven-aged management for a preferred species in a given forest type possible?

In Table 1, I have tried to synthesize (mostly from Agriculture Handbook 445) the potential for uneven-aged management without shifts in species composition. During the construction of the table and review of the eastern workshop proceedings, I have tried to identify generalities which are relevant to consideration of management alternatives. The bulk of my paper will be their presentation and illustration with examples. Note that only the species compositional consequences of selection cutting are being considered, not the overall feasibility of actually practicing uneven-aged management in a given type.

1. Forest types composed of shade-tolerant species will undergo no major shift in composition under uneven-aged management. Assuming thatthe tolerant species is also the preferred one for the site, selective management is obviously feasible.

   In Table 1, we can see that most of the subalpine forest types fall into this category. Major constituents, such as Engelmann spruce and subalpine fir in the Rocky Mountains, are shade tolerant. By tailoring the silvicultural prescription the uneven-aged systems can even be made to discriminate (to some degree) between two or more tolerant species.

   In western hemlock--Sitka spruce we have an example of a type suited in autecological requirements to selective management--

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Table 1.--Potential for uneven-aged management without changes in species composition by forest type and preferred species (based mainly on Agriculture Handbook 445).

Forest Type	Preferred Species: Name	Preferred Species: Shade Tolerance	Selective Cutting Possible Without Species Shift
Western Hemlock-Sitka Spruce	Western hemlock	Very tolerant	Yes, but not applicable for other reasons.
	Sitka spruce	Tolerant	Yes, but not applicable for other reasons.
Coastal Douglas-Fir	Douglas-fir	Intolerant	No, shift to western hemlock.
Redwood	Coast redwood	Tolerant	Yes.
	Douglas-fir	Intolerant	No, shift to more tolerant associates.
Sierran Mixed Conifer 1/	Sugar or ponderosa pine or Douglas-fir	Intolerant	Generally no, shift to white fir and incense-cedar.
Rocky Mountain Mixed Conifer 2/	Ponderosa pine or western larch	Intolerant	No.
	Douglas-fir	Intolerant	Sometimes (if more tolerant associates absent).
	Grand fir	Tolerant	Yes.
Lodgepole pine	Lodgepole pine	Intolerant	Often yes (other species absent) but not applicable for other reasons.
Ponderosa pine 3/	Ponderosa pine	Intolerant	Usually yes (more tolerant associates absent).
Southwestern Mixed Conifers	Several	Variable	Often preferred method.
True Fir-Mountain Hemlock	Noble fir or Douglas-fir	Intolerant	No, shift to hemlocks and/or Pacific silver fir.
	Hemlocks or Pacific silver fir	Tolerant	Yes.
Red Fir-White Fir	Red or white fir	Tolerant	Yes.
Engelmann Spruce-Subalpine Fir	Engelmann spruce or subalpine fir	Tolerant	Yes

1/ Includes "California Mixed Conifers" and "Mixed Conifers of Southwestern Oregon" in Agric. Handbook 445.
2/ Includes "Mixed Pine-Fir of Eastern Oregon and Washington", Rocky Mountain Douglas-Fir", "Western Larch", and "Western White Pine and Associated Species" in Agric. Handbook 445.
3/ Includes "Northwestern Ponderosa Pine", "Pacific Ponderosa Pine", "Rocky Mountain Ponderosa Pine", "Southwestern Ponderosa Pine", and "Black Hills Ponderosa Pine" in Agric. Handbook 445.

i.e., no major problems with species composition. But uneven-aged management is not considered generally suitable for other reasons, particularly because of windthrow.

2. A forest type dominated by an intolerant tree species, <u>but</u> in which the species is climax due to absence of more tolerant associates, presents no compositional problems to selective management. No shift in composition will occur and the species can be perpetuated using an uneven-aged system.

   Several widespread examples of this exist (Table 1). Many of the ponderosa pine forests are of this type--they occur essentially as monocultures on sites where more tolerant competitors grow poorly or not at all. Lodgepole pine forests of this type are to be found in the Rocky Mountains and in eastern Oregon. Mountain hemlock forests in the southern Oregon High Cascades are a third example.

   These examples illustrate several other key points as well. First, for considerations other than compositional, selection management has been and is widely used in some of these types (pondersoa pine--insect risk) and considered inappropriate in another (lodgepole pine--windfall pathogens). Second, the sites occupied by such forests (monocultures of intolerant trees) are typically very severe; selection cutting can be essential in such situations.

3. Forest types or stands where intolerant species are dominant and preferred, and where there are prolific shade-tolerant associates, are those where compositional shifts are major constraints on uneven-aged management. Selection systems will inevitably favor an increasing percentage of the more tolerant species. Particularly where the associates are aggressive (generally the more productive or favorable sites) nothing short of the shock associated with clearcutting will be sufficient to keep the shade-tolerants in check.

   Our classic illustration is the coastal Douglas-fir type where the preferred Douglas-fir is typically subject to continuing successional pressure from species such as western hemlock, western redcedar, and Pacific silver fir. On most of these sites limited experience and logic and intuition (which go to make up our conventional wisdom) indicate that Douglas-fir will not hold its own under single tree or group selection.

The mixed conifer types of the Sierra and many of those in the Rocky Mountains will also undergo compositional shifts with selective cutting. Whether these are undesirable or not depends upon the preferred species. It is clear that on habitats that will support more shade-tolerant species (white fir, grand fir, or on some, even Douglas-fir) selective management for the soft or hard pines or for western larch is going to be difficult.

4. From the above examples and Table 1, it is clear that consideration on a species' shade tolerance is not a guide to whether it can be managed selectively. I have cited several examples of an intolerant species which can potentially be managed selectively because of the absence of aggressive shade-tolerant competitors. There are even xeric habitats within the heart of the Douglas-fir region where selective management of Douglas-fir is possible and (perhaps) even essential. Which leads to the next point.

5. Considerations of habitat type are essential in determining whether compositional shifts are going to be a problem. It is the environment, the habitat type, which is going to determine whether species are going to turn up against aggressive competitors. On some sites it will be, and on others it won't. Ponderosa pine is an obvious example. Ponderosa pine type on habitat types where it is climax are highly suited to uneven-aged management. On habitat types where Douglas-fir, grand fir, or white fir are climax, uneven-aged management of ponderosa pine has marginal utility.

   The need to consider the species in the context of a particular environment or habitat type is so obvious you might wonder why I bring it up. Partially to remind us of our good fortune in the Western United States in the distinctiveness of our habitat types and progress we have made in recognizing them. We need to use them more extensively in our silviculture prescriptions, i.e., move away from talking about forest types and talk more about a species and its competitors on specific habitat types. In reading the proceedings of the eastern uneven-aged management workshop, it was apparent in several papers that they feel an acute need for something like habitat types and do not have them. For example, Carl Tubbs concludes his paper, "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." Our western habitat type work gives us an excellent handle on such variations.

6. These are two broad classes of habitat types or environmental conditions about which some useful generalizations are possible--the very severe, hot and dry sites and very productive moist and moderate sites.

   On hot, dry forest sites light is not a major limiting factor--moisture and temperature are the factors which "sort out" species relationships. Shade tolerance has little relevance since stands often lack a closed forest canopy. On this broadly defined set of sites (hot, dry) uneven-aged management is often the safest, most dependable system for perpetuating forest cover. Indeed, on severe sites, it is clearcutting that is likely to result in undesirable compositional shifts.

   At the other extreme are the series of mesic, moderate, highly productive habitat types such as the swordfern group along the northwestern coast. Here we have to seriously consider competition from understory plants as well as from other tree species. It is possible that uneven-aged management could lead to structural (as well as compositional) shifts--from trees to tall shrubs and herbs!

   A recent request from the Siuslaw National Forest to appraise the potential for selection management of western hemlock on steep headwall areas brought this possibility clearly into focus. Periodic entry in such stands (with western hemlock as the acceptable species) could tend to gradually convert the area from forest to shrubfield. Logging would remove the major seedbed for the hemlock (down logs) and the opening of the overstory would bring quick response in the understory shrubs (e.g., salmonberry) and herbs.

   Such compositional shifts are, perhaps, more properly considered under regeneration problems. There is, however, clearly a class of sites where shrub and herb composition can make regeneration of any tree species difficult thus limiting potential from uneven-aged management. This is analogous to the severe site where the environmental constraints make regeneration of any tree species difficult and thus limit the potential for clearcutting.

7. Ultimately, the shade tolerance of a preferred species or, more generally, the environmental conditions necessary for successful establishment and growth of regeneration, is rarely, if ever, the major constraint in applying uneven-aged management. Stated another way, the trend toward undesirable or unacceptable compositional shifts can probably be handled by going to group selection, underplanting, and other cultural operations.

In effect, I am suggesting that most tree species have ecological amplitudes for establishment and subsequent growth great enough to allow for use of a variety of systems. Factors other than the ecology of the tree species tend to be determining--economics, overall environmental impacts of different densities of road systems and entry schedules, pathogens and wind, etc. And foresters can be grateful at the plasticity of the materials they deal with.

To illustrate we can perhaps refer again to coastal Douglas-fir. It is not the intolerance of the species or the aggressiveness of its competitors that really limit the potential for uneven-aged management. It is, in fact, factors such as:

the costs of harvest cutting in small groups;

the costs of cultural treatments to maintain the Douglas-fir component;

the damage done to boles, roots, etc., of residual stems in felling and yarding these tall, large diameter trees;

soil and watershed damage associated with greater densities of roads, frequent stand entries;

possible reductions in yields;

etc.

We know that it is technically possible to regenerate and grow Douglas-fir in patch cuts of 1/4 to 1 acre in size. Economically and environmentally the costs are too high on ordinary forest lands, however.

8. We have to be very careful in considering the overall ecological impacts of uneven-aged management on recreational lands, at least in some parts of the western United States. Uneven-aged management is viewed as a way of obtaining some yields while maintaining a high forest cover and an array of values, particularly aesthetic. Undesirable functional as well as compositional changes are possible, however. For example, the natural tendency is to remove dead and down along with the selection of green trees in a given entry. Yet at least some of this material is critical, not only for wildlife habitat, but also as seedbed for tolerant tree species in coastal conifer forests. Frequent light entries can result in accelerated stand deterioration as the stand is opened up to wind, root systems are damaged, etc.; we may be better off letting "nature" identify small groups or patches for cutting rather than attempting to practice single tree selection over an entire tract.

   Shifts in species composition are considerations even on recreation sites but for different reasons--aesthetics, a resistance to human impacts than on other forest lands where wood quantity and quality may be major concerns.

9. In conclusion, it is probably technically possible to practice some form of uneven-aged management with the western forest types and species without undergoing unacceptable shifts in composition. Both the autecology of a species and its successional role on a specific habitat type (existing and potential competitors) have to be considered. The strongest tendencies toward shifts in species composition come on the environmentally moderate to very favorable sites where a preferred intolerant species is subject to successional pressures from aggressive tree (and sometimes shrub and herb) competitors.

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STAND STRUCTURE

by

Marvin W. Foiles[1/]

Silviculturists and forest managers in the Western United States are somewhat behind our counterparts in other areas of the world in the application of uneven-aged management in our forests. Many of us have lived through periods of "selective cuttings," "economic selection," and other extensive management practices that approximated selection systems of uneven-aged management. However, we cannot match the long history of Europe and Eastern U.S. in uneven-aged management. Nevertheless, increasing attention to forests and their management has begun to focus interest in selection management for a number of reasons. It thus seems to me an appropriate time for this meeting to assess the present state of knowledge and to discuss the future of uneven-aged management in our area.

My assignment was to lead a discussion of stand structure; so perhaps I should start with a definition of what we are to discuss. The term "stand structure" mostly refers to diameter distribution--numbers of trees by d.b.h. classes. Size distribution implies a related age distribution, but for many stands, that implication is misleading. However, much of the available information presents age distributions, so they may enter the discussion also. In discussing stand structure, we cannot avoid mention of stocking or density, species composition, growth and yield, regeneration, and other parts of the total management system because they are all interrelated.

Balanced Stand Structure

There is considerable difference of opinion as to what growing stock a well-stocked, uneven-aged forest should contain and the best size distribution. However, there is general agreement that the eventual goal is a balanced structure that will produce a sustained yield and fairly even flow of harvests from a forest property.

At one time, structures of even-aged stands were used to try to develop structures for all aged stands. The theory was that sustained yield from a property could be attained from a series of even-aged stands in which

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each age class was allotted equal area. It followed that in an uneven-aged forest the age classes should be represented in the same proportions as in the even-aged system. That idea has been discounted by a number of authors who illustrated that a fully stocked selection forest has a greater proportion of growing space occupied by the larger size classes and that the number of trees in the smaller sizes may be much less than in the even-aged system.

The most popular theory of stand structure at present is the familiar inverse J-shaped curve of numbers of trees by d.b.h. classes. DeLiocourt originally recognized that a balanced structure characteristic of a normal uneven-aged forest consists of a decreasing geometric series of numbers of trees in successive diameter classes. When that distribution is plotted on semilogarithm paper, the result is a straight line. Each of these distributions is described by a value q, which is the quotient of the number of trees in one diameter class divided into the number of trees in the next smaller diameter class. The q value should remain nearly constant throughout the distribution. The value of this ratio varies with changes in the proportion of small, medium, and large size trees.

Actual examples of balanced structure in managed stands are difficult to find. Figure 1 was plotted using data I borrowed from Gil Schubert in Arizona. Schubert derived some diameter distributions of ponderosa pine from the levels-of-growing-stock study at Taylor Woods. Table 1 contains Schubert's recommended size class distributions for a number of different growing stock levels. The structure for growing stock level 80 is illustrated in Figure 1. You can see that the curve is very smooth and regular. It makes a very straight line when plotted on semilog paper. Schubert did not use a q factor to develop the distribution, but it does fit a distribution of q=1.22.

It is very unlikely that any actual stand will have as smooth a distribution as shown in Figure 1, but that idealized structure makes a good guide for future cuttings. If such an idealized model of a sustainable distribution is available, cutting can be concentrated in those size classes with more trees than the model distribution curve.

Most of the time it is not necessary to maintain a very close adherence to the model distribution. In fact, it is nearly impossible when one considers the variability of regeneration, mortality, and tree growth. My experience with ponderosa pine indicates that adequate regeneration is unreliable in regular time intervals. Good seed crops combined with favorable weather conditions and site preparation occur at irregular intervals. Irregular waves of regeneration will create irregular humps or valleys in the rest of the distribution. Harvest cuttings may be controlled more by requirements for regeneration than by the stocking level giving optimum growth.

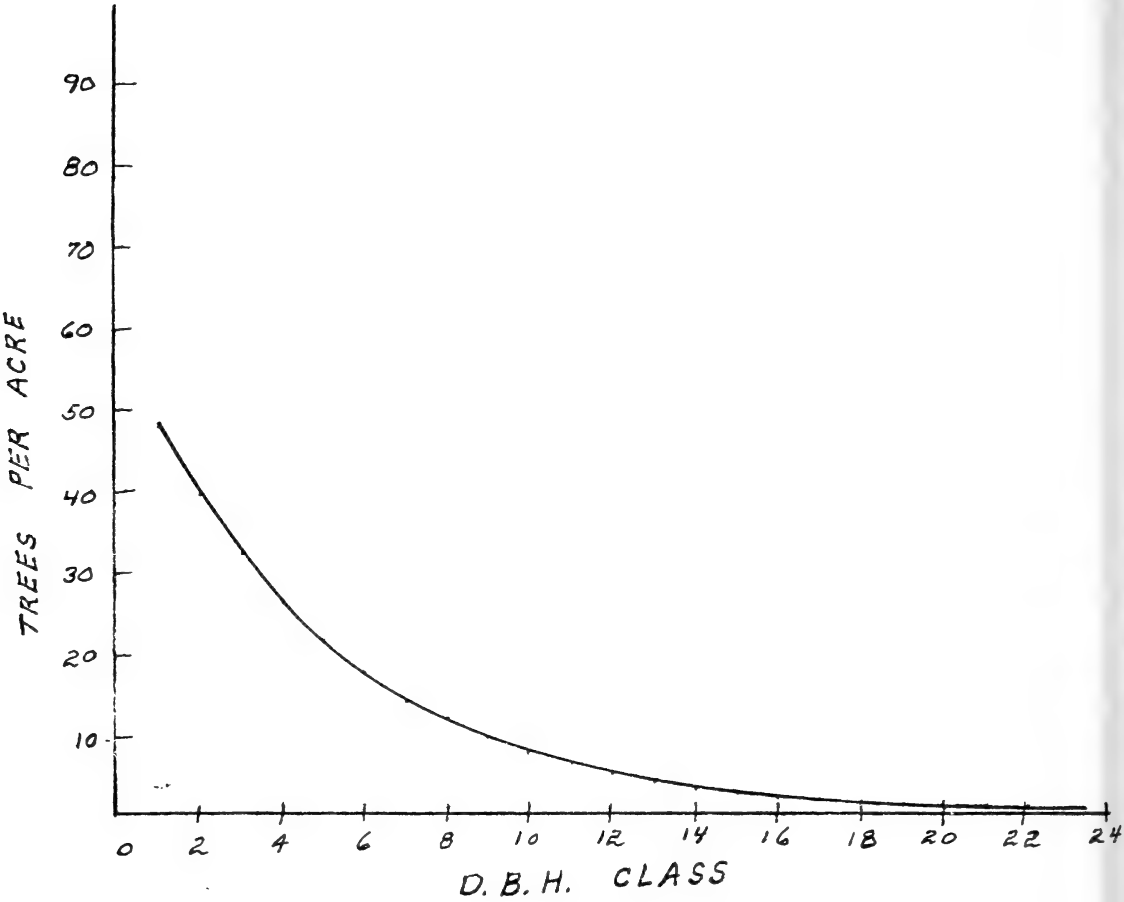

Figure 1.-- Diameter distribution goal for growing stock level 80 ponderosa pine in the Southwest.

Table 1.--Residual trees per acre, by d.b.h. classes, for various growing stock levels, for a fully regulated southwestern ponderosa pine selection forest.

D.b.h. class	Growing Stock Level (Sq. Ft. B.A. per acre) 30	40	50	60	70	80	90	100
Inches	Number							
1	18.00	24.00	30.00	36.00	42.00	48.00	54.00	60.00
2	14.80	19.73	24.66	29.59	34.52	39.46	44.39	49.32
3	12.16	16.22	20.27	24.32	28.38	32.43	36.49	40.54
4	10.00	13.33	16.66	19.99	23.33	26.66	29.99	33.32
5	8.22	10.96	13.70	16.44	19.18	21.91	24.65	27.39
6	6.76	9.01	11.26	13.51	15.76	18.01	20.27	22.52
7	5.55	7.40	9.25	11.11	12.96	14.81	16.66	18.51
8	4.56	6.09	7.61	9.13	10.65	12.17	13.69	15.21
9	3.75	5.00	6.25	7.50	8.75	10.00	11.26	12.51
10	3.08	4.11	5.14	6.17	7.20	8.22	9.25	10.28
11	2.54	3.38	4.23	5.07	5.92	6.76	7.61	8.45
12	2.08	2.78	3.47	4.17	4.86	5.56	6.25	6.95
13	1.71	2.28	2.85	3.42	4.00	4.57	5.14	5.71
14	1.41	1.88	2.35	2.82	3.29	3.75	4.22	4.69
15	1.16	1.54	1.93	2.31	2.70	3.09	3.47	3.86
16	.95	1.27	1.59	1.90	2.22	2.54	2.85	3.17
17	.78	1.04	1.30	1.56	1.82	2.09	2.35	2.61
18	.64	.86	1.07	1.29	1.50	1.71	1.93	2.14
19	.53	.70	.88	1.06	1.23	1.41	1.59	1.76
20	.43	.58	.72	.87	1.01	1.16	1.30	1.45
21	.36	.48	.60	.71	.83	.95	1.07	1.19
22	.29	.39	.49	.59	.68	.78	.88	.98
23	.24	.32	.40	.48	.56	.64	.72	.80
24	.20	.26	.33	.40	.46	.53	.59	.66
Total	100.20	133.61	167.01	200.41	233.81	267.21	300.62	334.02

Table 1 (cont'd).--Residual trees per acre, by d.b.h. classes, for various growing stock levels, for a fully regulated southwestern ponderosa pine selection forest.

D.b.h. class	Growing Stock Level (Sq. Ft. B.A. per acre) 110	120	130	140	150	160	170	180
Inches	Number							
1	66.00	72.00	78.00	84.00	90.00	96.00	102.00	108.00
2	54.25	59.18	64.12	69.05	73.98	78.91	83.84	88.78
3	44.60	48.65	52.70	56.76	60.81	64.87	68.92	72.97
4	36.66	39.99	43.32	46.65	49.99	53.32	56.65	59.98
5	30.13	32.87	35.61	38.35	41.09	43.83	46.57	49.31
6	24.77	27.02	29.27	31.52	33.78	36.03	38.28	40.53
7	20.36	22.21	24.06	25.91	27.76	29.61	31.47	33.32
8	16.74	18.26	19.78	21.30	22.82	24.34	25.86	27.39
9	13.76	15.01	16.26	17.51	18.76	20.01	21.26	22.51
10	11.31	12.34	13.36	14.39	15.42	16.45	17.48	18.50
11	9.30	10.14	10.99	11.83	12.68	13.52	14.37	15.21
12	7.64	8.34	9.03	9.72	10.42	11.11	11.81	12.50
13	6.28	6.85	7.42	7.99	8.56	9.14	9.71	10.28
14	5.16	5.63	6.10	6.57	7.04	7.51	7.98	8.45
15	4.24	4.63	5.02	5.40	5.79	6.17	6.56	6.94
16	3.49	3.81	4.12	4.44	4.76	5.07	5.39	5.71
17	2.87	3.13	3.39	3.65	3.91	4.17	4.43	4.69
18	2.36	2.57	2.79	3.00	3.21	3.43	3.64	3.86
19	1.94	2.11	2.29	2.47	2.64	2.82	2.99	3.17
20	1.59	1.74	1.88	2.03	2.17	2.32	2.46	2.61
21	1.31	1.43	1.55	1.67	1.79	1.90	2.02	2.14
22	1.08	1.17	1.27	1.37	1.47	1.57	1.66	1.76
23	.88	.96	1.05	1.13	1.21	1.29	1.37	1.45
24	.73	.79	.86	.93	.99	1.06	1.12	1.19
Total	367.45	400.83	434.24	467.64	501.05	534.45	567.84	601.25

The regeneration and growth problems are even more complicated if the stand contains several species differing in shade tolerance. For example, the mixed conifer forests of northern Idaho commonly contain six or more species ranging from intolerant western larch and lodgepole pine to moderately tolerant western white pine and Douglas-fir to tolerant grand fir, western redcedar, and western hemlock. The moderately tolerant and intolerant species are the fastest growing timber species. Therefore, when timber production is a primary objective, harvest cuttings must be heavy enough to encourage regeneration of the moderately tolerant and intolerant species. This kind of management may result in a relatively low level of total stocking, but it will maintain all the species in the stand.

On the other hand, many stands are being converted to selection management for purposes of site protection or esthetics, and wood production is not a primary use. In these cases, the intolerant species may be sacrificed in order to maintain a more complete cover of tolerant species. Harvest cuttings can be lighter because hemlock, cedar, and grand fir will regenerate and grow in the small openings created by cutting single trees. Total stocking in these stands will be relatively high, but the shape of the diameter distribution curve will be the same.

Achieving Stand Structure Goals

Seldom do we get to start selection management with a stand that already has all the desired size classes. Most of the time we start with the task of converting a stand that is essentially even-aged or two-storied into an uneven-aged stand. The silviculturist then must devise a plan for making that conversion to a stable stand structure. I will use an example from central Idaho to illustrate different approaches to that problem.

In the early 1950's, a high priority problem was the orderly conversion of old-growth stands of ponderosa pine and Douglas-fir to managed, regulated stands. It was decided to use several compartments on the Boise Basin Experimental Forest to test converting to uneven-aged stands using stem selection and group selection silvicultural systems. The eventual goal was a rotation age of 180 years with six age classes, 30 years apart. The initial stands consisted of an irregular overstory of overmature trees. The understory was an intermingling of areas with no trees and irregular groups of trees of smaller size than in the overstory.

Along with the use of stem and group selection, two approaches to the conversion process developed. In the stem selection compartments, the first cutting was throughout all merchantable size classes and aimed at two objectives: (1) removing poor vigor trees not expected to live 10 years and (2) releasing pole-sized trees to grow faster. Top priority in this system was increasing the net growth of quality timber in the residual stand. Residual volume was used to regulate the cut.

In the group selection compartments, first priority was given to creating the new youngest age class by clearcutting groups that had no understory and initiating actions to encourage regeneration in those groups. Both area and volume regulation were used. One-sixth of the area was clearcut and regenerated in the small groups; then if additional volume was available for harvest, we removed groups of large trees overtopping groups of saplings. If still more volume could be cut, it would be used to release pole-sized groups. Top priority in this approach was to bring the compartment under complete area regulation as quickly as possible. This use of group selection with area regulation is an orderly and decisive way to establish a stable stand structure for continuous management.

Both of these approaches to achieving stand structure goals have advantages under certain circumstances. In forests featuring one or two species, like the ponderosa pine type of central Idaho, I think either system could be used successfully with careful planning and execution. The stem selection system aimed at improving growth in the larger size classes could be advantageous in ponderosa pine stands, especially if the original stand were younger than the one with which we started. The biggest problem I see there is getting adequate regeneration during each cutting cycle. Regeneration is not that easy to get when you want it. I understand that since I left Boise, Dale Hall and his co-workers have changed the structure goals of the Production Study rather drastically. They are now planning a rotation of about 80 years with 8-year cutting cycles producing 10 age classes. They are also programming lower stocking levels and maximum diameters of 20 inches in some compartments and 28 inches in others. Data in Table 2 were taken from Dale Hall's stand structure model for the tree selection system. The table shows distributions of trees by d.b.h. classes for two levels of basal area stocking standards and three levels of reserve basal area.

The stocking levels are quite low, but Hall combined economic criteria with tree growth rates to determine rotation length and stocking levels. The low stocking levels should ease the regeneration task, but getting adequate regeneration in successive 8-year periods is a potential problem.

The group selection system with area regulation should work equally well in ponderosa pine forests, and it presents an advantage of concentrating the thinning and regeneration (natural or planted) efforts on smaller areas. In mixed species forests, such as those described earlier in northern Idaho, the group selection system is more flexible and more readily adaptable to a variety of conditions encountered and to the silvical characteristics of a variety of species. Tree selection cuttings, particularly in old-growth stands, often accelerate deterioration of residual stands. If cuttings are light enough to avoid damage, reproduction of the intolerant trees is usually unsuccessful. Group selection can be applied to these forests if the groups are made large enough for reproduction and stocking control of the intolerants. With group selection, stand structure is controlled by area, but the groups are often so large they could easily be called patch clearcuts instead of groups.

Table 2.--Stems per acre by d.b.h. classes, for various basal area levels and two upper diameter limits, model for a regulated central Idaho ponderosa pine selection forest.

D.b.h. Class	Basal Area Standards (Sq. Ft. B.A. per acre)					
	Low Level			High Level		
	20	35	50	45	60	75
	stems per acre					
0	70	100	150	140	180	220
4	20	31	44	41	51	64
8	12	23	32	30	38	47
12	7	14	19	18	23	28
16	3	6	8	8	10	12
20	1	2	4	3	5	7
0	50	60	90	100	120	150
4	12	20	30	34	40	50
8	10	12	20	20	26	31
12	5	8	12	16	20	24
16	3	5	8	8	11	14
20	2	3	3	3	4	6
24	1	2	2	2	2	2
28		1	1	1	1	1

Maintaining Stand Structure

The primary purpose of the conversion process is to mold the stand into an uneven-aged stand structure. Once that is accomplished it is not necessary to press immediately toward an ultimate or optimum q distribution. One reason for using a tree selection structure is to direct a high proportion of the growth into high quality sawtimber production. To gain this advantage, future cuttings should be directed primarily toward reducing mortality and increasing growth of the medium and large size trees. Close adherence to the q distribution in lower size classes may depend on the availability of funds for noncommercial thinnings. If thinnings are not feasible and reproduction is plentiful, the actual q distribution may vary through the diameter range. A lower q in the larger size classes may be beneficial because that is where the growth of quality sawtimber occurs.

Whatever silvicultural strategies are used, it is important to have a stand structure goal to guide the marking and to keep residual stocking within limits. Within those limits any cutting that is silviculturally beneficial to the stand and economically profitable will produce an acceptable distribution curve.

In the group selection system, stocking levels for individual groups should follow even-aged stocking guidelines. The uneven-aged structure defined by the aggregation of groups will be held constant by maintaining the distribution of groups by size classes.

Determining the maximum size to which trees will be grown is a logical first step in developing a model stand structure. The maximum size will largely determine the rotation length and aid in setting cutting cycles and stocking goals. Future cutting guides should include removing all trees larger than the maximum size. Additional cutting should be concentrated in those merchantable size classes containing more trees than specified in the model.

Uneven-aged management is a feasible alternative in the management of many forests in the West. Either single tree selection or group selection is reasonably applicable to some forest types, such as ponderosa pine, with a few species compatible with a selection environment. Group selection is more adaptable to the variety of conditions and species represented in most mixed conifer forests. A wide range of stand structures and stocking levels are attainable within the overall definition of population distribution in uneven-aged forests. By applying cutting policies and cultural practices that are silviculturally beneficial to regeneration and development of the stand, reasonably balanced diameter distributions should evolve that can be feasibly maintained.

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GROWTH AND YIELD IN UNEVEN-AGED STANDS

by

Robert O. Curtis[1]

We can perhaps think of two main categories of growth and yield estimates: (1) estimates of current growth of existing stands, with projections for short periods into the future assuming continuation of current management practices; and (2) estimates of growth and yield under long term application of possible management regimes, intended in part at least to identify options and provide a basis for choice among alternatives. The first usually comes from inventories of existing conditions. The second, from construction of some type of predictive model, often based on quite limited data from small experimental areas, since the stand conditions concerned may not as yet exist over the forest as a whole. Here, I am talking primarily about this second type of estimate.

Basic Differences Between Even-aged and Uneven-aged Stands

1. Areal arrangement by age classes:

By definition, an even-aged stand is composed of one main age class over an area large enough to be mappable and recognized as a distinct unit in management. An uneven-aged stand is anything else, and consists of two to many age classes in any areal arrangement from stemwise mixture to even-aged groups of up to several acres each.

2. Diameter distributions:

The even-aged stand has the typical bell-shaped diameter distribution, while the uneven-aged stand--considered over any substantial area--has a more or less J-shaped distribution (which may be a summation of other distributions for numerous small areas).

3. Height growth:

Even-aged stands: Dominants have a well-defined and consistent sigmoid growth pattern characteristic of the site.

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Uneven-aged stands: Depending on areal arrangement of age classes, the pattern may vary from that characterizing even-aged stands to one showing a prolonged period of slow growth in early life followed by later acceleration; differences will be greater for some species than others (Figure 1).

4. Diameter growth:

Differences will resemble those for height growth (Figure 2).

5. Regeneration

In the even-aged stand regeneration occurs at a single distinct point in time, is readily controlled, and is often regarded as a separate object of study, distinct from the yield studies which deal with subsequent growth and stand development. In the uneven-aged stand regeneration is more or less continuous, no such clear distinction in time and location exists, and the topics are not separable.

Yield Estimation Procedure--Even-aged vs. Uneven-aged Stands

The steps involved in development of managed-stand yield estimates for even-aged stands predominantly of one species generally consist of:

1. Develop a site classification based on the height-age relationship.

2. Measure growth on a series of plots representing the range of stand conditions and possible treatments, characterizing these conditions and treatments by quantitative variables.

3. Relate growth to stand variables by regression and use the results in some type of simulation procedure to calculate expected yields.

Now consider the differences which arise when we go from the even-aged to the uneven-aged condition:

1. Site classification

Site quality is a major determinant of yield under any form of management. Existing site index techniques are reasonably satisfactory for even-aged stands but are often unusable for uneven-aged stands because of the effect of early suppression on the height growth curve. And, some less productive sites in the arid West, often associated with uneven-aged stand conditions, show differences in stocking capacity and potential productivity not fully expressed by conventional site index techniques.

Several alternatives have been used or proposed at one time or another.

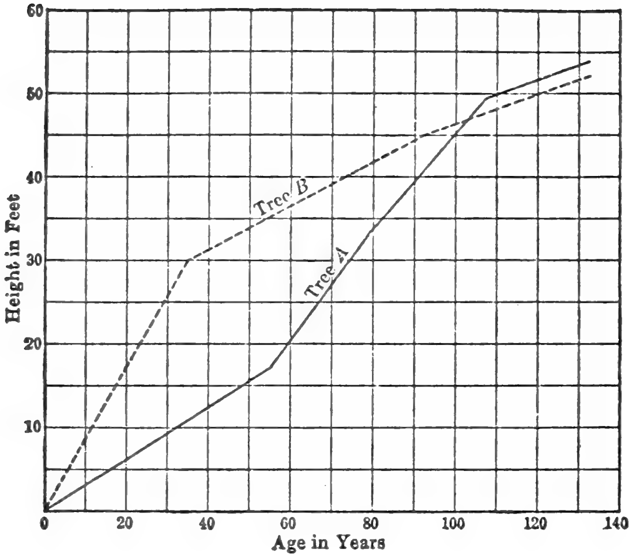

Figure 1. A diagram showing the height growth based on age for two hemlock trees (Hawley 1946).

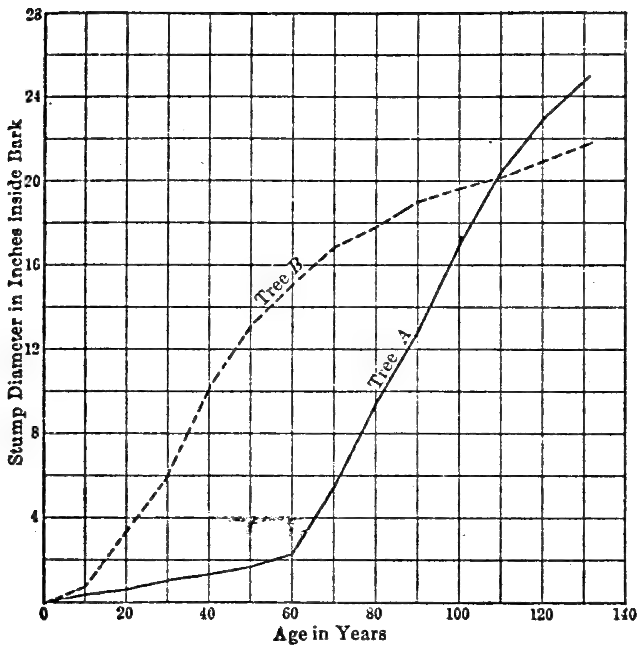

Figure 2.--A diagram showing the diameter growth based on age of two eastern hemlock trees of approximately the same age and size growing on the same site. Tree A grew under conditions prevailing in an uneven-aged stand. Tree B grew under conditions prevailing in an even-aged stand. For the first 50 to 60 years of its life tree A was overtopped (Hawley 1946).

a. Adjustment for suppression:

In cases where a relatively short and distinct period of suppression is recognizable on increment cores, currently free-growing trees may perhaps be used for site estimates after adjustment for the period of suppression (Flury 1929, as cited in Assmann 1970, Stage 1963).

b. Height in relation to diameter:

Some (Flury 1929, as cited in Assmann 1970, McClintock and Bickford 1957) have proposed using maximum height or height attained at a specified reference diameter as a measure of site in uneven-aged stands. These are certainly roughly related to site, but also appear to be affected by differences in diameter distribution, stand density, and age structure (Assmann 1970).

c. Current growth rate:

Observed current growth rates indicate relative site quality for truly comparable stands, but do not provide a generally applicable measure since they are much influenced by differences in stand structure, and may differ considerably in successive periods because of climate fluctuations (Figure 3).

d. Conventional site curves:

If the forest is in fact composed of recognizable even-aged groups perpetuated by group selection, then careful selection of site trees should produce consistent site estimates, comparable to those in even-aged stands.

Allied to this is the idea that if an intolerant species is present as a minor component, which becomes established only in openings large enough to permit unrestricted growth, then this might be used as an indicator of site for associated species (Frothingham 1921). Examples are species such as noble fir or larch.

e. Soils and/or plant communities:

This seems the most generally applicable method. Quantification and grouping into categories of similar productivity requires some tie to growth and yield under standaridized conditions. In some situations this can be obtained from existing information for even-aged stands on comparable soils or plant communities. If recognizable even-aged groups exist, conventional site procedures applied to these may give a basis for assigning relative productivity ratings to such classifications.

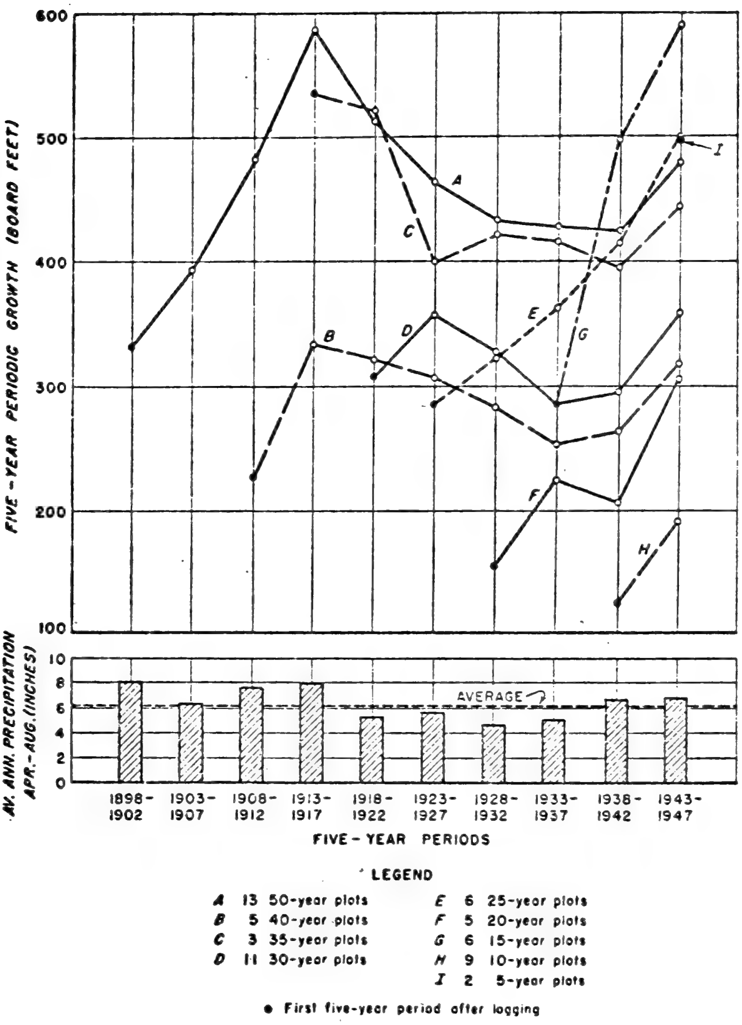

Figure 3.--Five-year periodic growth and growing season precipitation for ponderosa pine sample plots, 1898-1947 (Roe 1952).

2. Size of Experimental Areas

In even-aged yield studies we generally work with plots of one acre or less, and these can usually be considered as representative of conditions or treatments feasible on a stand basis.

An experimental plot must be large enough to include the full range of diameters and ages present and give a stable estimate of the distribution curve. In uneven-aged stands this is likely to require areas of several to many acres, with corresponding increased site variability, hence less precise results. The time required to achieve any desired stand structure will be greater than in even-aged thinning studies, since all ages up to 100+ years are involved.

Hence, we are quite limited in our ability to examine directly any stand structure materially different from what we can now find on the ground. The usual type of small plot experimentation with cutting treatments, fertilizers, etc., hardly seems feasible.

3. Species Composition

Species composition in even-aged stands is largely fixed at the time of stand establishment. We usually assume that little change will occur during the rotation except that deliberately produced by cultural operations, and that we will have a new opportunity to alter species composition as needed at the start of each rotation.

In uneven-aged management we do not have this degree of stability and control.

Years ago Bob Wilson published a graph for a compartment at Bartlett, New Hampshire, reproduced here as Figure 4. If we read noble fir, Douglas-fir, hemlock and silver fir in place of birch, ash, maple, and beech, this could be the Northwest. Viewed simply as number of stems per diameter class, this is a reasonably well balanced J-shaped distribution. But note the position of the various species. What we have is an even-aged overstory with species segregated by growth rates, plus a developing uneven-aged understory. The rapidly growing intolerants now comprise most of the large trees. If these are gradually removed in single-tree selection cutting, species composition will change and growth rates will fall even if the same distribution of total stem numbers is maintained.

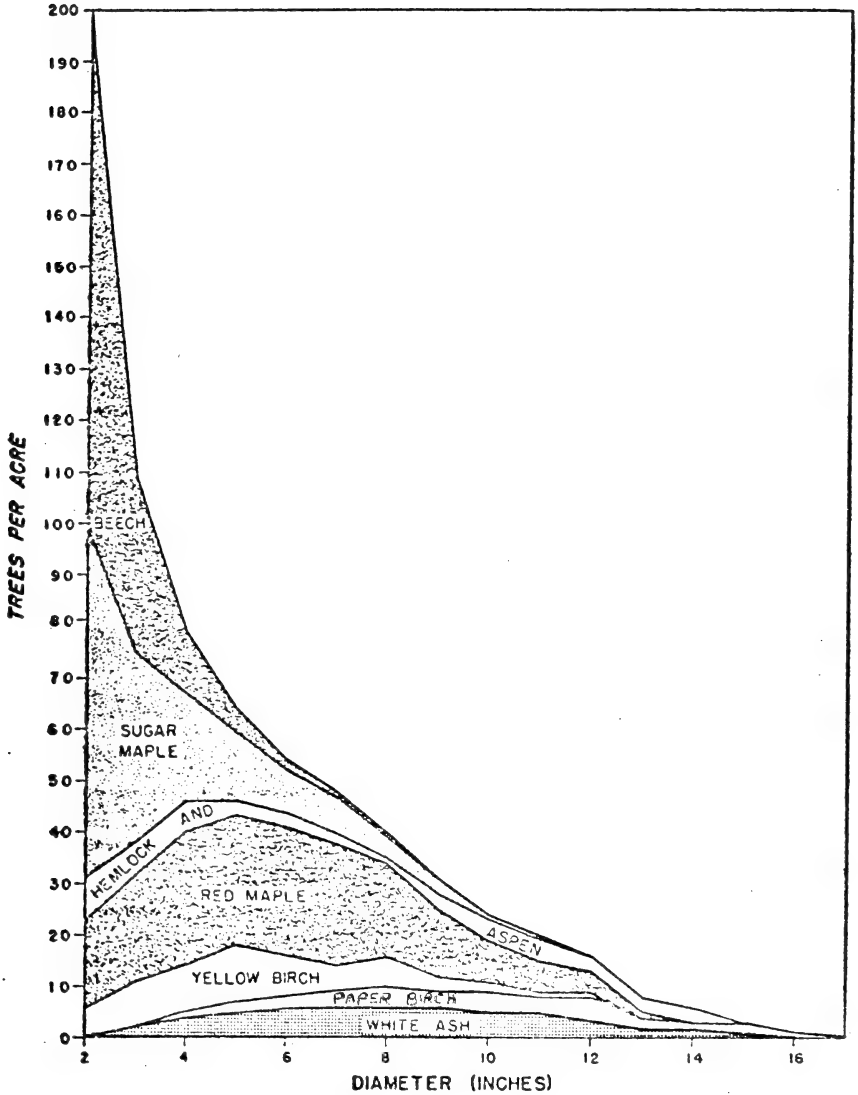

Figure 4.--Distributions by species in a northern hardwood stand.

Yield predictions under uneven-aged management must consider trends in species composition over time arising from differential inherent growth rates, differential response to competition, and differential regeneration rates. Change in species composition may be a more important factor in yields than changes in diameter distributions or stocking levels.

4. Stand Structure

Even-aged stands of a given species are quite satisfactorily described by a small number of simple variables; age, site index, basal area, and average diameter or number. Thinnings are readily described by d/D and g/G ratios. Analyses are facilitated by relative simplicity of variables and by the fact that basal area, average diameter, and number fall naturally into regular and easily described trends over time.

We do not have equally concise and complete descriptors for uneven-aged stands. In part, this is because "uneven-aged" is not a specific condition but simply anything that does not qualify as "even-aged." It includes everything from the balanced stemwise all-aged stand of theory through two storied stands through stands which are in fact collections of even-aged groups.

DeLiocourt's "q" or similar J-shaped curves are popular expressions of uneven-aged stand structure. Since in most real situations age, size, and species distributions are highly variable within the aggregate area represented by these expressions, these should be regarded as devices for regulating or guiding the cut over fairly large areas rather than as measures of conditions affecting growth of the trees on an individual acre.

For stands comprised of mixtures of species of varying tolerance and growth characteristics, change in species composition may be a very important factor in future yield. Therefore, evaluation and regulation of stand structure requires examination of distribution by species and of relative rates of species movement through diameter classes, rather than merely overall totals.

Summation of diameter distributions for even-aged stands over the full range of ages included in a rotation produces diameter distributions with the J-shaped characteristic of balanced uneven-aged stands (Figure 5). Where management is primarily by group selection, these may be reasonable indicators of desirable structure and corresponding estimates of yield for even-aged stands may be reasonable approximations to attainable yield. As management approaches individual tree selection, this assumption becomes increasingly uncertain, since--compared to the even-aged condition--time of passage through the small diameter classes will be increased.

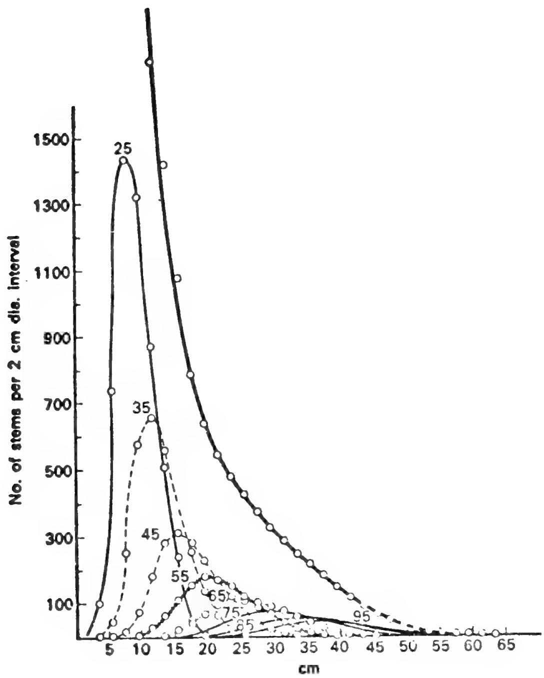

Figure 5. --Diameter distribution for a spruce working section, deduced by adding the diameter distributions of 10-year age classes (Assmann 1970).

5. Competition and Tree Growth

If one had a fully regulated balanced stemwise all-aged stand, basal area should be a sufficient expression of density; since average tree size should be about the same throughout the stand and constant over time. Real uneven-aged stands are irregular and generally more or less groupwise in arrangement by size, species, and age; and an overall basal area figure may have little relationship to growing conditions affecting the individual tree or group. Depending on size and uniformity of groups, the conventional measures used with even-aged stands may or may not be meaningful.

How does one measure competition influencing growth of a tree or group of trees, when this competition is exerted by trees of widely differing diameters, heights, ages and species, relative to the subject tree?

Are simple extensions of conventional measures such as CCF or SDI, or individual tree measures developed for even-aged stands, adequate?

What degree of competition will allow satisfactory reproduction and development of younger stems, and how does this differ by species and site?

Can one formulate spacing criteria based on quantitative measures of competition, for use either as field guides or in stand simulation?

Comparative Yield of Even-aged and Uneven-aged Forests

Arguments about comparative productivity of even-aged versus selection forests go back at least a century and more, and are still inconclusive. Much of this is in the European literature and not easily accessible because of the language difficulty. And, much of the argument concerns the idealized stemwise all-aged stand, which--when it exists at all--is generally a creation of man found on small experimental areas and certain European forests. Two-storied and groupwise uneven-aged stands are far more common in the West.

My general impression is that in those types for which selection management is a rational alternative, any differences in productivity between systems will be due mainly to their influence on species composition plus physical and administrative difficulties in application, rather than to differences in age structure per se.

One alleged advantage of selection management is the ability to produce a high proportion of large timber while retaining a relatively small amount of growing stock in the smaller diameter classes. Assmann (1970) argues, however, that the diameter distribution in the all-aged selection stand is analogous to that in a normal series of even-aged stands with a longer than usual rotation; and that this alleged advantage is actually an age effect also obtainable in even-aged management. See Figures 6 and 7.

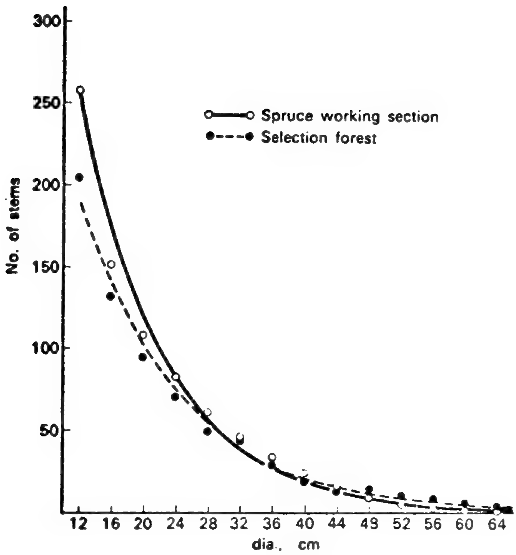

Figure 6.--Diameter distribution curves for a spruce working section (quality class II; r = 120) and for a selection forest (Schömberg) (Assmann 1970).

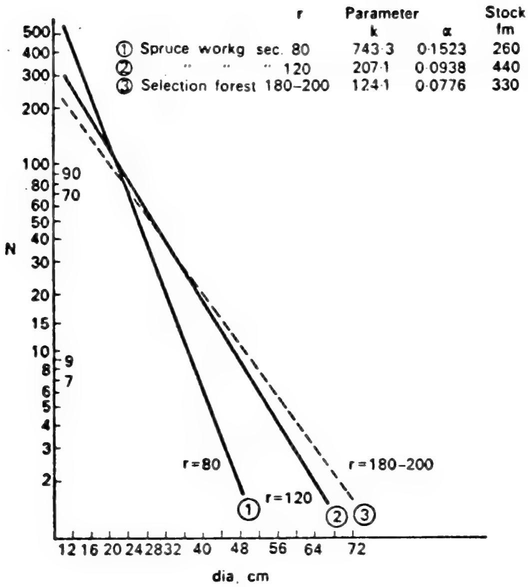

Figure 7.--Fitted diameter distribution curves (log N = f(d)) for two spruce working sections and one selection forest area (Assmann 1970).

Presumably, the same economic arguments used to justify short vs. long rotations also apply to choice of felling age and size in uneven-aged stands.

Yield Estimation Methods for Uneven-aged Stands

Because of the difficulties of small plot experimentation in uneven-aged stands, it seems to me that the main sources of information must be some combination of inventory-type data and individual tree studies.

Short term projections of uneven-aged stands can be and are made by well established stand projection methods (Wahlenberg 1941; Meyer 1942) or recent elaborations (Larson and Goforth 1974; Bruner and Moser 1973). Generally, these give good estimates of current growth and short term projections. They are of limited value for evaluation of alternative stand treatments or long term projections for a specific management regime, since they use average growth and mortality rates for the forest as it now exists and do not usually allow for rate changes associated with changes in stand composition and structure due to treatment.

There have been many attempts in the West to predict growth of residual stands using stand variables, mainly limited to first cuts in previously unmanaged stands (e.g. Roe 1952) and therefore of limited generality. Regression relationships have been developed for uneven-aged mixed stands (Herrick 1944), and recently Moser and Hall (1969) and Moser (1972) have formulated a system of differential equations to represent growth of uneven-aged stands in terms of stand variables other than age. I personally have trouble visualizing how one would introduce effects of cutting and structural and species changes in such a model, but maybe that's my problem.

Myers et al. (1976) have provided a procedure for estimating yields of two-storied stands of one species, projecting each component separately over time. This seems a rather special situation and a procedure which probably cannot be extended to the more complex situations.

In the long run it may be that the only feasible means of investigating the effects of alternate stand structures and management regimes will be stand simulation based on some type of individual tree projection in the manner of Adams and Ek (1974). At the present time the only simulators I know of which purport to have this capability are those of Stage (1973) and Ek and Monserud (1974). I have no detailed acquaintance with either, but it seems clear that application of these or similar simulators to predict long term development of mixed uneven-aged stands on a variety of sites will require much more detailed study of basic growth-species-competition relationships, regeneration requirements, and measurement procedures than has yet been done. This is a far more complex undertaking than similar simulations for pure even-aged stands, and predictions will be much less easily validated.

I also think that there is a continuing usefulness for the conventional type of even-aged site classification and corresponding variable density yield tables, even for species and areas where the even-aged condition is and will be a small proportion of the total acreage. These provide the quantitative tie to soil and plant community classifications which permits grouping and ranking by relative productivity, ranking of species productivity, and an upper limit on potentially attainable yields. And, with adjustments for edge effects, they may provide reasonable guides to desirable stocking and yield in those cases where uneven-aged stands are perpetuated primarily by group selection.

All this may sound more like a catalog of difficulties rather than a constructive approach to the problem of yield estimates in uneven-aged stands. But it does point out some of the reasons why we don't have good estimates for uneven-aged stands, and are not likely to get them in the immediate future, except perhaps for a few quite special situations.

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BENEFITS AND COSTS OF UNEVEN-AGED REGULATION

by

Dale O. Hall[1/]

It was suggested that I pattern this presentation after George Trimble and Bob Manthy's (1966) comparison of even-aged yellow-poplar management with uneven-aged sugar maple management. Trimble and Manthy assumed their selection system stocking level and size distribution to be optimum. Because of growth differences between the two species they found even-aged yellow-poplar management more profitable.

Without exception other published results have been based on similar, broad stand assumptions. Almost invariably some natural size distribution or only slightly modified stocking level has been used. But doesn't the stand represent invested capital? Doesn't the stand control the efficiency with which that capital is used? How can we make valid economic comparisons between management systems when the optimum stand conditions of each system aren't known?

I would like to explore further with you some of these problems. Let's first look at some general ground rules or definitions; then some silvicultural areas of interest; and finally, some "tools" for making economic analyses.

A Basic Framework

Economists try to have decision bases which are totally rational; that is, without emotions. Economists in our society generally work with value scales based on dollars, but other value scales are also recognized. For now let's limit ourselves to the dollar value scales.

Let's consider (a) capital, (b) the cost of capital, (c) the period of capital use, and (d) the alternative rate of return. I don't mean to offend with this elementary beginning, only to stress the importance of these basic elements.

Capital is inherent in the land foresters manage, the growing stock on that land, and our investments in stand treatments.

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The cost of capital, or rate of interest, is composed of the pure or real interest rate, an inflation factor, a risk or uncertainty factor and the time to maturity of the investment. Don Billings, Economist at Boise State University, illustrated this: the current nominal rate of interest is about 8½ percent. This 8½ percent rate is composed of a real rate of 3 to 4 percent, and an inflationary rate of about 5½ percent. Further, a very safe AAA grade bond may return 8.47 percent, while a less certain B grade bond may return 8.93 percent. The difference between the rates of the AAA and B bonds, is the risk or uncertainty factor.

To digress briefly, risk or uncertainty factors are especially important in a forestry enterprise. Dowdle (1962) describes a technique for explicitly considering uncertainty in forestry investment decisions. The Forestry Economics Section of IUFRO zeroed in on uncertainty at the 1971 Congress (Lundgren and Thompson 1972). Uncertainty is being incorporated into current decision models (Lembersky and Johnson 1974). A totally rational investor would select the investment opportunity with the commensurate interest rate and uncertainty factor which suit his particular financial objectives. Flora (1966) found that many forestry investments are not totally rational in economic terms.

Time is the third element, the period of capital use. With uneven-aged regulation the time element is generally related to the cutting cycle.

The alternative rate of return is most significant. There is competition for capital. The alternative rate of return is the price a manager places on the use of his capital. He will accept this return, or interest rate, and no less.

Marginal analysis comparisons are based on the concept of the alternative rate of return. As Duerr (1960) states: "The best stocking of a selection forest is that which equates the marginal value growth percent of timber with the firm's alternative rate of return. This is because (1) at any lower stocking, extra investments in stock will pay more than alternatives, and so the firm had better build up its stock, whereas (2) at any higher stocking, the alternatives pay more than some of the stock is paying, and the firm had better liquidate this surplus stock."

Marginal evaluations for optimum growing stock for a particular acre minimally requires that the manager (a) set the alternative rate of return and (b) a cutting cycle, (c) determine a growth function related to growing stock, and (d) assign values to the growing stock and the growth. This is equivalent to setting the price for capital, determining the investment period, and estimating the rate of return for varying levels of capital.

Once a manager has selected his alternative rate of return, what amount of capital should he invest in the growing stock in order to meet his required rate of return? How long should he hold that growing stock (the cutting cycle)? Only when the alternatives within these constraints have been determined is it reasonable to make comparisons with other regulation options.

The fragmentation and incompleteness of published economic evaluations makes it unrealistic to compare relative costs and benefits of even-aged and uneven-aged regulation. Instead let me touch on some general areas of interest relating most specifically to the economics of uneven-aged management in the West.

Particular Silvicultural Concerns

Smith and DeBald (1975) gave an excellent review of the literature on economics of even- and uneven-aged silviculture and management in eastern hardwoods. I commend their review to you. I will follow their subject ordering.

Species Composition - Reproduction

I am not aware of any western cost/benefit publications dealing with mixed uneven-aged species. Some unpublished results may be of interest to you. Boise National Forest timber people recently evaluated the Growth Basal Area (GBA) techniques of Frederick Hall[2/] On a Douglas-fir habitat type where about 80 percent of the stand was 100-year-old ponderosa pine--stocking levels of 100 to 60 ft^2 of basal area--Douglas-fir rings-per-inch (RPI) growth rates were 1.5 to 2 times that of ponderosa pine (Figure 1). There is slight difference in market value of the two species, inferring that Douglas-fir is economically more productive[3/].

Species composition for economic evaluation may become academic. As wood demand increases, stumpage value differences between species seem to diminish. Restricted quality ranges for young-growth timber contribute to this equalization in stumpage value.

Regeneration of uneven-aged stands of conifers is generally by inexpensive natural seeding (Alexander 1971, 1972, Twight 1973, McDonald 1966), which is contrasted with \$150 to \$300 per acre planting costs under clearcutting. The area of site disturbance depends on the proportion of the stand logged and slash disposal methods. The residual stocking level may be controlled to meet seedling light and moisture requirements. As few as 10 to 20 established seedlings per year on 8- to 12-year cutting cycles can provide the basis for continued production.

2/ Unpublished talks and mss.

3/ Unpublished data on file, Idaho City Ranger District, Boise National Forest, Idaho City, Idaho.

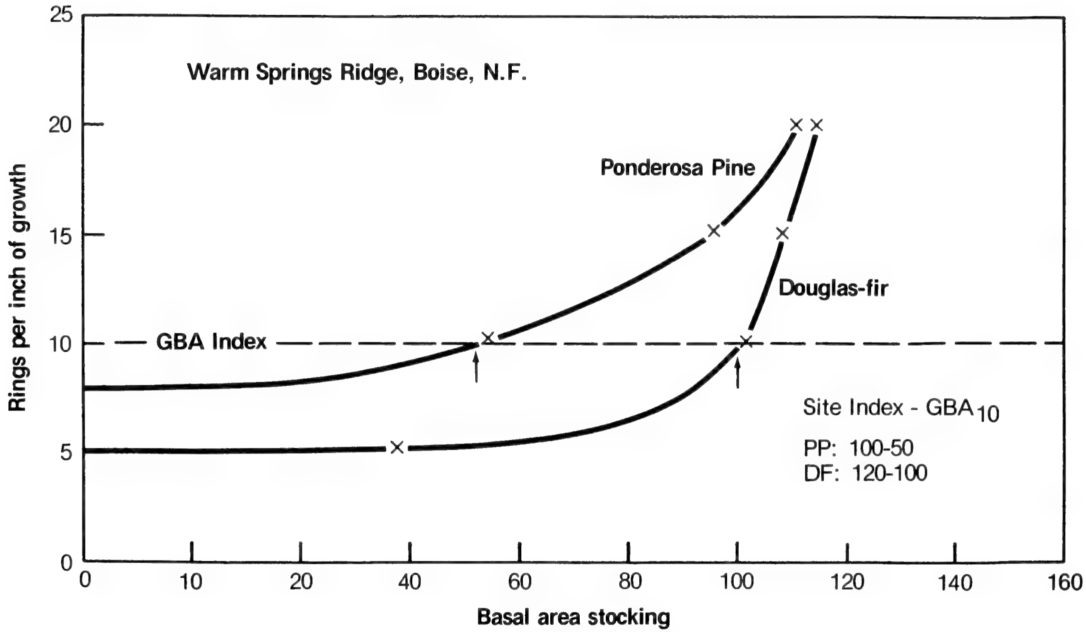

Figure 1.—Site index-growth-basal-area relations.

Seed-tree or shelterwood cuttings (Corbett 1962) can provide equivalent inexpensive reproductive potential. Slash disposal costs should be considered in each case. (Is slash disposal a regeneration, harvesting, or protection cost?)

Growth

Diameter growth seems more clearly related to stocking level (McDonald 1973, Meyer 1934, Schubert 1971) and tree class (Mowat 1961, Dunning 1928, Wellner 1952, Roe 1948) than to age structure although economic comparisons are lacking.

Volume growth differences are strongly influenced by stocking levels and by relative species composition as noted above. Species differences can be quite large.

Quality changes in western young-growth conifers over economically viable growth periods seem slight. Wood density appears to be the single best indicator of quality changes under these limitations (Paul 1963).

Value growth is primarily a function of tree size relative to merchantability limits, and to stand volume increment.

Regulation

Uneven-aged regulation is geared to cutting cycle length. Shorter cutting cycles limit the time over which volume losses accrue and thus reduce some of the costs of regulation.

Costs of regulation include the values lost due to over- or under-estimation of harvest volumes (Schweitzer 1970). These losses may not be recognized until half of an even-aged rotation has passed. Such losses carried at compound interest can become sizeable.

Growth rates and cutting cycles determine the proportion of volume removed at each re-entry (Davis 1954) (Table 1), and thus the impacts on the stand from light, wind, site disturbance and slash accumulation.

Increased growth from intensive management becomes harvestable sooner with uneven-aged management. Again the uncertainty from errors in estimation is less so that capital may flow more surely into these management practices.

Tree marking for harvest is a major concern (Twight 1973) and can be a cost of regulation. Intermediate cuts in even-aged stands are similar to the cyclic cuts of uneven-aged regulation. Boise National Forest timber markers estimated that marking 4- to 20-inch leave trees to a prescribed all-aged stand model of about 50 ft^2 b.a. required 20 to 30 percent longer than marking for an intermediate cut. The extra time cost came from marking unmerchantable trees 4 to 10 inches in d.b.h. and from adjusting the marked stand to meet the stocking standard. Some benefits should accrue in the form of mechanical thinning of small unmarked trees as the stands are logged.

Markets

The average size of pieces harvested should be slightly larger under uneven-aged regulation when stocking standards are similar. This is because equal areas are assigned to each age class under even-aged regulation. Under all-aged regulation the area occupied by a specific size class can be varied somewhat with slightly more space allocated to trees in larger size classes.

Table 1.--Percentage of a stand that may be cut and restored by growth for various cutting cycles and rates of growth (after Davis 1954)

Cutting cycle, Years	Growth Percent 2	4	6	8
6	11	21	30	37
9	16	30	41	50
12	21	38	50	60
15	26	44	58	68

Roads

Roads are a fixed investment for protection, harvesting, and management. Road costs should not vary with the type of regulation unless the available logging system for an age structure requires different road spacing or faster road development. From a practical viewpoint both even- and uneven-aged regulation would probably be used on a western forest property so that roading costs could not reasonably be separated by type of age regulation.

Logging

Logging costs vary principally with the volume of material removed from each setting (or acre) and the costs for moving settings or landings (assuming the same location and method of logging). Costs at Challenge Experimental Forest (Atkinson and Hall 1963, McDonald 1965, McDonald, Atkinson and Hall 1965) differed only slightly between tree and group selection, seed tree, and clearcutting methods when average volume ranged from 10 to 27 MBF per acre. Other operators have suggested the slight differences in logging costs would hold for as little as 1.5 to 2 MBF per acre under any cutting method[4/].

4/ Personal communications.

Accelerated mortality, a cost may result from poor logging practice (Glew 1963). Logging practice is considered a major concern in implementing a selection system (Twight 1973).

Some operating cost advantage may accrue to even-aged systems if logging equipment is specifically tailored to a limited size class, i.e., as for the 8- to 12-inch d.b.h. class. Such a specialization would require additional capital investments in equipment, partially offsetting the operating cost advantage.

Logging residues are directly related to stocking, utilization standards, and to the proportion of the stocking harvested in either form of regulation. In the uneven-aged form, short cutting cycles can reduce the need for special, costly slash treatments. With longer cutting cycles larger volumes are removed (Table 1), more slash is developed, and protecting the residual stand can make slash disposal very costly.

Water and Wildlife

Water yield is also a function of tree stocking. Long term yields may be increased by reducing average stocking (Douglas and Swank 1972), and thus transpirational drains, under either age structure.

Road produced sediments are as serious a water quality problem in the West (Megahan and Kidd 1972, Packer 1967) as they are in the East (Smith and DeBald 1975). Logging in selection cuts did not produce serious soil losses in Idaho (Haupt and Kidd 1965).

Diversified conditions tend to foster a diversity in birds (Thomas et al. 1975) and other wildlife. Such diversity may reduce the abundance of certain species. Value judgments thus depend on the scale--diversity or abundance--which one uses and the size of area being considered.

Baker (1975) and others (Clary et al. 1975, O'Connell 1971) describe an excellent multi-resource model with trade-offs among timber, herbage and water yields with deer use and esthetic potentials. Economic evaluations for the Beaver Creek watershed are in progress.

Monetary Returns

Josephson (1941) was an early advocate of "selective cutting" in the Sierra Nevada to improve growth and stabilize income. The economic principles he outlined are still sound. The Douglas-fir region had a similar advocacy in Kirkland and Brandstrom (1936) who compared the advantages and disadvantages of clearcutting and selective cutting.

Michel Chavet[5/], a recent graduate student from France at the University of California, prepared an excellent review and comparison of three uneven-aged economic models (Duerr and Bond 1952, Adams and Ek 1974, Stumph[6/]). He extends from these models to develop a more complete simulation model. Chavet includes the earlier variables of (a) the cutting cycle, (b) the ratio of trees in the preceding d.b.h. class, and (c) the largest d.b.h. class, but adds (d) basal area as a means of linking (b) and (c). Basal area also carries the notion of site occupancy. Implementing Chavet's model should permit determination of the optimum combination of economic cutting cycle, maximum tree size, size distribution and stocking level.

Recent modifications[7/] to the Ponderosa Pine Production Study in Idaho (Curtis 1955) dovetail nicely with Chavet's model. The Study will examine growth and returns from an intuitively derived high value growth size-distribution model with two tree size limits (20 and 28 inches) and six basal area stocking standards (ranging from 20 to 85 ft^2) on an 8-year cutting cycle. Preliminary simulation runs with 40 ft^2 of initial basal area (PP, SI=90) suggest returns of 8 to 12 percent on the growing stock value.

There are a number of computer simulation and planning programs and/or languages which include or could include cost/benefit evaluations of uneven-aged regulation options. Row (1975) outlined the tasks and aids for making investment analyses (Table 2). He then prepared a simulation language to accept data from task 1, accomplish tasks 2 to 6 and prepare input for task 7.

MULTIPLOY (Row 1975) is that special forest investment simulation language. Row's objective is to provide systematic comparisons of sequences of management actions and yields. The Forest Service's INFORM plan calls for incorporation of MULTIPLOY in the timber subsystem.

Stage's (1973, 1975) PROGNOSIS models tree and stand development based on inventory plot data. Management options may be simulated and yields compared. Output units have been designed to permit economic characterizations. Subroutines to make cost/benefit comparisons still need to be written.

The Bureau of Land Management is using SIMIX which was derived from SIMAC (Sassaman et al. 1972) to determine even-flow allowable cuts based solely on volume regulation. A 3-stage partial cut is their closest approach to uneven-aged regulation.

5/ Unpublished term paper for Forestry 295, 1974. Univ. of California.

6/ Unpublished term paper for Forestry and Conservation 214, 1974. Univ. of California.

7/ Unpublished 1973 revision to 1951 study plan on file at Intermountain Forest & Range Experiment Station, Boise, Idaho.

Linear-programming systems have been developed to optimize choices among alternatives (Johnson and Scheurman 1974). Timber-RAM (Navon 1971), the Roading Timber RAM (Navon 1975), and an integrated silvicultural-transportation model (Weintraub and Navon 1976) illustrate this type of program. Both volume and value comparisons are possible.

Dynamic programming has also been used for finding optimal investment decisions within an industry or regional context (Schreuder 1968).

The old saw, "Garbage in, garbage out," applies in using all such programs for cost/benefit comparisons. Changes in growing stock capital, cutting cycles, and treatments can seriously alter program results, yet this potential is seldom discussed.

Table 2.--Tasks in making investment analyses (Row 1975)

Task	Present Forest Service computer programs
1. Identify feasible projects	TRI, CISC, GELD, GIM
2. Determine treatment-harvest sequence	
3. Assemble or simulate needed information	
Timber yields	Various simulators
Costs	
Prices	
Nontimber yields	Various simulators
Losses	Various simulators
4. Compile schedules of revenues and costs	
5. Compute measures of economic returns	Invest, ROR, NCTRN
6. Select projects within fund limits	SASSY
7. Incorporate alternatives into management plans	RAM

Some Concluding Comments

A general scheme of the relative impacts of the cost of capital and of uncertainty suggests a framework for estimating returns and making decisions in an uneven-aged framework (Table 3).

Investment differences between established even-aged and uneven-aged regulation systems are significant. In uneven-aged regulation capital is retained as growing stock. Limited investments in light thinning or weeding may be necessary. Infrequent outlays for regeneration may be required. There should be no regeneration time lag. Somewhat higher regulation costs could be incurred--marking, maintaining stand structure--but these may be balanced by reduced mortality and improved estimates of yields.

In even-aged regulation the growing stock is essentially liquidated at harvest and capital is reinvested in regeneration. The regeneration period represents a cost, either for unproductive ground or for carrying residual seed-tree or shelterwood capital. If a short period, costs may be nominal; if more than 2 years, costs increase rapidly. If planted, the high level of capital investment becomes all too visible and uncertainty about long term survival and growth should be magnified. Extensive precommercial thinning investments may be needed to offset overplanting caused by uncertainty of survival or naturally dense seeding.

Table 3.--Relative economic impacts of uncertainty and the alternative rate of return on forestry decisions (+ = positive and - = negative impact; b = broad and n = narrow range of options)

Prob. of loss:	a%		>a%	
Cost of Capital (Alternative rate of return)	Mod	Hi	Mod	Hi
Capital in-flow	-	++	--	+
Resource Supply and characterization:				
Accessible areas	++	+	+ or -	--
Site productivity levels	++	+	+ or -	--
Value estimation error (Schweitzer 1970)	-	--	--	---
Management options:				
Species composition	bb	b	b or n	nn
Length of cutting cycle	bb	b	b or n	nn
Amount of growing stock & growth rate	bb	b	b or n	nn
Age- or size-class distribution	bb	b	b or n	nn
Marketing alternatives	bb	b	b or n	nn
Harvesting alternatives	bb	b	b or n	nn
Regeneration alternatives	bb	b	b or n	nn

In short, even-aged systems appear to require more capital with a higher level of uncertainty and a slower rate of turnover than uneven-aged systems. And making this statement I have now come full circle. The statement is based on broad assumptions, supported by incomplete data and includes some half-vast simplifications. May our frustrations find solace together.

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REGULATION AND CONTROL UNDER UNEVEN-AGED MANAGEMENT

by

Robert R. Alexander and Carleton B. Edminster[1/]

Regulation and control of cut is the process that deals with the technical aspects of organizing and maintaining a forest property with the objective of determining and controlling the yield of forest products--in this paper we will consider regulation to be concerned only with the amount of timber that may be harvested annually or periodically from a specified area over a stated period of time to accomplish management objectives. Since one of the objectives of forest management is to bring previously unregulated stands into a balanced structure, emphasis should be placed on control of growing stock while attempting a relatively stable yield during the adjustment period.

In this discussion we are primarily concerned with stands that have irregular structure, and/or composed of tolerant species. The species with which we are most familiar that fall into these categories are southwestern ponderosa pine, southwestern mixed conifers and Engelmann spruce--subalpine fir. Other western species adapted to uneven-aged management are the true fir, hemlock and interior Douglas-fir with irregular stand structure and free of dwarf mistletoe.

The silvicultural systems applicable to uneven-aged management are (1) individual tree selection and (2) group selection. The latter is subject to endless controversy. Many silviculturists consider group selection a harvesting and regeneration system that does not meet the constraints of uneven-aged management for sustained yields because (1) there is no realistic procedure for regulating harvest in small groups and (2) methods have not been developed for determining adequate stocking and acceptable growth of individual trees or groups of trees.

Personally we think uneven-aged regulation can be made to work, with group selection especially if some of the regulatory unit is under individual tree selection management. Residual stocking, diameter distribution goals, marking, and growth projection will be the same as for individual tree selection but they will be for the regulatory unit rather than individual stands--some groups

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will be cleaned, others thinned, and still others harvested. It will be difficult, expensive, require good records and frequent checks on marking. It is not essential that the uneven-aged forest be defined in a strict silvicultural sense for the purpose of forest regulation. The somewhat arbitrary definition that the uneven-aged forest is a forest in which no separate age classes are recognized is all that is necessary (Meyer and others 1961). Even-aged groups may be present, but formal age class regularity of the even-aged forest will not be a goal of management.

Differences in Regulation Between Even- and Uneven-aged Management

Uneven-aged management is the cultural treatments, thinning and harvesting necessary to maintain continuous high forest cover, provide for regeneration of desirable species either continuously or at each harvest, and provide for the controlled growth and development of trees through the range of size classes needed for a sustained yield of forest products. Managed uneven-aged stands are characterized by trees of many sizes intermingled singly or in groups. Regulation is accomplished by setting a residual growing stock goal in terms of volume (basal area) that must be maintained to provide adequate growth and yield, a stand structure goal in terms of a diameter distribution that is necessary to provide regeneration, growth and development of replacement trees and a maximum tree size goal. Information on growth and yield in relation to stocking, stand structure and species composition upon which to base growth projections is lacking.

Even-aged management is the cultural treatments, thinning and harvesting necessary for the periodic regeneration of desirable species, the orderly growth and development of trees to a given size in each stand and the progressive development of stands to provide sustained yield of forest products. Managed even-aged stands are characterized by a distribution of stands of varying age classes throughout the forest. Regulation is accomplished through control of the area in each size or age class and the length of rotation, i.e., time required to grow trees to some specified measure of maturity. There is a considerable body of growth and yield information. Calculations of projected yields under different management systems are straightforward and reasonably accurate.

Regulation of Reserve Growing Stock

Many of the past problems associated with uneven-aged management in the United States resulted from attempts to base regulation on volume control alone. Timber harvests were prescribed on the basis of projections of past growth on the merchantable portion of the stand. Regeneration was left to chance, and little or no treatment was applied to the sapling and pole component of the stand. As a consequence, the high quality stems were cut, quickly, long term yields were reduced and stand vigor declined.

In managed or unregulated stands being brought under management, a procedure must be established so that stands can be periodically cut back to some desired residual structure with some degree of accuracy. The difference between the volume (by diameter classes) of the existing stand and volume of the specified residual stand is current yield. Finally, growth must be projected into the future for at least one cutting cycle to determine expected future yield. The problem is to decide what kind of trees, and how many are to be cut on what schedule to obtain the balanced stand needed to provide sustained yields.

Total stand growth for many species adapted to uneven-aged management doesn't differ greatly over the range of stocking levels likely to be management goals. Consequently, stocking levels set near the lower limit where no growth is lost, concentrates increment on the fewest number of stems. This reduces the time required to grow individual trees to specified size, and represents a minimum investment in growing stock.

The residual stocking level with the best growth varies with species, productivity, diameter distribution, etc. The only stocking standard we could find for Rocky Mountain species was developed by Bert Lexen for southwestern ponderosa pine. Based on his studies of space requirements of ponderosa pine of different diameters, he recommended a residual basal area of 98 sq. ft. for a range of site indices from 75 to 100 (Table 1). Although Lexen's growing stock table was developed from actual data in existing stands, it is essentially 57 percent of normal stocking for all-aged stands synthesized from normal yield tables for even-aged stands (Meyer 1961). Cliff Myers adopted Lexen's standard as one stocking goal for a study of yield of individual tree selection forests of ponderosa pine, and obtained another by proportion. Gil Schubert adapted it to a range of basal areas from 20 to 180 sq. ft.

In unregulated old-growth spruce--fir stands with irregular structure, stocking usually ranges from 150 to 300 sq. ft. of basal area per acre. This probably represents something close to full to overstocking. While no guidelines are available for uneven-aged stands, residual stocking goals of 80 to 120 sq. ft. of basal area per acre are suggested for managed even-aged spruce--fir, depending on site productivity, number entries and other management objectives (Alexander and others 1975). These levels should be useful in estimating initial stocking goals for that part of the stand that will eventually be regulated under uneven-aged management.

The use of yield tables for even-aged stands in setting stocking goals for uneven-aged forests may not be appropriate for all species. This method assumes that there is little difference between the growing stock of even-aged and uneven-aged forests other than a redistribution of age classes over a

Table 1: Lexen's Growing Stock for Selection Forests of Ponderosa Pine in the Southwest.

DBH Class	Trees Per Acre	Basal Area Per Acre
Inches	Number	Ft^2
2	105.4	2.29
4	71.0	6.20
6	48.0	9.50
8	32.4	11.31
10	21.8	11.89
12	14.8	11.62
14	10.0	10.69
16	6.8	9.49
18	4.5	7.99
20	3.1	6.72
22	2.1	5.44
24	1.4	4.40
Totals	322.4	97.55

smaller area (Bond 1952). This pattern may well develop when stands of intolerant to moderately tolerant species are harvested using a group selection method. The end result may well be a series of small even-aged groups represented in the same proportion as the series of age classes in even-aged management. If, however, more shade tolerant species are harvested using a group or individual tree selection method, a different pattern may develop. Often advanced growth of smaller trees will become established under a canopy of larger trees. Growing space occupied by each age or size class is being shared (Reynolds 1954). Assuming that damage to the understory trees resulting from removal of the overstory trees can be controlled, advance growth will successfully establish a series of age classes on at least some acres. In this situation, more trees at larger size can be grown per acre than possible with a balanced even-aged growing stock (Bourne 1951, Meyer and others 1961). The use of yield table data for stands in such uneven-aged forest conditions can produce inaccurate results (Walker 1956).

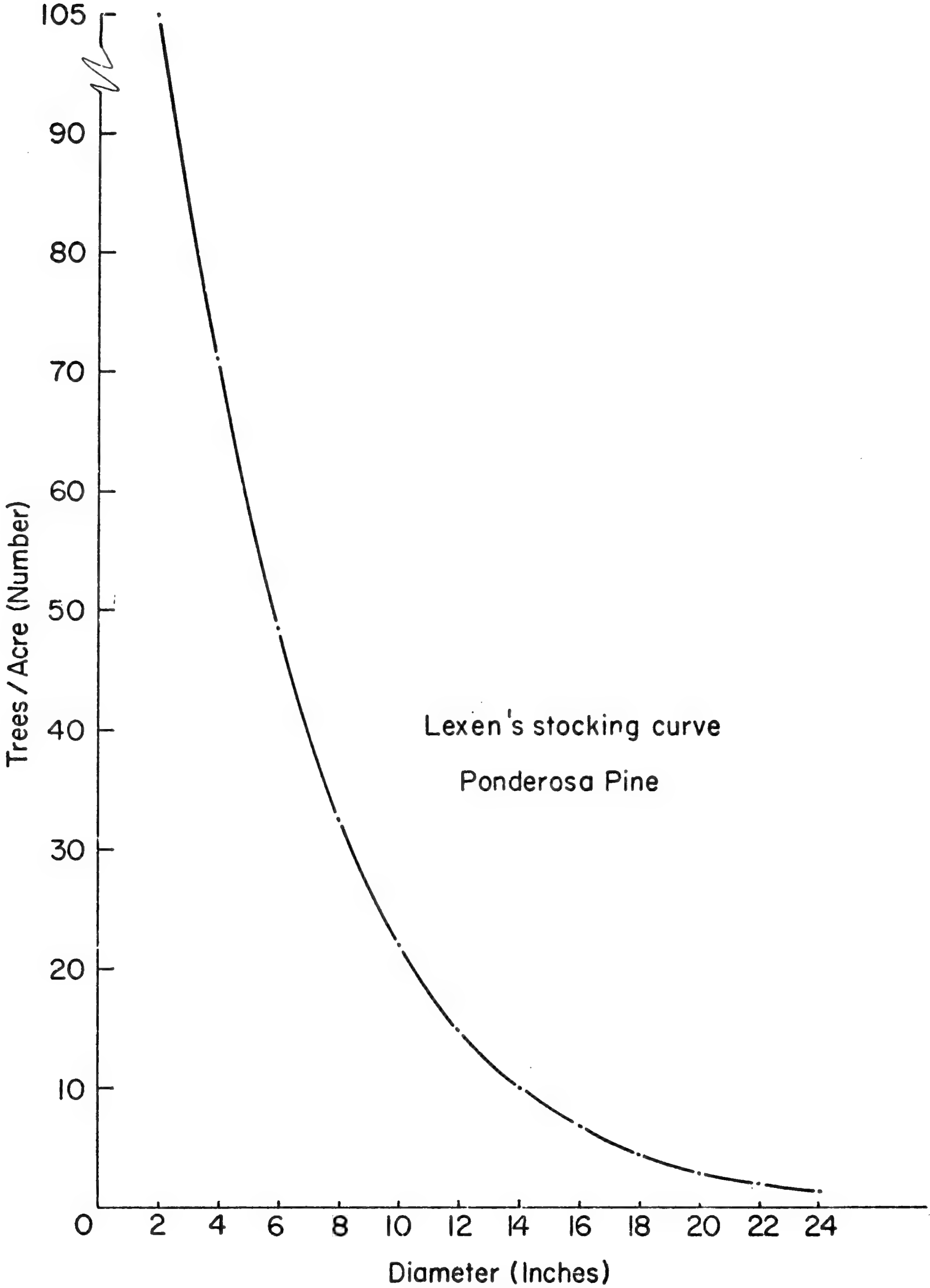
As pointed out earlier, control over the diameter distribution is also necessary to regulate yields under uneven-aged management. This is the most important step and is accomplished by establishing the desired number of trees for each diameter class.

To allow for continuous yields, number of trees over diameter class should follow something approaching an inverse J-shaped curve form. There are a number of ways to express, measure, or present diameter distributions. But when used with flexibility, the quotient (q) between number of trees in successive 1- or 2-inch diameter classes to calculate the desired distribution has been an accepted method (Meyer 1952). Quotients ranging between 1.3 and 2.0 (for 2-inch class) have been recommended for various situations. The lower the "q" the smaller the difference in number of trees between diameter classes. Stands maintained at a small "q" have a higher proportion of available growing space in larger trees.

Lexen did not use "q" to establish diameter distribution for ponderosa pine in the Southwest, but when the residual number of trees per acre are plotted over diameter classes, the resulting curve is a typical inverse J shape (Figure 1). The "q" value for the distribution approximates 1.5.

In irregular spruce--fir stands, the diameter distribution from plot data provide the basic information needed to obtain an actual stocking curve. In the absence of any experience data or good growth and yield information, some arbitrary "q" levels (1.5 for example) could be used to calculate the number of trees by diameter classes and obtain basal area. This basal area can be adjusted by proportion to obtain the number of trees in each diameter class to meet desired residual basal area (Trimble and Smith 1976).

Figure 1


Trees / Acre (Number)
105
90
80
70
60
50
40
30
20
10
0
2
4
6
8
10
12
14
16
18
20
22
24
Diameter (Inches)
Lexen's stocking curve
Ponderosa Pine

Comparing curves of the actual and desired diameter distribution will show where deficits and surpluses occur (Figures 2 and 3). To bring a stand under regulation, management should be concerned with increasing the number where needed along the residual stocking curve and cutting within the range of surplus trees. As a guiding policy, enough trees should be left above the curve in the surplus diameter classes to balance the deficits in diameter classes below the curve.

The need for developing diameter distributions for trees in the unmerchantable diameter classes is questionable. In the Rocky Mountains, minimum merchantable diameters are 5 to 8 inches for most species. Trees below these sizes would be unregulated, but they should not be ignored in recordkeeping. These trees may compete for growing space with larger stems and we need to know what is happening, but more important, they provide the ingrowth into the merchantable size classes needed to practice individual tree selection. Since these trees are likely to be unregulated, cutting will be heavy in the threshold size classes to obtain the desired numbers of trees.

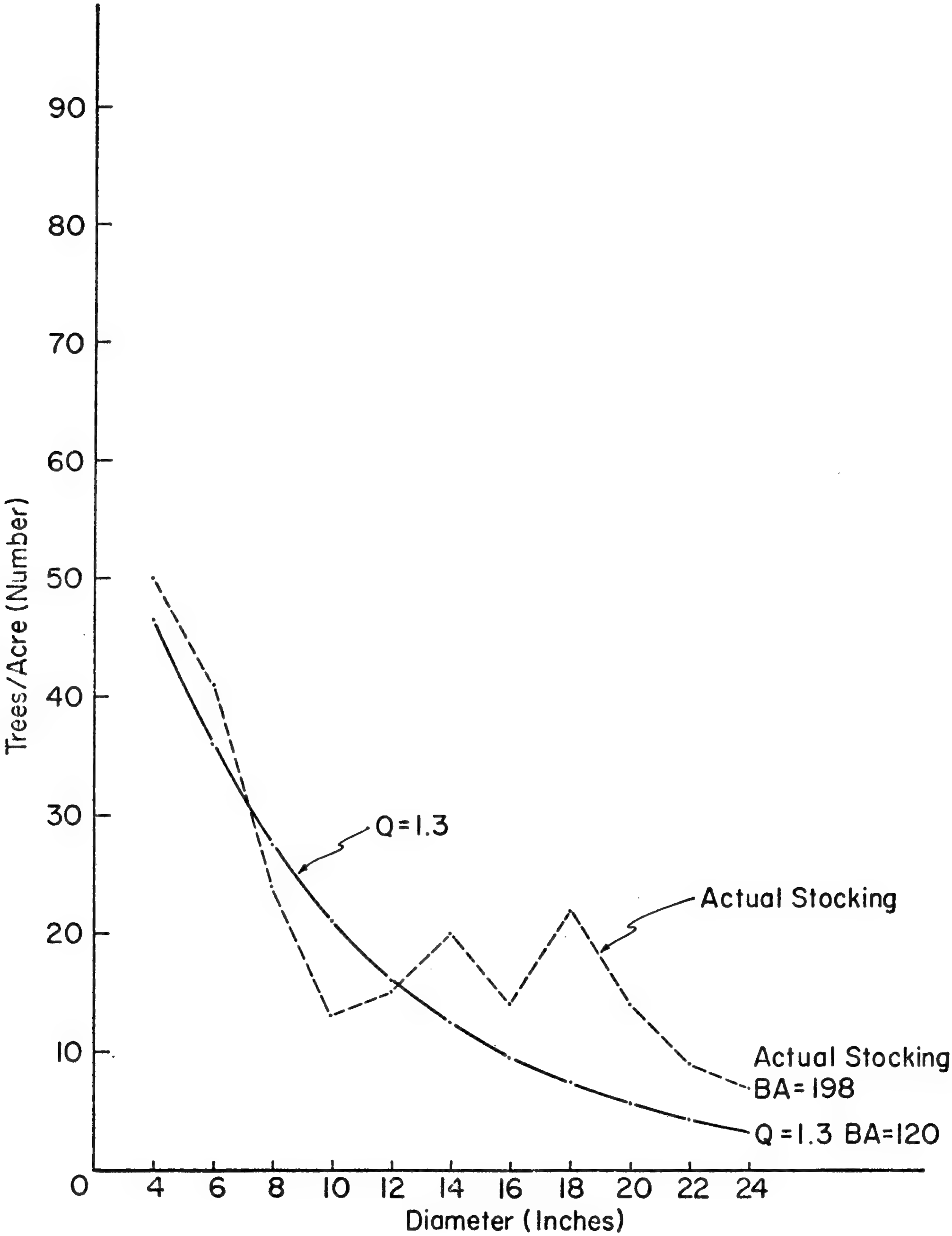
It is not likely that unregulated stands will be brought under control with one cut or even a series of cuts. More likely limitations imposed by stand conditions, windfall, and insect and disease susceptibility will result in over- or undercutting. Yields from harvest will fluctuate until some balanced diameter distribution is obtained. Even under regulation, it is not possible or necessary to obtain a theoretical diameter distribution on every acre. Furthermore, when it comes time to mark stands for cutting, diameter classes broader than 1 or 2 inches will be used (Meyer 1943).

The use of a stand structure goal to regulate uneven-aged stands is primarily to provide a balanced diameter distribution to support periodic yields of about equal volumes. Growth and yield determination may have to be based on inter-tree competition, independent of structure.

The maximum tree size to leave after each cut depends upon site quality, species, management objectives, etc. Without any readily apparent reason, Lexen selected a top diameter of 24 inches at b.h. Examination of yield table predictions for even-aged spruce stands, and plot inventory information from unmanaged stands with irregular structure suggests a diameter of 24 inches can be attained within a reasonable period of time for a wide range of stocking and site quality. In the absence of any information on growth rates, rate of return for specific diameter and stocking classes, this seems like a reasonable first approximation to set for timber production. Trees of larger diameter with a lower rate of return on investment may be appropriate for multiple use reasons.

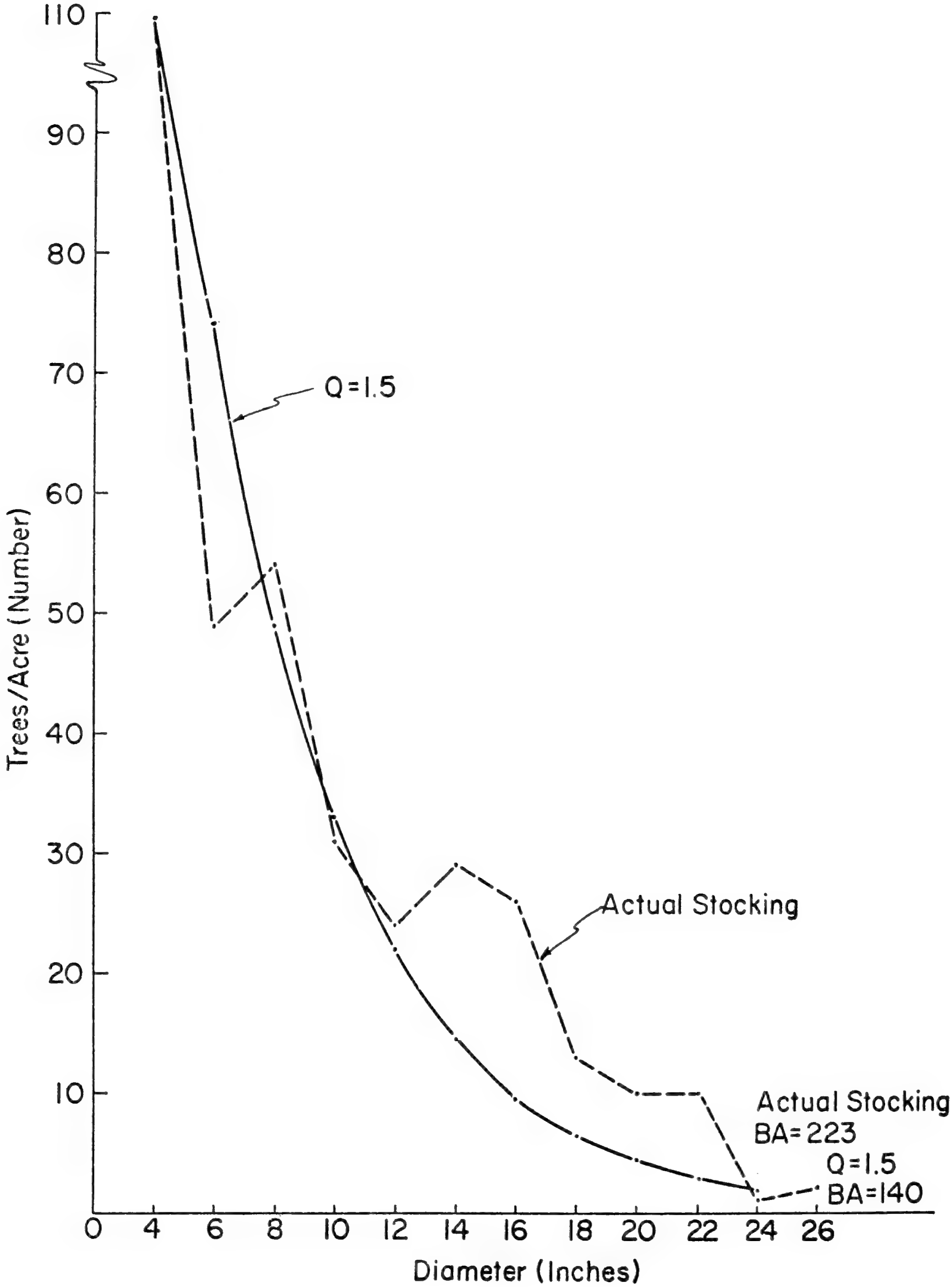
Prescribing residual volumes, diameter distributions and tree size goals that cannot be applied or attained is an exercise in futility. Regulation of uneven-aged forests blows up unless the prescribed structure can be marked

Figure 2



Trees/Acre (Number)
90
80
70
60
50
40
30
20
10
0
4
6
8
10
12
14
16
18
20
22
24
Diameter (Inches)
Q=1.3
Actual Stocking
Actual Stocking
BA=198
Q=1.3 BA=120

Figure 3



110
90
80
70
60
50
40
30
20
10
Trees/Acre (Number)
Q=1.5
Actual Stocking
Actual Stocking
BA=223
Q=1.5
BA=140
0
4
6
8
10
12
14
16
18
20
22
24
26
Diameter (Inches)

in the field with some degree of accuracy. Marking in stands of a species mixture like spruce--fir for example, is difficult because of limited inventory information. The marker must designate cut or leave trees adequately with one pass through the stand. At the same time, he must apply good silviculture and be aware of economic limitations. As a general rule, good silvicultural prescriptions are more important than strict adherence to structural goals, especially in unregulated stands being cut for the first time. However, marking without a structural goal defeats the objective of regulation.

Marking for individual tree selection is more complex than for other systems, and some formal procedure is usually necessary to control marking. Often only an estimate of the initial stand and the desired residual diameter distribution is needed. With these estimates, basal area and number of trees to be removed by diameter class can be determined. Control is maintained by processes of successive checks and revisions toward the desired stand structure.

Rotation Age, a Valid Concept with Uneven-aged Management?

Under a system of even-aged management the rotation is the number of years required to establish and grow a stand of trees to some specified measure of maturity. Economic, pathological, technical, and silvicultural considerations should enter into setting the rotation age. Even-aged stands are regenerated, tended, and harvested during the specified rotation, and the sequence is then repeated. Stand development is a function of tree age. The rotation is a key component in regulating the cut, since the harvest is determined in relation to it.

With uneven-aged management, stands are continuously or periodically being regenerated, tended and harvested with no real beginning or ending. From the silvicultural standpoint, under given stand conditions, there exists a need to know the amount of time required to produce a tree of a certain size, but the cut is not based on tree ages. No separate age classes are recognized, and the actual age of a tree or group of trees is of little practical importance. Volume per acre cannot be expressed as a function of average tree age, and the rotation age is not a valid basis for regulation. Regulation of the cut is determined in relation to growing stock level and distribution, the cutting cycle, and the rate of volume and value growth. The size and condition of a tree and its capacity to grow is much more significant than its actual age. What is essential in a regulated uneven-aged forest is that all sizes of trees be represented in balanced proportion and that these trees be capable of growing as trees of their size should (Meyer 1943). The inadequacy of regulation based on fixed rotations applied to the management of irregular and uneven-aged forests has been discussed by Kirkland (1925, 1934).

Cutting Cycles in Uneven-aged Management

The interval between cuts or cutting cycles will vary with the rate of growth, residual stocking level, site quality, volume available for cutting, accessibility, economic constraints and intensity of management. In western coniferous forests, cutting cycles under even-aged management vary from 10 to 40 years. From a silvicultural point of view cutting should be timed to coincide with the return of the residual stand to something called full stocking--that point where growth begins to diminish. In actual practice, re-entry schedules are usually set at multiples of 10 for convenience of recordkeeping. In unregulated coniferous stands that are being brought under management where specific growth information is lacking, a cutting cycle of 20 to 30 years seems reasonable. In stands with incomplete representation of diameter classes, volumes available for cutting may not warrant this frequency of re-entry until a controlled diameter distribution is attained.

Intensity of silviculture and the relation of the growth rate to economic constraints are probably the most important factors in choosing the length of the cutting cycle. With intensive management and rapid growth, the growing stock distribution can be changed more rapidly with a short cycle. Frequent cuttings allow natural mortality to be reduced by removing trees which have high risks if left for the next cycle. With a short cycle relatively small volumes are removed per acre in a single cut which leaves a large growing stock for the next cut. Displacement of actual growing stock from growing stock distribution goals is relatively small.

Longer cutting cycles under more extensive management require that considerable volumes be removed per acre in a single cut. Significant displacement of actual growing stock from desired goals may occur, leaving a smaller residual growing stock to put on less volume growth than a denser residual stand. With longer cycles, mortality may also affect the estimate of net volume growth.

Cutting cycles are usually established for a compartment, but larger or smaller subdivisions may be used. Cutting can occur every year in some part of the management unit or it may occur as periodic cuts. Regardless of the intervals of re-entry, each stand should be examined before treatment to determine what needs to be done and when it will be accomplished. After treatment, another examination is required to determine what was accomplished in terms of goals set.

Allowable Cut Projections

Under uneven-aged management with individual tree selection, allowable cut projections are relatively simple and straightforward in concept, and easy to accomplish, at least for one cutting cycle. Attempts to project yields through many cutting cycles with present growth and inventory data are not realistic. The number of trees and basal area by diameter classes are obtained from the past logging inventory. Expected growth increases and the number of trees by diameter classes are projected forward in time to get the stand at the time of the next cut. The difference between the specified residual (present) stand structure and the projected (future) stand structure is the allowable cut. Allowable harvest for the regulatory unit would be obtained by following this procedure for each stand or compartment and summing the expected yields. Irregularities in year-to-year yields can be smoothed out to some extent by adjusting the time individual stands are cut.

The difficulty with this procedure is lack of growth data for even short term projections. Ideally these projections would be made from measurement data on growth plots in each regulatory unit. Unfortunately these kinds of remeasurement data are hard to come by, and published information on growth in uneven-aged stands of western coniferous species is almost non-existent. Furthermore, data obtained from present forest inventory procedures may not be suitable for growth projections. The major obstacle to growth projections is, of course, lack of long term yield estimates for managed stands comparable to that available for even-aged stands.

Two general approaches to determination of the allowable cut have long been recognized: (1) area control, and (2) volume control. A certain amount of confusion has resulted from this classification. Usually area control is most appropriate for even-aged forests and volume control for uneven-aged forests (Bond 1952). However, in practice, regulation of the cut and development of a cutting plan may include both volume and area regulation (Guilkey and Gevorkiantz 1949, Meyer and others 1961). They may, therefore, be used to compliment each other in determining the level of cut and the cutting plan.

The Rocky Mountain Station is currently working on the methodology needed to develop long range growth and yield projections for ponderosa pine stands with irregular stand structure comparable to the simulation procedures developed for even-aged stands by Myers (1971). Yield will be projected on the basis of the periodic growth of broad diameter classes for a range of site quality, residual stocking levels and maximum tree size goals.

Markets and Financial Aspects of Regulation

Regardless of the projected allowable cut, regulation is subject to supply and demand. On the National Forests we cannot increase the volume of timber sold above what the market can take. We can only limit the amount sold. Furthermore, timber sold may not be cut on schedule. Since uneven-aged management requires cutting in all classes, markets must be developed for small diameter trees. Otherwise the cost of removing this material will have to be carried by the merchantable portion of the stand.

Regulation under uneven-aged management is more expensive than for even-aged management. Stand examinations to update inventory and growth information must be made at more frequent intervals. More detailed records of average volumes, size classes, cutting schedules, etc., are required for control of the cut. A complete permanent road system is also needed for successful regulation.

One last thought, regulation is not a researchable problem--it is a management decision. The tools to make long term growth and yield projections for a wide range of structure goals, productivity classes, etc., are researchable problems.

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RESEARCH GAPS AND RESEARCH NEEDS FOR THE WESTERN FOREST REGIONS[1/]

by

Robert E. Phares[2/]

Although the western workshop has succeeded in consolidating some of the concepts of uneven-aged silviculture and management, some elements are not completely understood. Regulation of cut, getting adequate regeneration, difficulty in determining yield production, and the difference between single tree and group selection, all at one time or another, became the subject of inconclusive discussions. This situation points to the need for further emphasis on development of basic principles for uneven-aged silviculture and management in the western forest regions. Furthermore, a number of specific needs were surfaced by the individual work groups at the workshop which could well serve as a framework for planning new research programs in the future.

Regeneration

There is a west-wide need to install studies on establishment and growth of regeneration. Some of the regeneration problems needing attention include:

- -- The effect of soil compaction from frequent entry on suppression of regeneration and stand growth.
- -- The reduction of lag time in obtaining adequate regeneration when and where needed.
- -- Effect of grazing by livestock and wildlife on regeneration success in areas of heavy animal use.
- -- Effect of stand structure and composition on establishment, growth, and composition of regeneration.
- -- Alternative methods of controlling undesirable vegetation.
- -- Advantages and opportunities for using "habitat types" as the key approach to uneven-aged silviculture and management study and technology transfer.

1/ Condensed from work group reports by Don Gordon, Jerry Franklin, Bob Curtis, and Bob Alexander.

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-- Determine effects of pre- and post-logging forest floor residue on establishment, growth of regeneration, and interrelationships with nutrient cycling.

-- Investigate interrelationships between insect and disease pathogens and establishment and growth of regeneration under different uneven-aged silvicultural and management systems.

Stand Structure and Composition

For the long run, we need to develop a greater ability to predict various product outputs (biological options) for given stand-site conditions. The basic question is, what can we do silviculturally to produce the array of goods and services demanded by the public. We do not want to research uneven-aged management per se; our emphasis should be on increasing our knowledge of how to manipulate forest stands to achieve specific stand structure and composition goals. Research should focus on young- as well as old-growth forests. Specific objectives would be to develop predictive ability to determine what biological options are for a given habitat or stand combination to meet various management objectives.

We also need a better understanding of successional dynamics including rates, directions, and driving forces on different habitat types. This should be supported by more extensive studies of age-structure and age-size relationships. Greater attention should be given to components other than live trees, i.e., we should adopt a total ecosystem perspective.

Very little is known about impact of species composition trends on potential growth and yield. What is the relation between size of openings and establishment and growth of individual species? Can we define space requirements for species A to maintain itself in competition with species B? Can we predict the trend in species composition under a specified management regime?

As soon as possible, we should try to complete a west-wide compatible, site-type classification (based on habitat types, land stratification, etc.). This will allow us to go from general to specific in describing site conditions, and will also provide a better basis for extrapolating knowledge and generalizing predictions.

Growth and Yield

There are a number of problem areas needing research to better understand growth and yield potential under uneven-aged silviculture and management. For example, we need to do a better job in relating growth and yield potential to habitat types and edaphic factors. Especially needed are site estimation procedures not so dependent on suitable site trees. Where conventional site estimation procedures have to be used, we need to investigate possible adjustments for suppression effects, as well as investigate methods for evaluating site index where potential stocking is restricted--the "stockability" problem.

Better methods of tree vigor classification and assessment of tree growth potential are needed. Is advance regeneration capable of growth response?

How do we measure competition and assess the need for stocking control? Are analogs of conventional even-aged measures applicable under uneven-aged systems? What constitutes a situation where stocking control will pay off as an investment in promoting growth of small size classes? Does overstory competition have a differential effect on height growth versus diameter growth?

What are the trade-offs, including yield and management costs, between even-aged and uneven-aged management? There is need to assemble existing information on potential yield differences and other trade-offs; this will be useful as reference and justification for management decisions. We also need to know the advantages of uneven-aged management versus long rotation even-aged management from standpoints of environmental, recreational, aesthetic, and timber yield considerations.

New procedures and standards need to be developed to meet the National Forest Management Act of 1976 requirements for bringing stands up to potential productivity. This is probably more of an administrative job than a research job.

Better procedures are needed to derive estimates of long term yield under uneven-aged management. Several approaches can be taken. Case histories can provide first estimations but have limited usefulness. Individual tree projections, including distance-dependent competition measures, may have greatest potential; this is a complex problem but needs a start.

Regulation

There are very few regulation problems per se under uneven-aged management, but there are several problem areas, many of which have already been listed, that need further research to facilitate efficient regulation of forest yield:

(1) Efficient multi-resource inventory procedures should be developed as rapidly as possible. These procedures will probably vary by habitat type, soil type, or other criteria, but they also must tie into projection techniques.

(2) There is need to develop a workable base for yield projection such as habitat type, site index, soil capabilities, etc., or some combination of these. Habitat type may also help identify regeneration problems, site potential, growth potential of established stands, etc.

(3) There is need to identify advantages of uneven-aged management for various sites, species, and management objectives.

(4) Research must be keyed to National Forest System needs and the National Forest Management Act. On the other hand, NFS must do a better job in defining objectives of management before any system of management can be evaluated or applied. Even-aged management is probably cheaper and easier to administer but more research is needed to identify benefits and methods of uneven-aged management. Economics is probably one of the key elements.

(5) Individual tree growth and competition studies, inter-species competition studies, and product trade-off studies are needed.

(6) We need to develop alternative silvicultural prescriptions for protecting, maintaining, and enhancing other values or products such as wildlife, water yield, scenic quality, etc.

(7) We should develop growing stock studies in all applicable forest types. As an initial step to this, we should summarize data from the old "methods of cutting" plots.

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