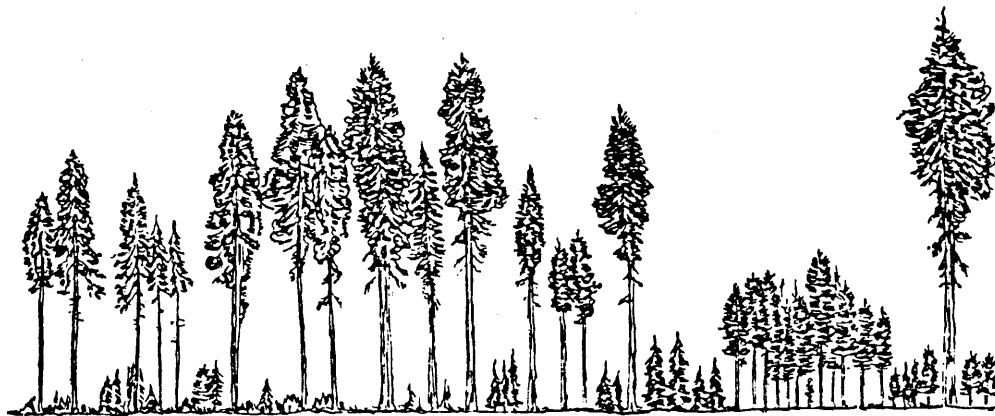


UNEVEN—AGED SILVICULTURE AND MANAGEMENT IN THE WESTERN UNITED STATES



Proceedings of an In-Service Workshop
Redding, California October 19-21, 1976



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

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FOREWORD

Forest managers are, and will continue to be, constantly confronted with the dilemma of choosing between different silvicultural and management systems to achieve various desired mixes of multiple-use benefits on specific forest properties. Such choices have to be made, unfortunately, because no single silvicultural or management system is ideal for all situations. Complicating these choices is the hard fact that our scientific knowledge is not well distributed over the range of silviculture and management options available to our use. There is no doubt that forest researchers know much more about even-aged silviculture and management than uneven-aged silviculture and management--simply because there has been more research done on the former systems. With the increasing concern over the alleged over-use of 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 workshop, summarized in this Proceedings, represented a joint effort by personnel from Research, National Forest System, and State and Private Forestry, to review the state-of-the-art knowledge about the applicability of uneven-aged silviculture and management in the western United States. One major objective of this review was to develop a much better mutual understanding of the definition of uneven-aged silviculture and management. A number of research gaps and research needs were also identified. Many of these needs are already being incorporated into the program planning for several research work units in the four western Experiment Stations. In addition, many of the papers presented at this workshop should serve as interim working guides for forest managers in better understanding the complexities of uneven-aged silviculture and management of public and private forest lands throughout the western United States until some of the needed research can be completed.

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OPENING REMARKS

by

C. M. Berntsen^{1/}

Welcome to the Western Workshop on Uneven-aged Silviculture and Management. As you know, this workshop is the counterpart to the Eastern Workshop held in Morgantown, West Virginia, July 15-17, 1975.

Robert Buckman, Deputy Chief of Research, sends best wishes for a successful session and regrets that he could not attend because of other high priority business. Also, Dave Tackle's transfer to the Rocky Mountain Station prevents his attendance. Dave was instrumental in setting up this workshop.

We have good representation of research and user groups: about 20 western and 7 eastern research silviculturists; 8 National Forest Systems silviculturists or administrators; 4 State and Private Forestry representatives; and 1 forester from Forestry Extension, California.

The purpose of this workshop is to clarify the issue of uneven-aged management and the selection system and to determine where do we go from here. I refer to uneven-aged management as an "issue" because of its recent popularity in discussions involving alternatives to clearcutting. In this regard, this workshop is indeed timely as it coincides with the enactment of the National Forest Management Act of 1976. Among other things, this Act sets forth limitations on where even-aged management can be applied, and requires that Forest Service management plans incorporate management systems, harvesting levels, and procedures in the light of all uses including wilderness. Uneven-aged management, therefore, gains attention as a system that will accommodate some of the new requirements of the Act of 1976.

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You may recall that earlier this year we asked several members of the WO and field staff to prepare a series of background papers on the silvicultural and management practices currently used on the National Forests to support the Chief's testimony before legislative hearings. These hearings were instrumental in the passage of the National Forest Management Act of 1976. The background papers have subsequently been published as an In-Service report entitled, "The Scientific Base for Silvicultural and Management Decisions in the National Forest System," which has been distributed to all Regions and Stations. This report, and the proceedings of the eastern, and now the western, Uneven-aged Silviculture and Management Workshop, represent part of the continuing documentation and direction needed to guide future research and management decisions in the application of both even- and uneven-aged silviculture and management.

Although the "Act of 1976" seems to impose a kind of mandate to give greater consideration to uneven-aged management, it was not our intent to force the selection system into either our research programs or management plans. Our first priority is to gain a better understanding of the biological and ecological implications of such systems and how they might fit into scientifically sound management practices. To this end, our discussions should be wide open to allow for imaginative and innovative interplay in exploring the basic fundamentals of tree and stand growth as well as the adequacy of current silvicultural concepts to meet the needs of our times.

This workshop allows us four opportunities to dig out the essential elements. The first cut is via the formal papers to be presented. The second is to observe conditions in the forest where a system of uneven-aged management is being practiced. The third is the setting up of small-group workshops where each group, using a set format, will discuss in more detail one of four major topics. The fourth cut is the reconvening of the entire workshop to hear group reports and discussion.

This is your show. We look forward to a productive and stimulating workshop session.

HISTORY AND PHILOSOPHY OF SILVICULTURE AND MANAGEMENT SYSTEMS IN USE TODAY

by

A. P. Mustian^{1/ 2/}

Most of you have probably read the proceedings of the eastern workshop on uneven-aged silviculture and management and my paper by the above same title. Therefore, about all I'm going to do here is highlight some of what was said in that paper and its relevancy to our consideration here of uneven-aged silviculture and management in western timber types.

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 have 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.

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^{2/} This paper was presented at the Workshop by Robert E. Gillespie, Assistant Director, Timber Management Staff, U.S. Forest Service, Washington, DC.

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).

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. 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 such situations has been to protect what timber was left or to replace (regenerate) the timber resource or a combination of both. The cultural practices advocated or improvised to treat the problem usually reflected a desire to extend the existing supply of timber or put existing stands in a condition for more intensive management in the future. In other words, the order of the day was first things first--consideration of the whole set of cultural treatments from harvest and regeneration to harvest and regeneration again could come later when we had forests to which a complete system of management could and should be applied.

Note should be taken that a number of recorded events or laws, ordinances, and regulations in various parts of the Old World from as far back as Biblical times have been cited as reference points in the development of classical silviculture systems. However, the development of silviculture and forest management in Europe, particularly Germany, has had probably the greatest influence on the development and growth of forestry in this country.

The situation in this country's forestry development during the last 80 years or so has paralleled somewhat the situation in Germany and Europe for the preceding 300-400 years--successional, but sometimes concurrent, curtailment of the quantity of timber cut, introduction of silvicultural measures for forest replacement, activities for improvement of stands, and finally, the organization of the forests for sustained yield. Hopefully, though, none of us are guilty of believing that in just 80 years we have traversed the whole range of experience of our colleagues and predecessors in Europe in the development and use of silvicultural systems. With the experiences of the last 6 or so years, we may justifiably feel we have aged that much!

For a quick review of some of the historical similarities and parallels of forest management and silviculture development and practice in yesteryears with those encountered since the turn of the century in this country I again refer you to the text of my previous paper, and also to the legislative record of the recent congressional action on management of the National Forests.

It is obvious, I think, that the 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 socio-economic factors and resource conditions. (Troup 1952, Fernow 1902, Larsen 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 in our own time.

It has been suggested that we are following or have followed a spiral course with the idea that each time around advances have been made and we have risen a little higher than the previous time around. I get the feeling sometime that in the evolution of silviculture in America we are on a merry-go-round rather than the second or third loop of the spiral. We may not yet have experienced the drastic changes in practices or the all or none approaches to silvicultural problems which characterized the previous 2 or 3 centuries in Europe, but some of the proposed restrictions on National Forest management and the prescriptive nature of recently considered legislation certainly raise specters of the past.

How does all this relate to the development of silviculture in the United States and to western timber types? We got on the road around the turn of the century at the beginning of another spiral, which meant we started at a little higher level, but the situations were 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, et al.). Pretty early in the game, cutting practices on the National Forests and recommendations for other lands reflected an accommodation 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." In another section, 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.

On regulation of yield, the old Manual stated:

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.

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.

I might inject here a few questions for your consideration. Are the arrays of silvicultural methods we have available applicable to the forest types and situations in the western United States? Do you feel that the fact--if it be fact--that early silvicultural developments in Europe and the eastern United States dealt largely with second growth and mixed stands has unduly or adversely affected development of silviculture systems and practices for western forest types? If so, how do we adjust or compensate?

Henry Graves suggested back in 1908 that silviculture in the United States would be a conversion process, 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. He subsequently 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. 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).

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).

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 at that time told the Forest Supervisors that "clear-cutting 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."

Some of the same vacillation or uncertainty was evident in the management of other types. For example, the claim was made by someone in the WO 30-40 years ago that we had studied lodgepole pine more and knew more about its management than any other type in the Rocky Mountains. Yet later recommendations to make overstory removal cuts and thinnings in young lodgepole were criticized by Raphael Zon because lodgepole growth would not respond to release! And in areas, we still have partial cuts in mature lodgepole and expect to regenerate under a kind of shelterwood in dwarfmistletoe infested stands.

Where does all this leave us, or more important, where do we go from here? Depending on whether you are talking about ponderosa pine in the Southwest, Douglas-fir in the Pacific Northwest, or some other type and place we are either still in the first evolutionary spiral of silvicultural progress, or approaching the starting meridian for the third time around.

Frankly, up to now, I don't believe we have given due consideration to the whole set of silvicultural practices or treatments making up a system of management from harvest and/or establishment of a new stand to harvest and regeneration again. We have been getting stands ready for management or applying cutting methods and other practices to achieve an immediate or short range objective only for about 80 years.

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. In the West, we have been preoccupied largely with extending the old growth, both for the "next cut" and for nontimber purposes. 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.

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. (Dave Marquis and Bud Twombly can tell you something about that.) 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.

We are here to talk about uneven-aged silviculture and management. Hopefully we can chart some direction for further research of uneven-aged silviculture and its application or adaptation to forest management that will achieve in combination or separately the increasing array of conventional and special resource management objectives confronting forest managers. Whether the outcome be new systems or just adaptations of the classical silviculture systems makes little difference as long as they are defined, practicable, effective, and understood by the forest managers who need and apply them.

For what it's worth and your own determination of its relevancy to what we are to do here, 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).

Then, lest we become hopelessly mired in the morass of that ubiquitous term "selective cutting," I tell you again the little anecdote about Dr. Carl A. Schenck. He was 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," Dr. Schenck commented, "Good! By all means give the bastard a name!" Enough said!

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

by

Carter B. Gibbs^{1/}

Introduction

During the fifteen months since the eastern workshop on uneven-aged silviculture we have seen 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 have been 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. This meeting, like the one in the East, provides us an excellent opportunity to clarify our own thinking on the subject of uneven-aged silviculture.

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.

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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 words rather than the processes or systems involved, do not reflect the degree 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.

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

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. Both even-aged and uneven-aged management may be used to produce timber, both are feasible and workable. They are sufficiently diverse so that together they provide the tools for overall forest management to meet effectively all management objectives except wilderness. Neither is the panacea for forest management to meet multiple use objectives and both must be considered in any well formulated plan of management for a large forested area.

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

In multiple use applications uneven-aged silviculture is best suited to travel influence zones, water influence zones, watershed protection, scenic areas, and 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, regeneration occurs during one short period just prior to or after the final harvest. Stands may be regenerated either naturally or artificially and it is easy to introduce improved genotypes.

Stand Composition

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

Stand Structure

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

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

Stand structure is perhaps the least understood and certainly 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 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 an 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 both systems, 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 differences that I feel are contributing significantly to our problems in research and application of uneven-aged.

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

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

Three, mistakes in uneven-aged management for sustained yield are not easily recognized. 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. This problem will not be evident until sometime in the future when it becomes apparent that sustained yield regulation is lost due to deficiencies in larger size classes, reduced harvestable volumes, and irregular stand structures.

Summary

In closing, I would like to emphasize two points:

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

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

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

by

David A. Marquis^{1/}

Introduction

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.

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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. 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).

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 achieve full site occupancy within the next 10 years, and should therefore be considered for replacement.

Somewhat similar stocking charts have been developed for some western types. I have reworked a chart that Bud Twombly send 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

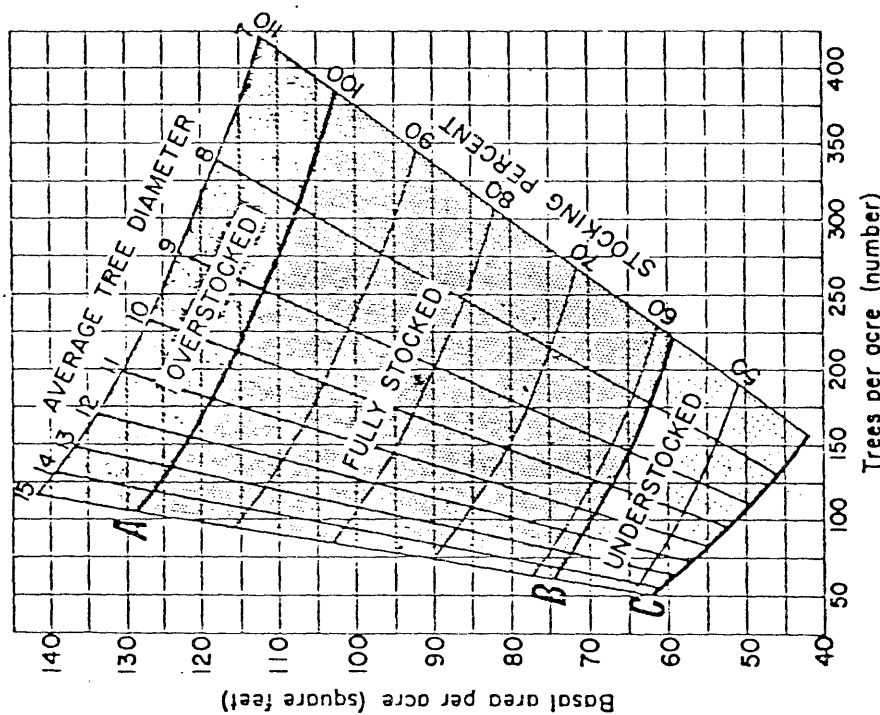
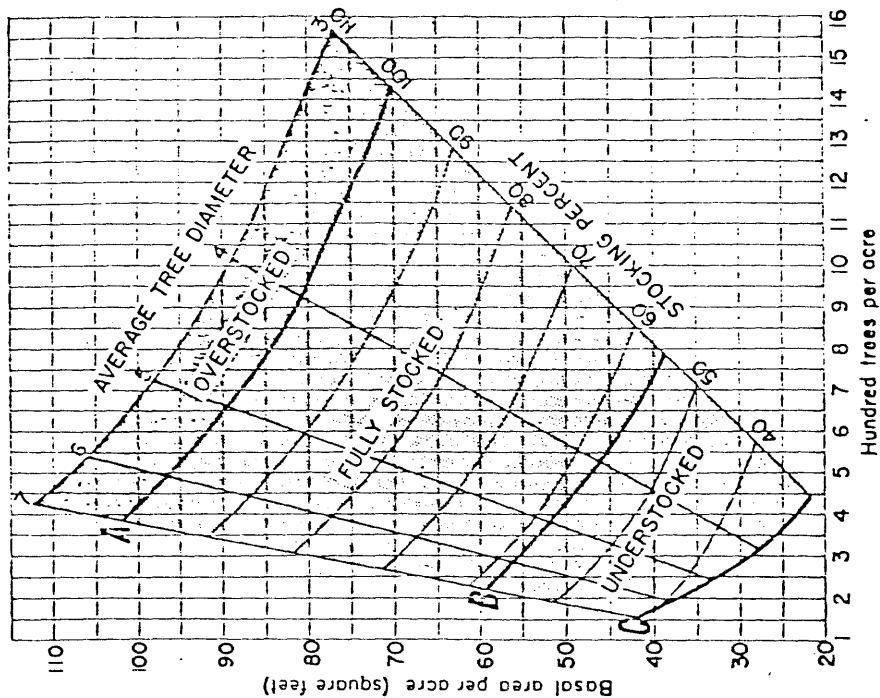
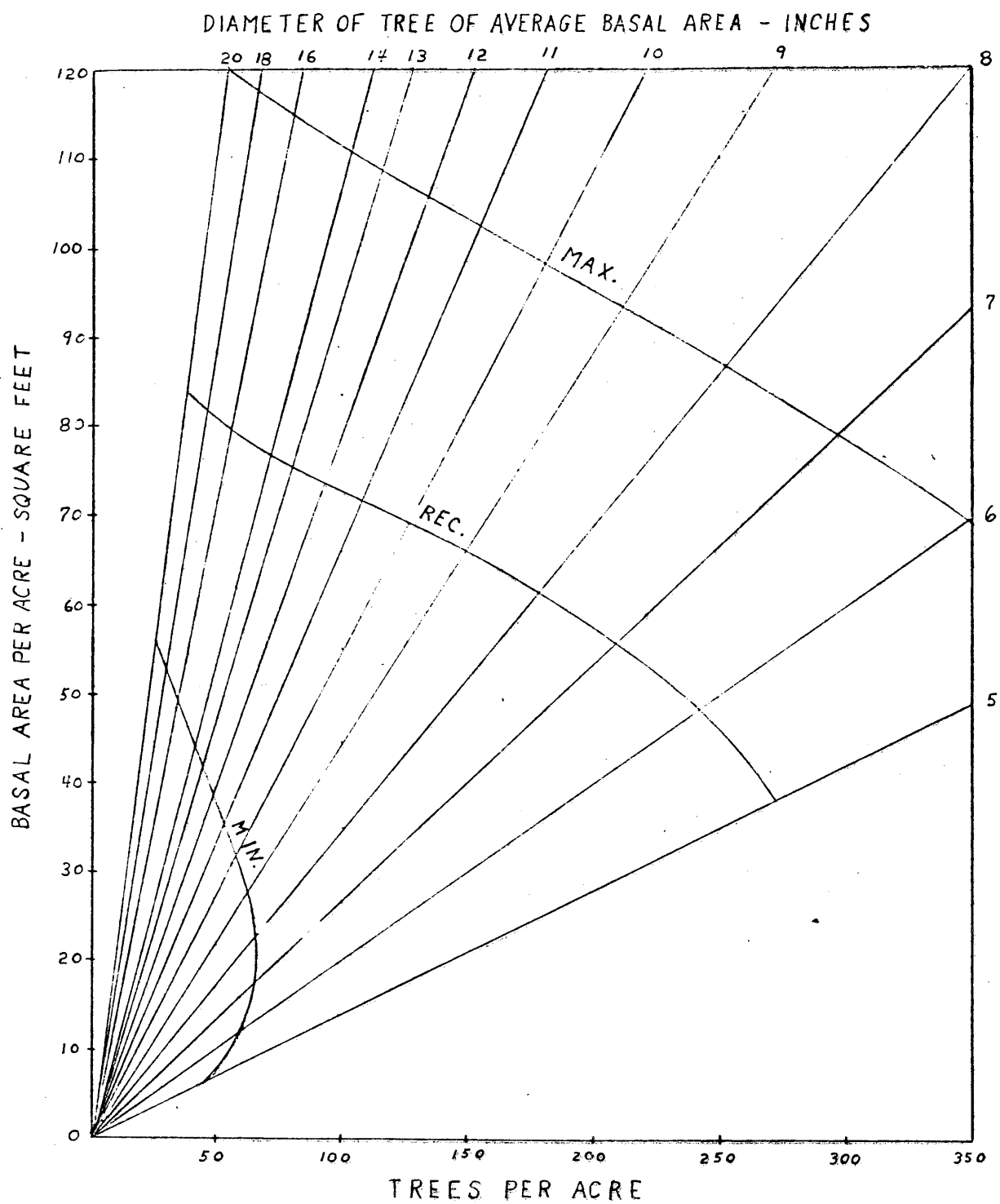


Figure 1.--Relation of basal area, number of trees, and average tree diameter to stocking percent for upland hardwood forests of average uniformity. Tree-diameter range 7-15 (left), 3-7 (right). The area between curves A and B indicates the range of stocking where trees can fully utilize the growing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



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 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.

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 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.

Table 1. --Average diameter and B level stocking for Ponderosa pine stands for various "q" factors and maximum tree sizes.

"q" factor	Maximum tree size (inches)			
	32		24	
	ave. diam. -inches-	B level -- -sq. ft. -	ave. diam. -inches-	B level -sq. ft. -
1.1402 (1.3)	10.0	69	9.0	66
1.2649 (1.6)	6.3	48	6.2	48
1.4142 (2.0)	4.5	33	4.4	33

For example, assuming that Ponderosa pine can actually be grown under single-tree selection cutting, and using Bud's stocking data, 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.

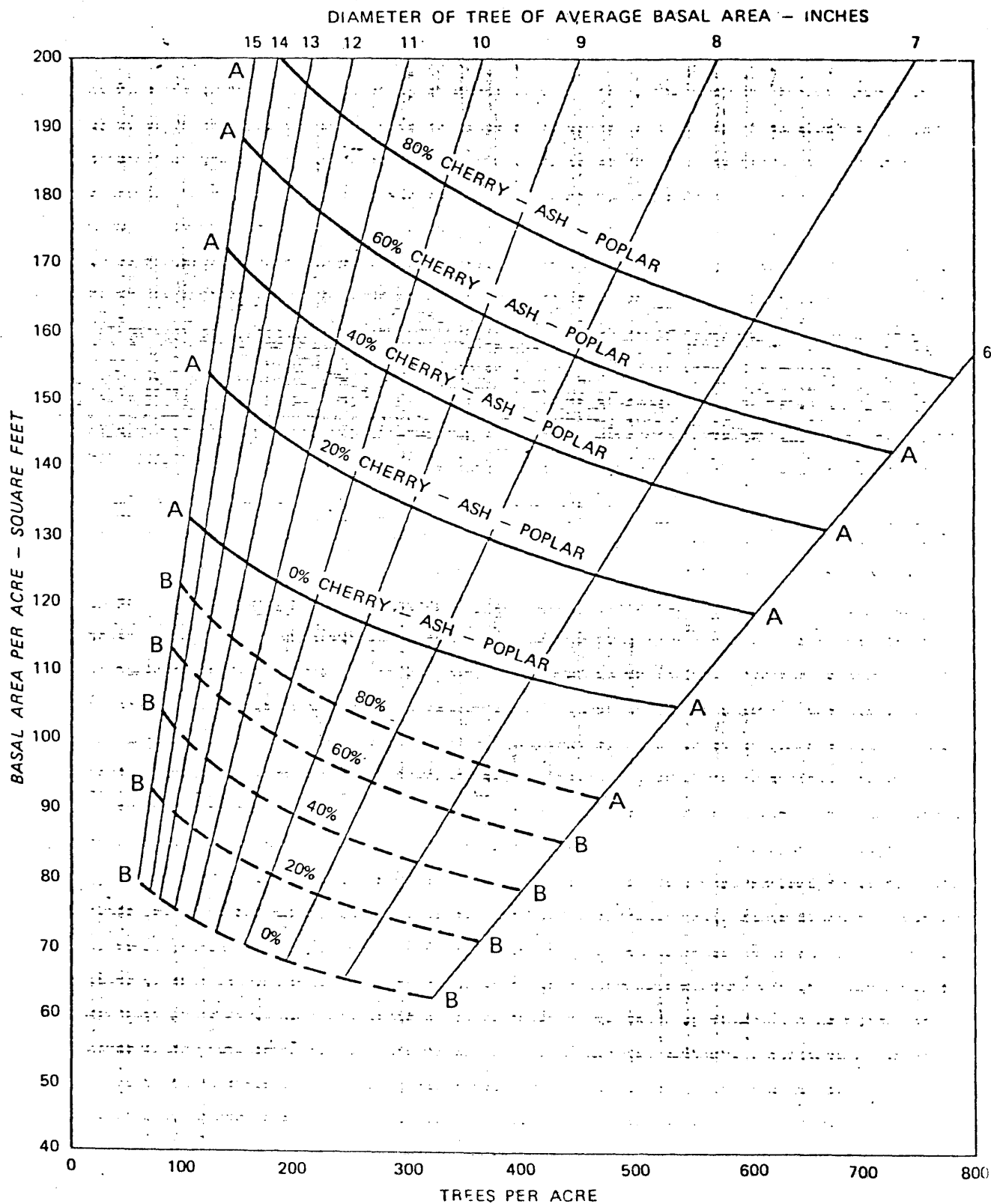


Figure 3. -- Stocking guide for Allegheny hardwoods for stands 6 to 15 inches in diameter (Roach 1975).

B level stocking for such a stand is about 66 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 33 square feet--33 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 reflect 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.

Control of Diameter Distribution

As I'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.

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

<u>D.b.h. class</u>	<u>No. trees</u>	<u>D.b.h. class</u>	<u>No. trees</u>
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

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. 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 for eastern hardwoods 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

NUMBER OF TREES PER ACRE

90
80
70
60
50
40
30
20
10

4

8

DBH ²⁹

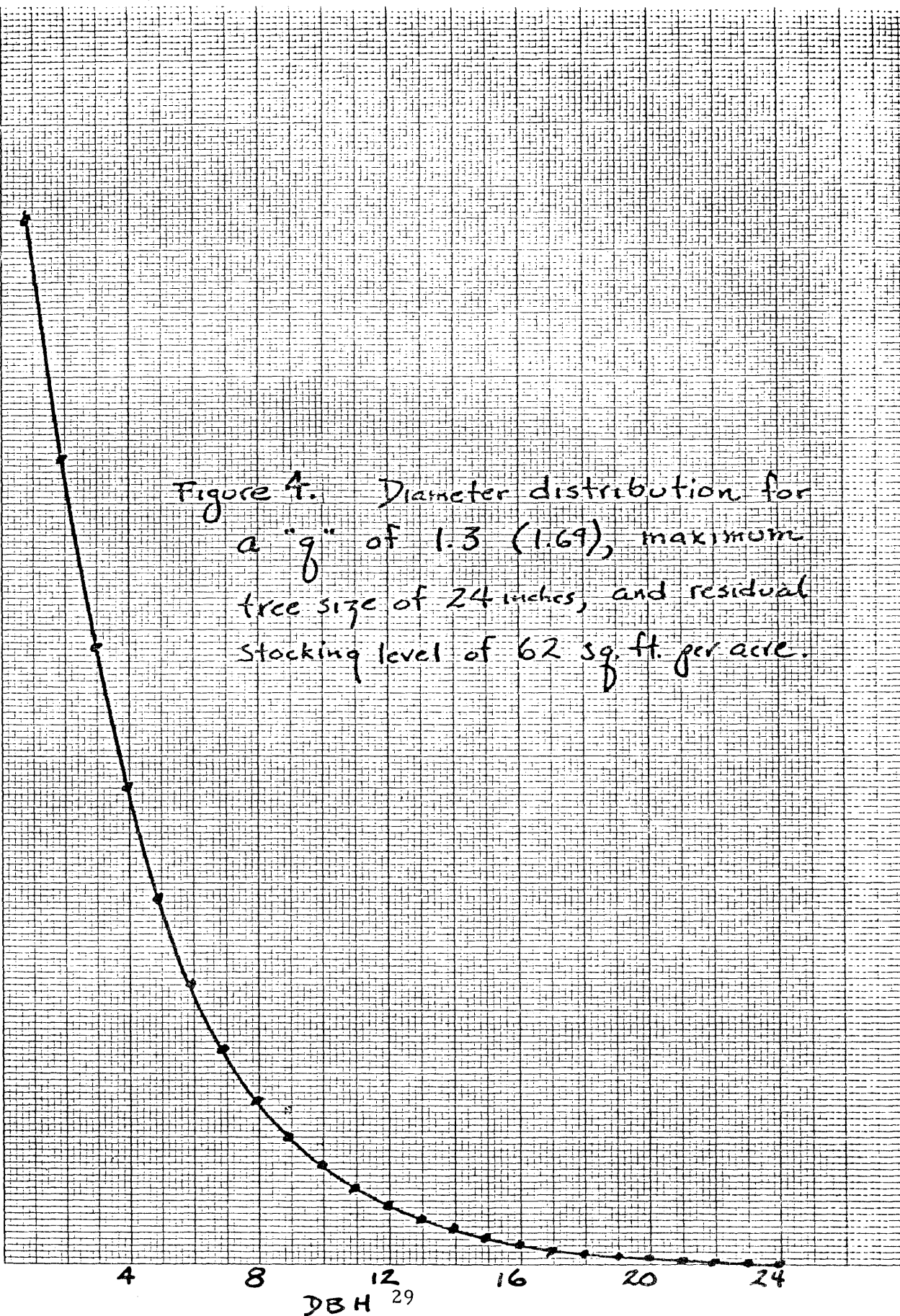
12

16

20

24

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



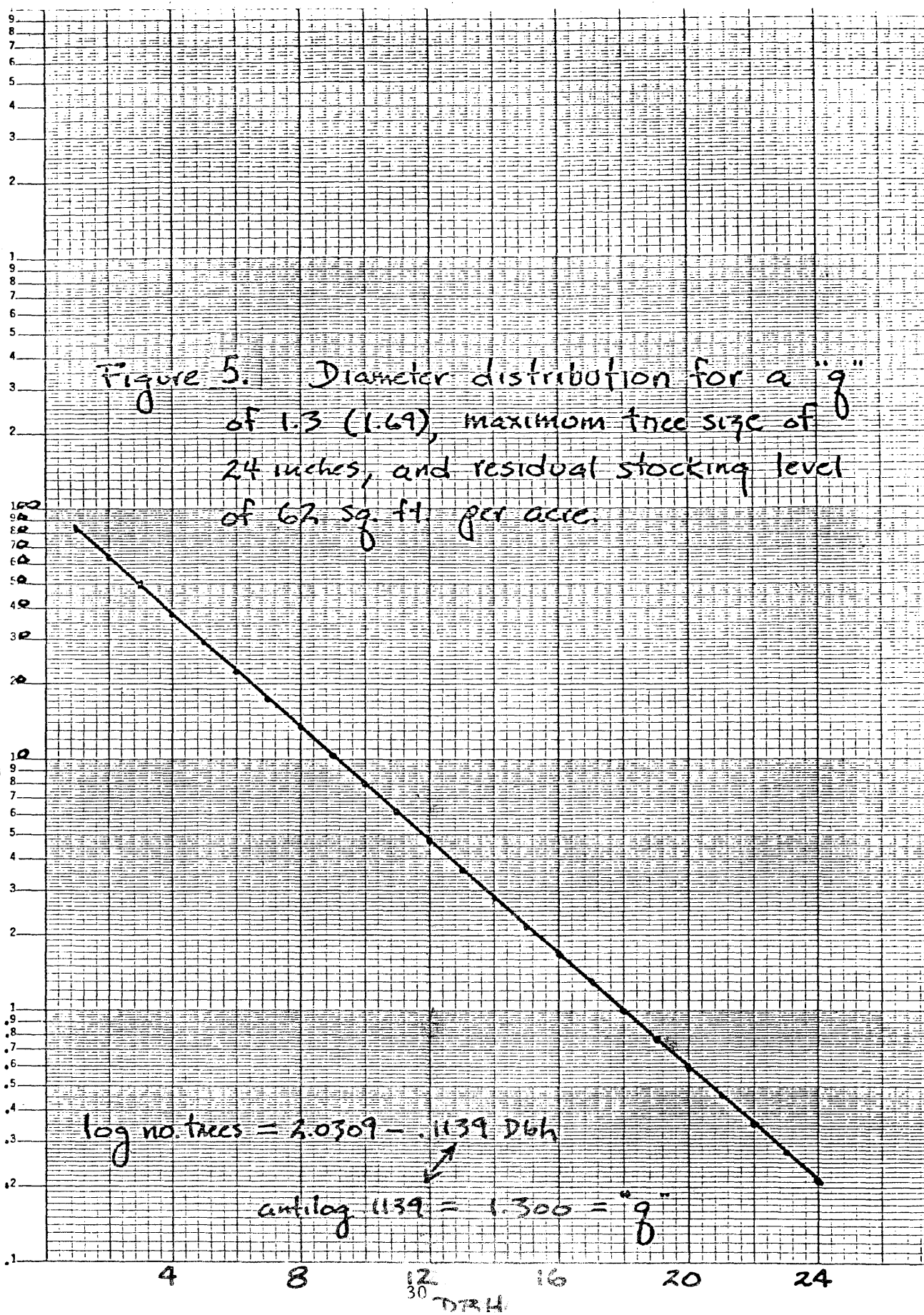


Table 3.--Maximum size trees for various rates of return, species
and site index (from Trimble et al 1974).

Species	Rate of return desired								
	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

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 numbers of trees between diameter classes. Stands maintained to a small "q" have a high proportion of the available growing space devoted to larger, more valuable trees and should theoretically produce somewhat higher yields than stands maintained to a high "q". But maintenance of a low "q" factor means that the excess numbers of small stems that usually develop must be removed periodically at some expense.

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

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 pre-logging "q" level will also be an important factor. In younger, second-growth stands where the existing "q" level may run over 2.0 and the number of large trees is limited, it would be unrealistic to shoot for a very low "q". But in old-growth, or stands that have already received several cuts aimed at balancing the diameter distribution, a lower "q" may be feasible.

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

Table 4.--Stand structure goals for various "q" levels

	Quotient		
	1.1402 (1.3)	1.2649 (1.6)	1.4142 (2.0)
DBH group	Average stand diameter		
	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

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

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

When it comes time to do the actual marking of trees, it is impractical to keep track of them by 1-inch or even 2-inch classes. Broader size classes are usually used. But the calculations are 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 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 record keeping, 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.

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

Dbh	Trial 1		Adjusted for B level stocking			
	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.

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

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.

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.

Figure 6

ALLEGHENY
Property or Compartment

SM-BE
Type or Major Species

7/7/75
Date

31
Stand No.

All-aged
Age Class

DM
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 % Stc
Original Stand	18	37	37	15	107	482	6.4	108	99
Residual Goal									
Residual Stand									
Cut Stand									
Cut Ratio									

Figure 7

ALLEGHENY
Property or Compartment

SM-BE
Type or Major Species

7/7/75
Date

31
Stand No.

All-aged
Age Class

DM
Crew

BASAL AREA AND TREE TALLY

Sample Point No.	Large Sawtimber	Small Sawtimber	Poles	Saplings	Tree Count, 1/20 Acre
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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					

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

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

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, and it is a simple matter to stop occasionally and count up the number of trees being marked in each size class to insure that the proper ratio of size classes is being removed. This, however, does not provide any clues to residual stocking level unless the area covered is known.

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 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

Figure 8.

ALLEGHENY
Property or Compartment

31
Stand No.

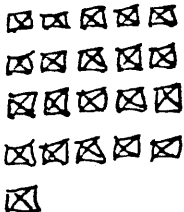
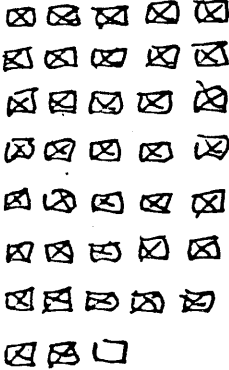
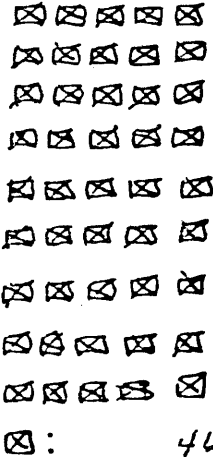
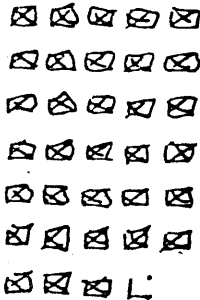
SM-BE
Type or Major Species

All-aged
Age Class

7/7/75
Date

DM
Crew

DOT TALLY OF RESIDUAL STAND

No. Sample Points	Large Sawtimber	Small Sawtimber	Poles	Saplings	Total
21	 210	 318	 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					

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^{2/}

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

^{2/} for maple stands 6 inches d. b. h. at 60 percent stocking.

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)

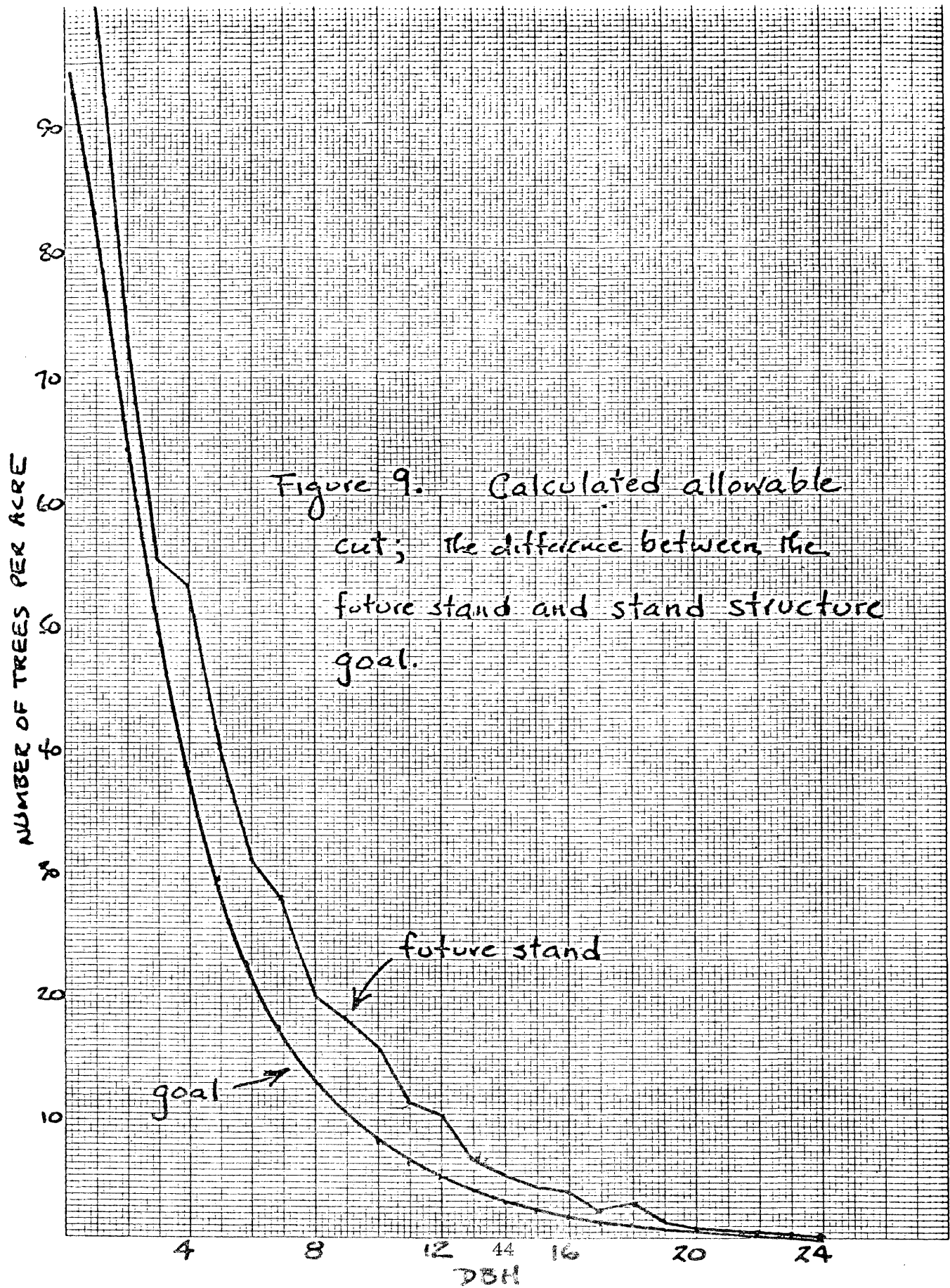
DBH	Residual Stand	Future Stand	Good	Cut	Cut ^{1/}	
	-Square feet of basal area per acre-				cu. ft/ac.	MBF/ac.
1-5	12.1	16.9	11	0	0	0
6-10	23.5	37.6	22	15.6	312	0
11-16	20.7	34.8	19	15.8	395	1.9
17-24	9.6	16.5	10	6.9	172	.8
Total	65.9	105.8	62	38.3	880	2.7

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 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). 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 in the western United States include western hemlock, western redcedar, Pacific silver fir, grand fir, red fir, white fir, subalpine fir, incense cedar, and Englemann spruce. 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 mixed conifer types such as: the mixed conifers of southwest Oregon, the true fir-mountain hemlock, the red fir-white fir, the

Englemann spruce-subalpine fir, and the southwestern mixed conifer types (U.S. Forest Service, 1973).

Group Selection

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

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

The actual manner in which group selection cutting is applied may vary considerably. At one extreme, group selection and single-tree selection cutting may be practiced together, with small group openings of a fraction of an acre created wherever a small group of trees can logically be removed together, and with single-tree selection applied in between these groups. At the other extreme, cutting may be entirely limited to larger openings of an acre or two in size in which all trees down to 2 inches d.b.h. are clearcut without examination and consideration of each individual stem. 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 opening 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 western 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 dwarfmistletoe 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 over-maturity 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 switch-back is required, attempt to border the margins of the turn with trees that will be removed during the sale. And make all major skid trail 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 1-1/2 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.

Some slash disposal will be needed after most partial cuts. 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 preferable 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.

Summary

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 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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REGENERATION

by

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Introduction

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 gradually 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

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requirements for insuring establishment of regeneration, then try to relate these tidbits to a number of interactions which would be experienced by the people at the operational level.

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 succeeded in removing all overmature trees from two-storied stands, and from park-like areas lacking understory. Some of that 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 those 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 by 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 had 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 the attempted use of stand structure as a control in applying silvicultural treatments. We can hope for and work towards 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 tract 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 prevents some of these past practices. I have not seen a report of artificial regeneration of conifers for an uneven-aged timber stand in the 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 insolation.

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 so 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 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 vs. 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.

Conclusion

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 titled "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 still 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 realised 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 endeavour 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 appear 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 the 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

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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 Agricultural Handbook 445) the potential for uneven-aged management without shifts in species composition. During 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 that the 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 system can even be made to discriminate (to some degree) between two or more tolerant species.

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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		Selective Cutting Possible Without Species Shift
	Name	Shade Tolerance	
Western Hemlock-Sitka Spruce	Western hemlock Sitka spruce	Very tolerant Tolerant	Yes, but not applicable for other reasons. Yes, but not applicable for other reasons.
Coastal Douglas-Fir	Douglas-fir	Intolerant	No, shift to western hemlock.
Redwood	Coast redwood Douglas-fir	Tolerant Intolerant	Yes. 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.
^{on} Lodgepole pine	Douglas-fir Grand fir	Intolerant Tolerant	Sometimes (if more tolerant associates absent). Yes.
Ponderosa pine ^{3/}	Lodgepole pine	Intolerant	Often yes (other species absent) but not applicable for other reasons.
Southwestern Mixed Conifers	Ponderosa pine Several	Intolerant Variable	Usually yes (more tolerant associates absent). Often preferred method.
True Fir-Mountain Hemlock	Noble fir or Douglas-fir	Intolerant	No, shift to hemlocks and/or Pacific silver fir.
Red Fir-White Fir	Hemlocks or Pacific silver fir	Tolerant	Yes.
Engelmann Spruce-Subalpine Fir	Red or white fir Engelmann spruce or subalpine fir	Tolerant Tolerant	Yes. 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.

In western hemlock--Sitka spruce we have an example of a type suited in autecological requirements to selective management--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, but 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 sort 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 (ponderosa 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 on 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 of 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 an 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 is going to be 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 the progress we have made in recognizing them. We need to use them more extensively in our silvicultural 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 competition can make regeneration of any tree species difficult thus limiting potential for 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 limits 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 yield 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 recreational sites but for different reasons--aesthetics, 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

towards 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

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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 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.

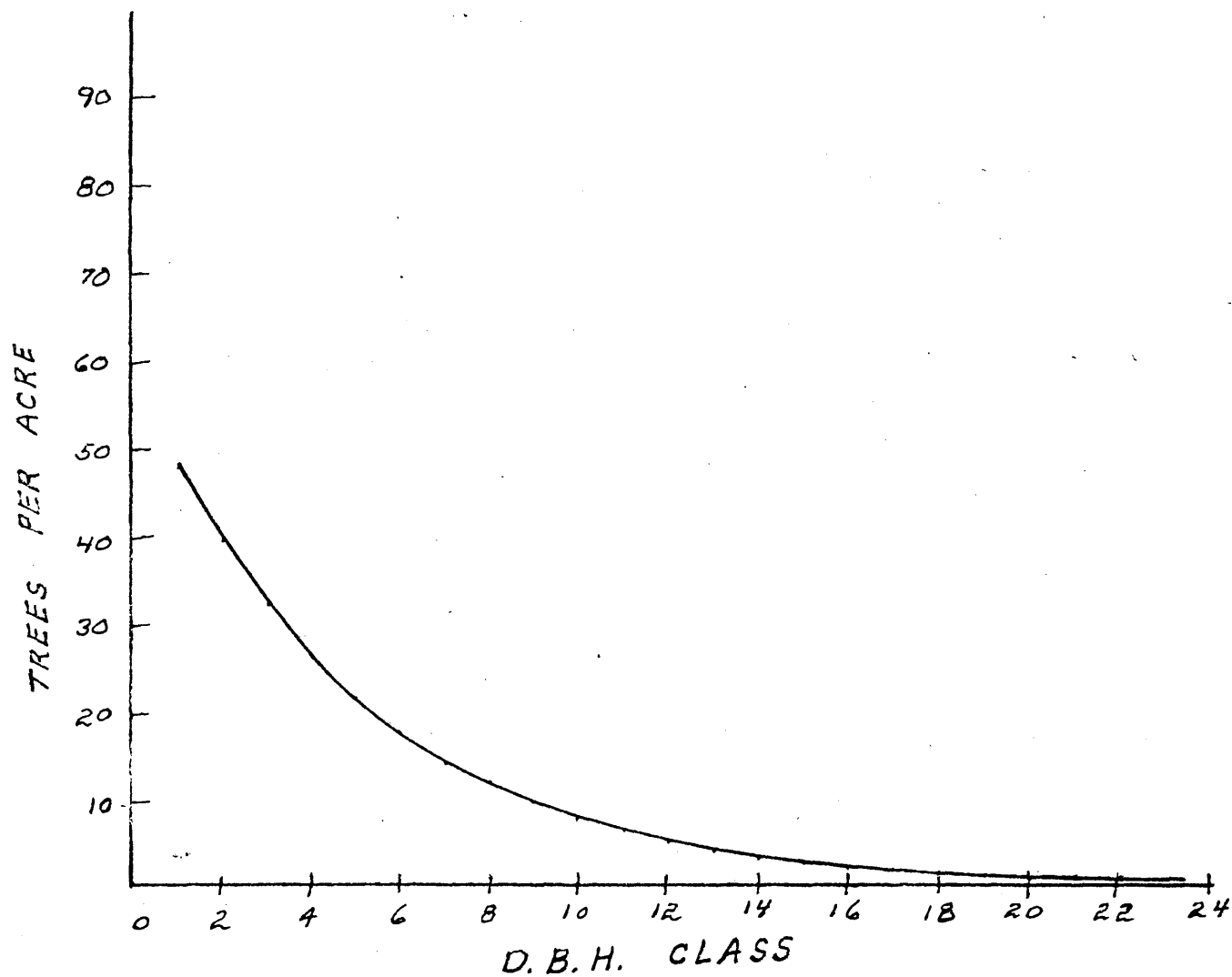


Figure 1.-- Diameter distribution goal for growing stock level 80 ponderosa pine in the Southwest.

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

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.

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 was 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.

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

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.

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.

Summary

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/}

Introduction

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

I. 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.

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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.

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.

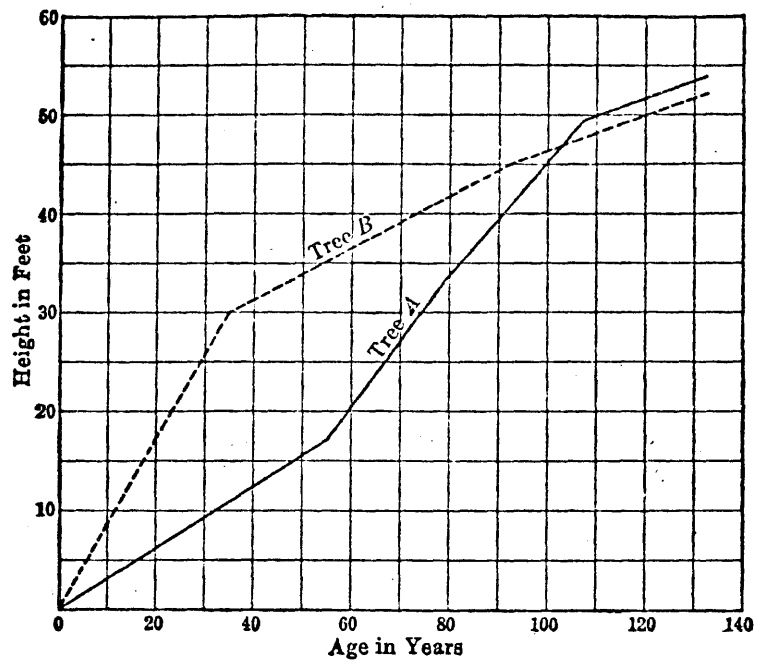


Figure 1. A diagram showing the height growth based on age for two hemlock trees (Hawley 1946).

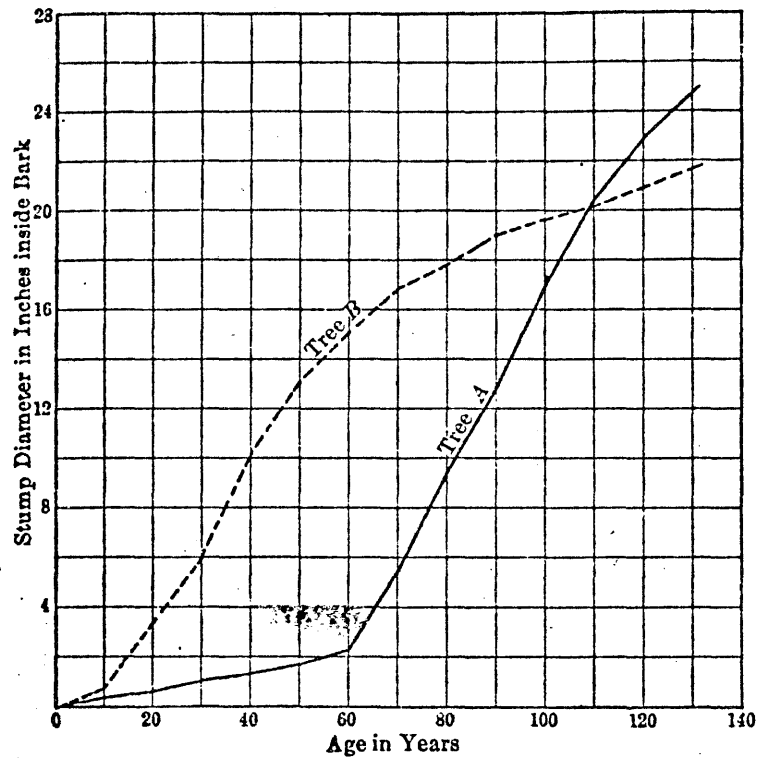


Figure 2.--A diagram showing the diameter growth based on age of two eastern hemlock trees of approximately the same age and size growing on the same site. Tree A grew under conditions prevailing in an uneven-aged stand. Tree B grew under conditions prevailing in an even-aged stand. For the first 50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

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.

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

- 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.

GROWTH OF SELECTIVELY CUT PONDEROSA PINE

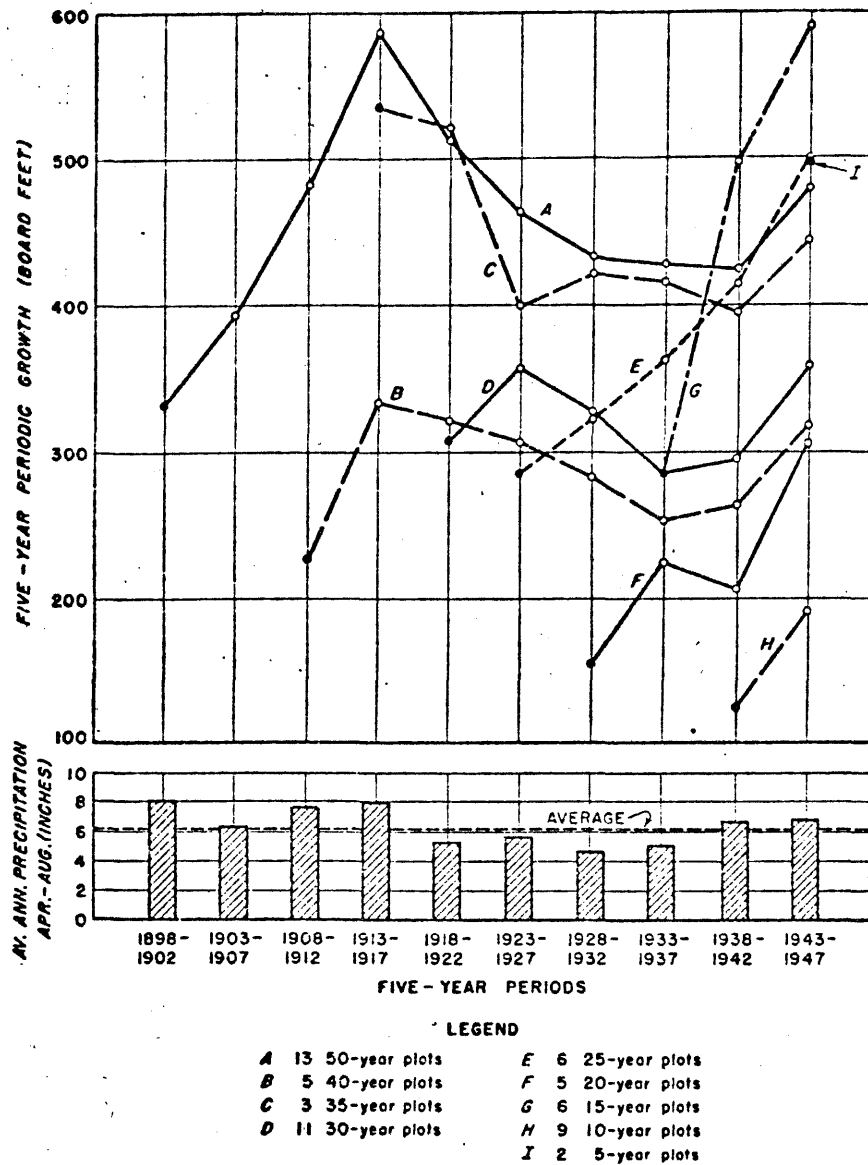


Figure 3.--Five-year periodic growth and growing season precipitation for ponderosa pine sample plots, 1898-1947 (Roe 1952).

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 standardized 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.

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, N. H., reproduced here as Figure 4.

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. Read noble fir, Douglas fir, hemlock and silver fir in place of birch, ash, maple, and beech, and this could be the Northwest.

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.

de Liocourt'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.

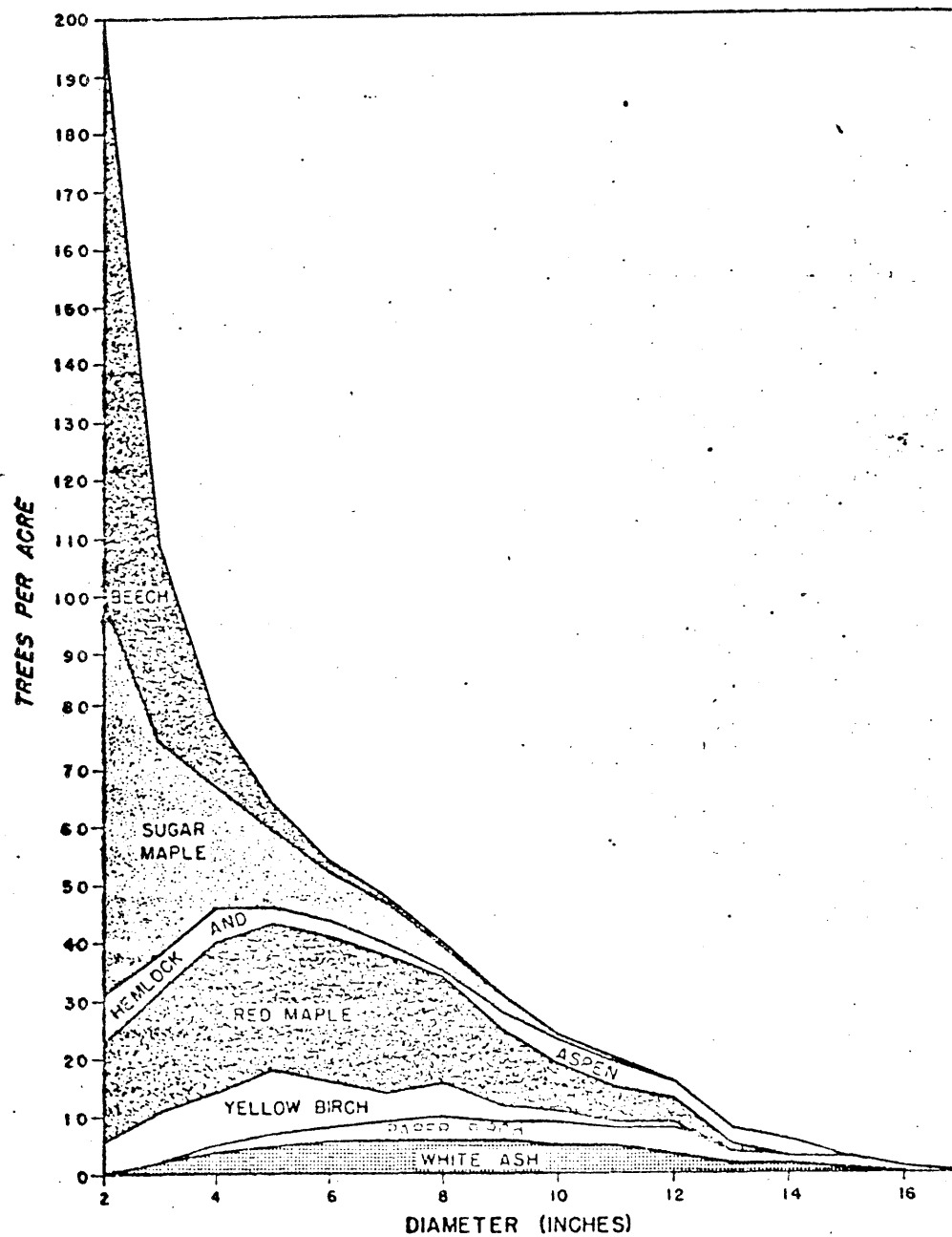


Figure 4.--Distributions by species in a northern hardwood stand.

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-shape 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.

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?

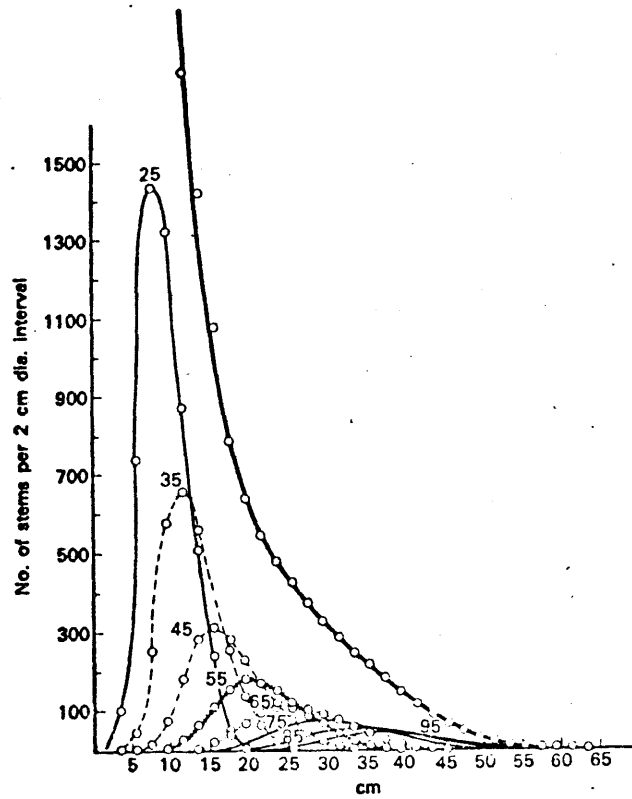


Figure 5.--Diameter distribution for a spruce working section, deduced by adding the diameter distributions of 10-year age classes (Assmann 1970).

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.

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.

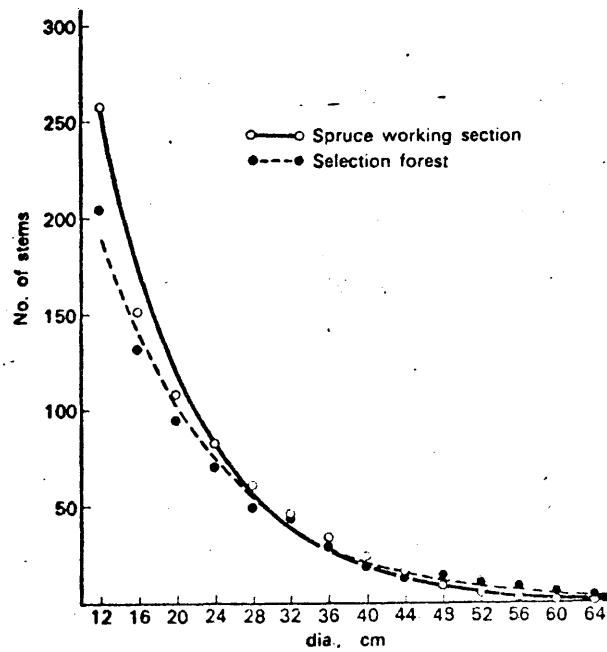


Figure 6.--Diameter distribution curves for a spruce working section (quality class II; $r = 120$) and for a selection forest (Schömborg) (Assmann 1970).

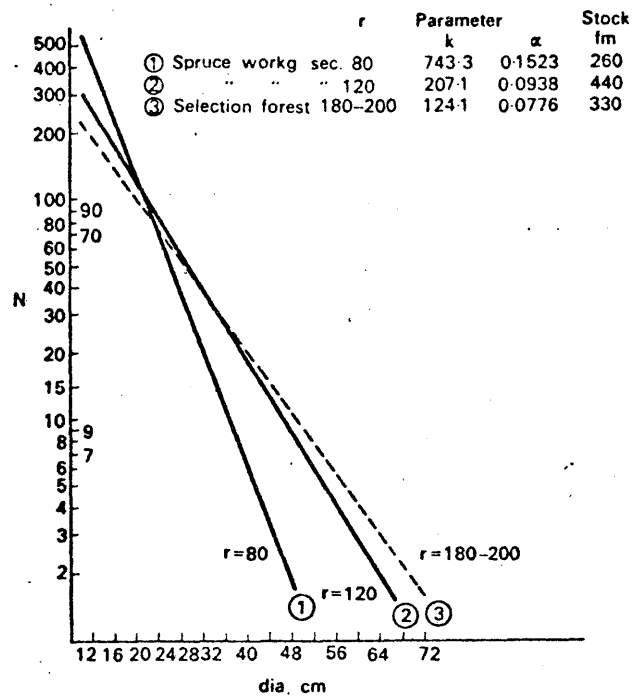


Figure 7.--Fitted diameter distribution curves ($\log N = f(d)$) for two spruce working sections and one selection forest area (Assmann 1970).

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/}

Introduction

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 run through an actual marginal analysis of growing stock by the Idaho Department of Lands (IDL) (Cooper 1976).

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.

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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.

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 8-1/2 percent. This 8-1/2 percent rate is composed of a real rate of 3 to 4 percent, and an inflationary rate of about 5-1/2 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 ft² 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/}.

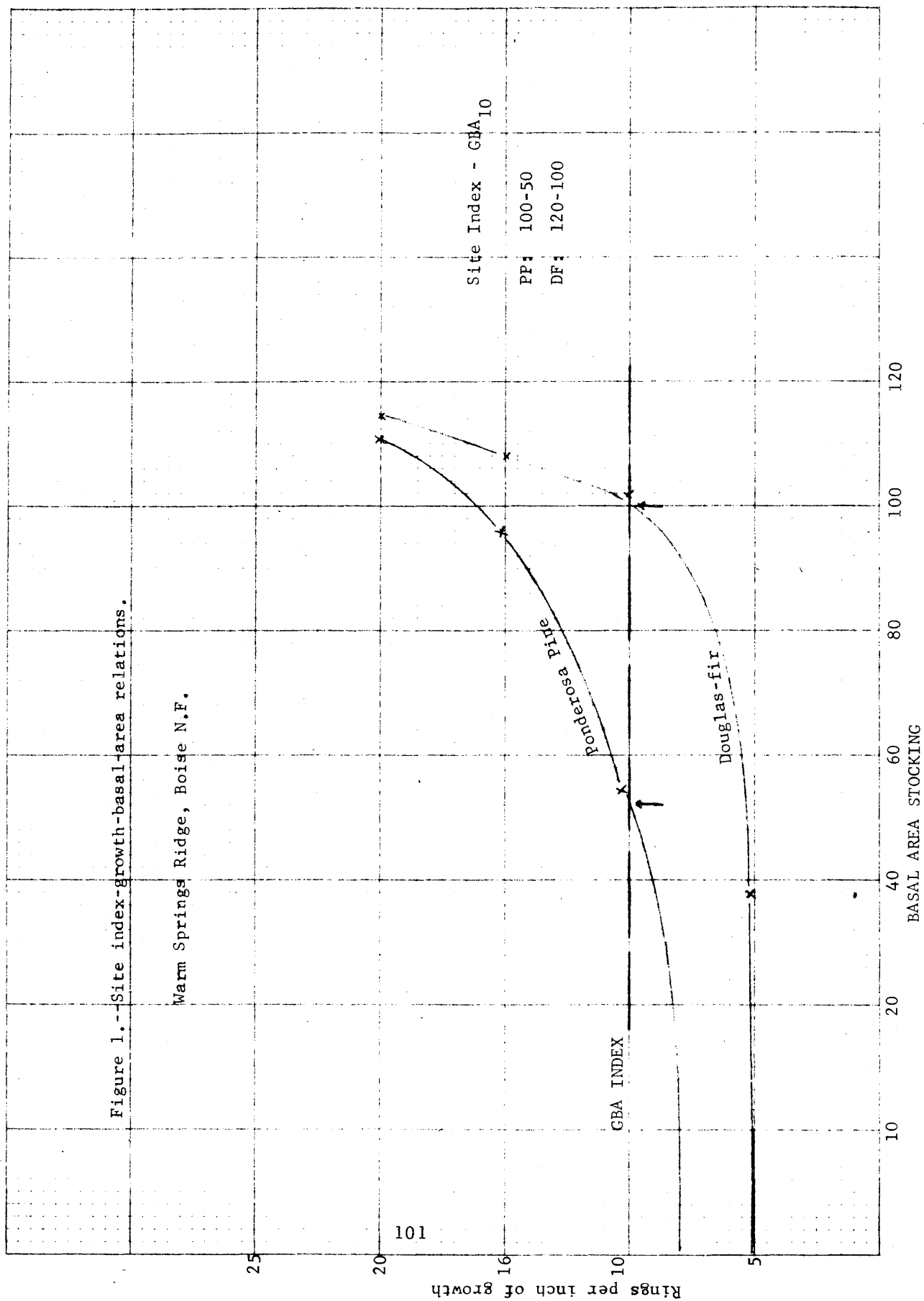
Species composition for economic evaluation may become academic. As wood demand increases, stumpage value differences between species seem to diminish. Restricted quality ranges for young-growth timber contribute to this equalization in stumpage value.

^{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.

Warm Springs Ridge, Boise N.F.



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 clear-cutting. 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.

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 ft² 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/}.

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.

^{4/} Personal communications.

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 ft²) on an 8-year cutting cycle. Preliminary simulation runs with 40 ft² 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.

^{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.

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.

Linear-programming systems have been developed to optimize choices among alternatives (Johnson and Scheurman 1974). Timber-RAM (Navon 1971), the Roding 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.

A Marginal Analysis of Growing Stock

An economic analysis of growing stock can suggest directions management might take, as well as information needs. The Idaho Department of Land's (IDL) objective is to ". . . assure maximum long term financial returns to the endowment funds" ^{8/} In reviewing a draft of their Southwest Area Inventory Report I found the necessary components for a marginal analysis as described by Duerr (1960): (a) a cutting cycle, (b) a prescribed alternative rate of return, (c) a growth function related to growing stock, and (d) stumpage value. I roughed-out and proposed inclusion of a marginal analysis. Area foresters felt the marginal analysis provided excellent direction for their management efforts and pointed up inventory data they

^{8/} Idaho Dept. of Lands, Operations Memorandum 901, August 1971.

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

<u>Task</u>	<u>Present Forest Service computer programs</u>
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

wanted their State organization to collect. With this support Cooper (1976) formalized the marginal analysis and the results provided a base for formulating management decisions for the Area.

Area foresters felt they could cut-over only 5 percent of their land in one year. This dictated a 20-year cutting cycle. Growth rates were based on the 20-year cycle.

Income from Idaho State forest land goes into the Idaho Endowment Fund for support of schools. The Endowment Fund Investment Board had a 6-year average return on their investments (1969-1974) of 5.6 percent. Based on this, the IDL accepted 6 percent as their alternative rate of return.

Inventory data from southwestern Idaho was used to determine the growth curve (Figure 2).

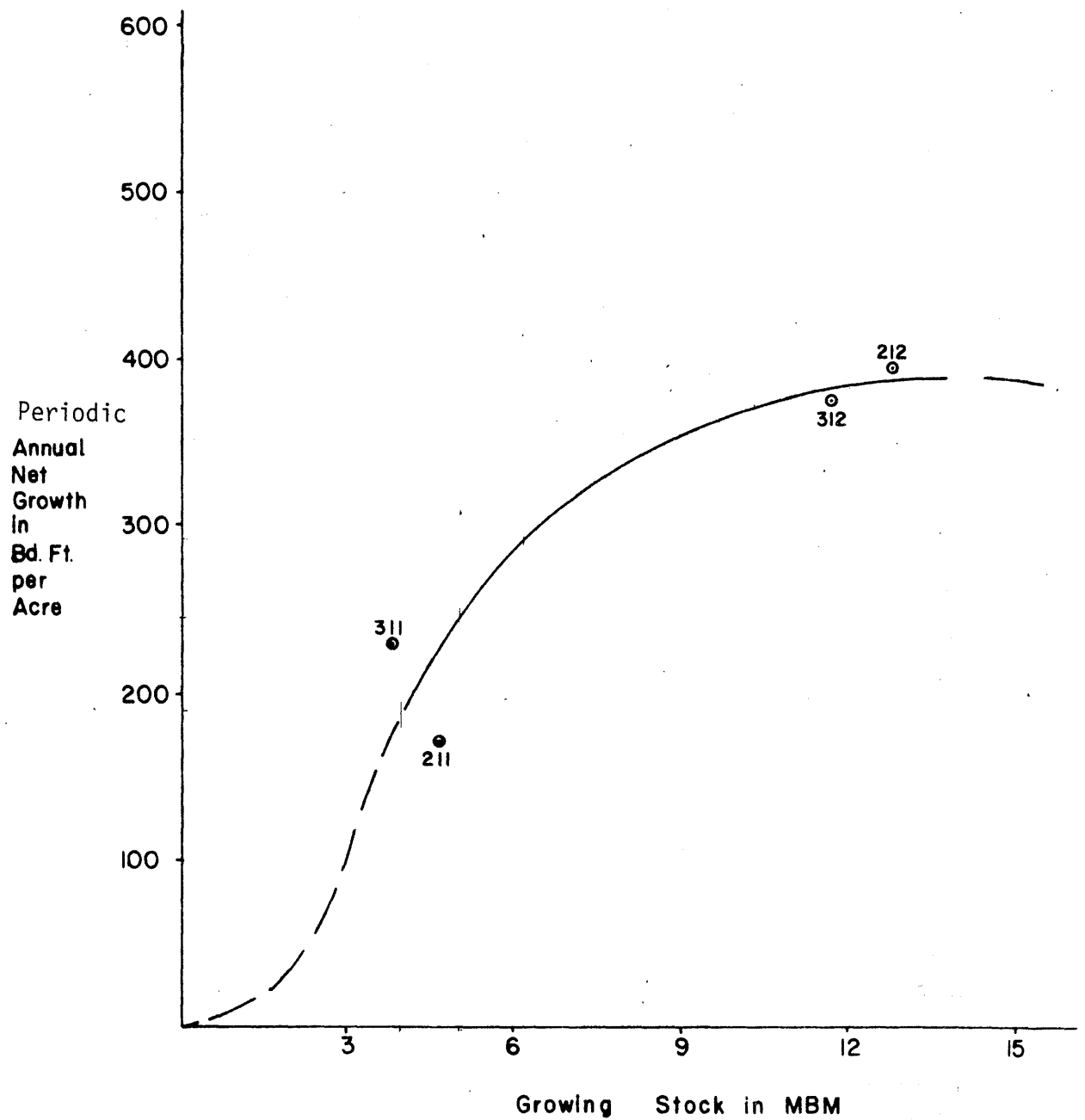


Figure 2.--Sawtimber growth for growing stock volumes, southwestern Idaho Area

Stumpage values, 1969-1974, ranged from \$5.83 to \$32.12 per MBF, with an average of \$15.60. This average value was taken as the marginal value for growing stock.

With these relationships, the marginal analysis (table 3) was completed with some interpolation. The suggested optimum level of growing stock for the Southwest Area was 3.7 MBF per acre, at a marginal revenue rate of 6 percent.

Area stands averaged 9.5 MBF per acre. The indicated optimum of 3.7 MBF suggested liquidation of almost 6.0 MBF per acre. The land managers found six reasons for not liquidating all of the excess growing stock volume. The reasons were: (1) other uses of the resource cannot be jeopardized; (2) high mortality rates suggest some uncertainty as to the transitional stand vigor; (3) regeneration potentials at low stocking levels have not been tested; (4) stocking reductions should be accomplished slowly to avoid increased mortality; (5) size-class distributions were unbalanced; and (6) there was limited growth information for low levels of stocking.

The recommendation was to reduce stocking to a level of 6 to 8 MBF per acre on a 20-year cutting cycle.

Questions raised by the IDL analysis include:

What are the true value growth potentials at moderately light stocking levels?

What values should be placed on sub-merchantable size classes?

How does growing stock value change with increasing stocking?

What are the benefits from reducing the cutting cycle?

For this workshop I prepared a second table which assumed a 25 percent increase in growth to show how decisions might change.

(1) The optimum stocking level is increased to 5.1 MBF.

(2) Net revenue is now positive.

Some other growing stock relationships become apparent with further study:

(1) Changing the average value does not change the optimum stocking level.

Table 3.--Marginal analysis of Southwestern Area sawtimber growing stock, Idaho Department of Lands

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Levels of growing stock	Growth	Value of growing stock @ \$15.60/M	Int. cost @ 6%	Value of Growth	Net Rev: (growth value minus int. cost)	Marg unit cost (int.)	Marg. unit rev. (growth)	Marg. value of growing stock	Marg. cost	Marg. rev.
<u>Board feet</u>					<u>Dollars</u>					<u>Percent</u>
(a) INVENTORY GROWTH DATA (Cooper, 1976)										
3,000	110	46.80	2.81	1.72	-1.09					
4,000	195	62.40	3.74	3.04	- .70	.93	1.32	15.60	6.0	8.5
5,000	245	78.00	4.68	3.82	- .86	.94	.78	15.60	6.0	5.0
6,000	290	93.60	5.62	4.52	-1.10	.94	.70	15.60	6.0	4.5
7,000	315	109.20	6.55	4.91	-1.64	.93	.39	15.60	6.0	2.5
8,000	335	124.80	7.49	5.23	-2.26	.94	.32	15.60	6.0	2.1
9,000	355	140.40	8.42	5.54	-2.88	.93	.31	15.60	6.0	2.0
(b) ASSUMED 25 PERCENT GROWTH INCREASE										
3,000	138	46.80	2.81	2.15	- .66					
4,000	243	62.40	3.74	3.70	- .04	.93	1.55	15.60	6.0	9.9
5,000	306	78.00	4.68	4.77	+ .09	.94	1.07	15.60	6.0	6.9
6,000	362	93.60	5.62	5.62	+ .00	.94	.85	15.60	6.0	5.4
7,000	393	109.20	6.55	6.13	- .42	.93	.51	15.60	6.0	3.3

(2) Increasing the value of growth (column 5) relative to the growing stock (column 3) increases the optimum level, i. e., reducing mortality, changing growth distribution over size classes, changing cutting cycle.

(3) Increasing the alternative rate of return decreases the optimum.

Let me touch on another public regulation objective before concluding.

Non-declining yields, as a policy, effectively override a marginal analysis. As an example (Table 3, a) assume IDL adhered to this objective and the yield level was 22,050 MBF per year (70,000 acres and 315 bf of growth per year). The indicated stocking level to meet this objective is 7 MBF per acre. The cost to the Idaho taxpayers of this policy, based on net revenue, would be $(-\$.64 - (-\$1.64) \times 70,000 \text{ ac.} = \$70,000$. Only by effectively increasing the growth performance (Table 3, b) could the stocking level be reduced to about 5.1 MBF and the nondeclining yield objective still be maintained. The extra cost to the Idaho taxpayers for a nondeclining yield would then be nil.

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 4).

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 4.--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: Cost of Capital (Alternative rate of return)	a%		>a%	
	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
Lenth 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 turn-over 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

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Introduction

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

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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 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 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 Mountains 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 indexes 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, W. H. 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

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

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 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, H. A. 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" level (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).

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 record keeping. 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.

Figure 1

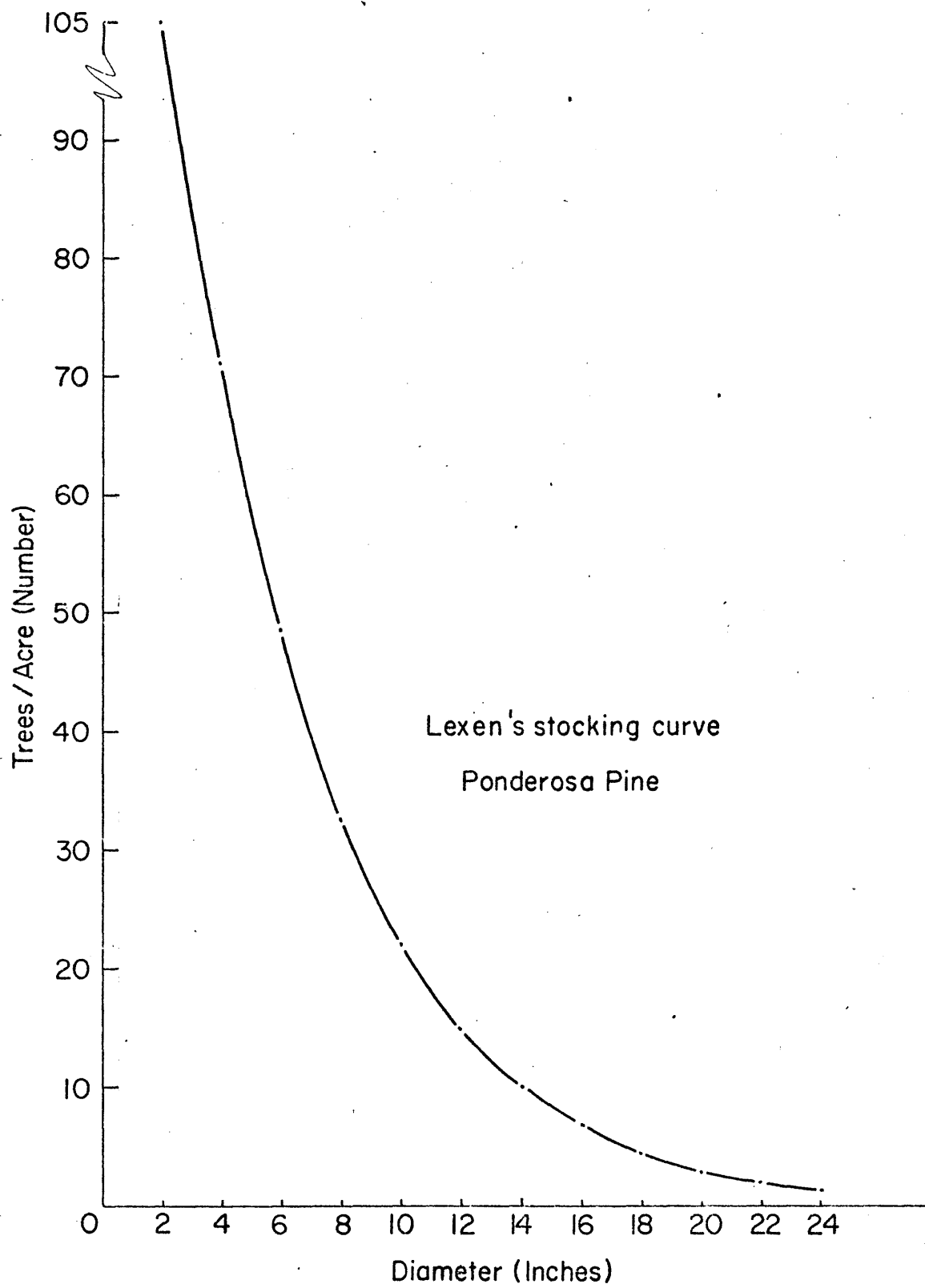


Figure 2

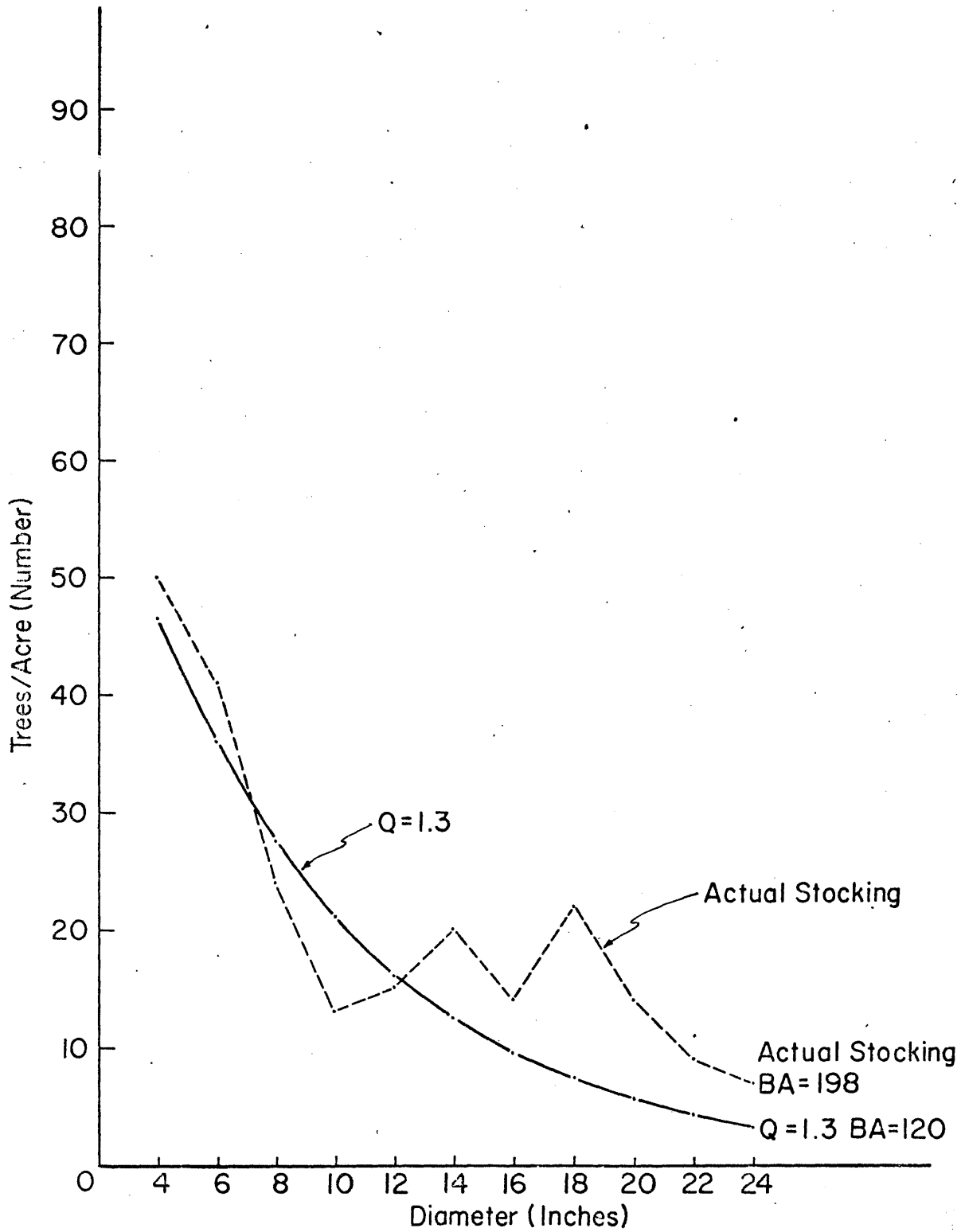
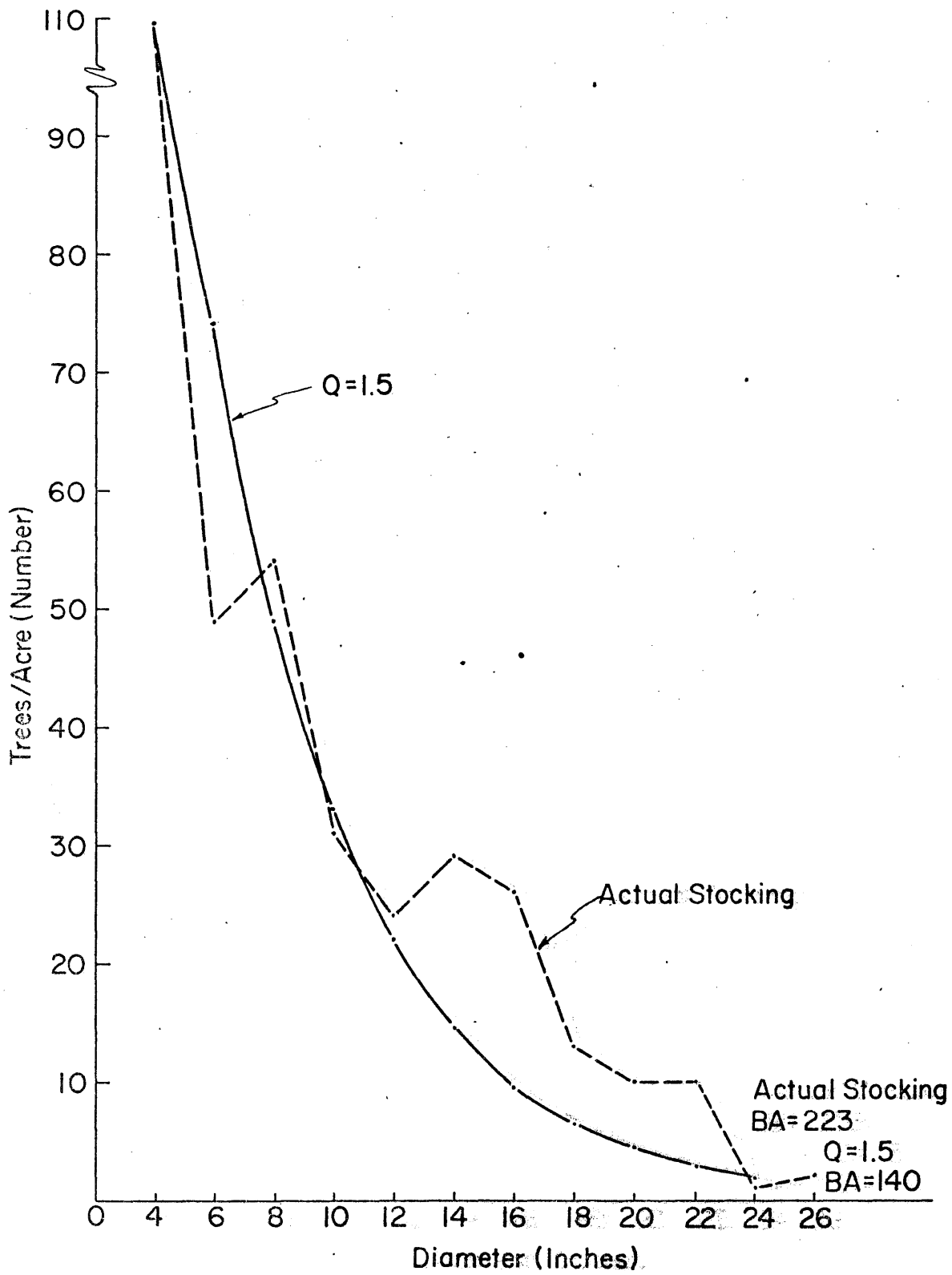


Figure 3



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 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 cycle 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 record-keeping. 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 nonexistent. 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

by

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A number of potential problems in applying uneven-aged silviculture and management in western forest types were surfaced by the individual work groups at this workshop. By summarizing some of these problems 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 it will stimulate forest researchers into initiating new research to fill some of the gaps in our knowledge.

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.

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--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.

--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 over-story 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.

response produced a few interesting proposals: one on stand structure definition, one on an array of silviculture and management systems, and one that stretched the imagination called, "super cut." These proposals were intended merely as a lighthearted touch to more serious thinking. But in fact, they are products of imaginative and inquisitive minds and as such serve as examples to stimulate others.

Although the workshop succeeded in consolidating some of the concepts of uneven-aged silviculture and management, some elements are not yet completely understood. Regulation of cut, getting adequate regeneration, difficulty in determining yield production, and the difference between single trees 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.

The time is right for moving ahead. The new National Forest Management Act of 1976 promotes consideration of alternatives to clearcutting on some forest lands. And, silviculture in western forests is experiencing a new thrust that involves enlightenment and interest on the part of both the general public and professional foresters. The cadre of specially trained silviculturists on National Forest stands is evidence of the importance placed on following scientifically sound silvicultural prescriptions. We hope the information contained in these proceedings will, at least in part, fill the need for pulling together most of the available knowledge on uneven-aged silviculture and management; and, equally important, provide the stimulus to initiate research to fill the gaps of knowledge.