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Quantitative Silviculture for Hardwood Forests of the Alleghenies

Dedication

This publication is dedicated to the memory of Roe S. (Sandy) Cochran, former Forest Resource Specialist with the Extension Service, The Pennsylvania State University. Sandy was a guiding light in the Allegheny Hardwood Silviculture Training Sessions on which this publication is based. He was instrumental in initiating, promoting, and conducting every session, from their inception in 1978 until his death in 1991. Sandy contributed to the technical and administrative aspects of the Training Sessions in many, many ways, but may best be remembered for his famous Wednesday night steak fry. It is to his untiring efforts to provide educational opportunities leading to good forestry practices in the Allegheny Region, his commitment to the forestry profession, and his exceptional drive and character that this publication is dedicated.

Cover Photo

The cover photograph was taken during one of the first Allegheny hardwood silviculture training sessions at the Kane Experimental Forest, sometime during 1976 or 1977. The individuals in the photograph represent the wide range of participants in the sessions, including University professors, consulting and industrial foresters, and foresters from public land management agencies. Among those in this photograph are several of the individuals who intiated the course, including Dave Marquis, at the left of the front row; Sandy Cochran, in the center in a light jacket; Ben Roach, on the right of the front row; and Rich Ernst, second from the left in the back row.

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Quantitative Silviculture for Hardwood Forests of the Alleghenies

David A. Marquis
Editor

A collection of lectures from the annual
Silviculture Training Sessions
conducted by the

USDA Forest Service
Northeastern Forest Experiment Station
Warren, Pennsylvania

and

The Pennsylvania State University
Cooperative Extension Service
University Park, Pennsylvania

Contents

Introduction--**David A. Marquis, Roe S. Cochran** 1
History and origin of Allegheny forests--**David A. Marquis** 5
Stand examination procedures--**James C. Redding** 41
Stand data summary and analysis--**Susan L. Stout** 79
Development of a silvicultural prescription--**Richard L. Ernst** 129
SILVAH computer analysis--**David A. Marquis** 163
Regeneration principles and practices--**Stephen B. Horsley, L.R. Auchmoody, Russell S. Walters** 205
Thinning principles and practices--**David A. Marquis** 247
Distribution of cut--**Richard L. Ernst** 289
Marking ratios and the SILVAH system--**James C. Redding** 323
Principles and practices of uneven-age management--**Susan L. Stout** 329
Summary--**David A. Marquis** 367

Preface

Forest Service research on hardwood silviculture has been under way in northern Pennsylvania since the Kane Experimental Forest was established in 1929. Throughout the 1930's the Civilian Conservation Corp provided the manpower to initiate many long-term studies of ecology and forest growth. The experimental forest was closed during World War II, and after the war, a small silviculture research program was maintained at both the Kane Experimental Forest and the Pocono Experimental Forest. The Pocono forest was privately owned, but research was conducted there by Forest Service personnel. Many studies were maintained and remeasured by Ashbel Hough and others throughout the long period of reduced activity until the late 1960's.

In the 1960's, the program was revitalized by combining the minimal staffs of the Kane and Pocono Experimental Forests and establishing a new laboratory in Warren, Pennsylvania. The silviculture research staff at Warren was expanded in 1970, which led to a comprehensive research program on the forest management problems of the region.

The new program, combined with the reopening of the 1930 studies at Kane, provided for rapid accumulation of scientific knowledge on the ecology and management of Allegheny hardwoods. Special efforts were made to organize that knowledge into a coordinated set of management guidelines. Initial guidelines included procedures to obtain satisfactory regeneration after harvest cutting, and to control stand density and structure during thinning. These guidelines have since been expanded into a complete system of stand evaluation and silvicultural prescriptions that cover the full range of forest conditions and management alternatives in the region.

Much other research is also applicable to the Allegheny region. Oak silviculture research at the Central States Forest Experiment Station (later divided between the Northeastern and North Central Forest Experiment Stations) in Ohio, Kentucky, and other Central States has been used extensively, as has research of The Pennsylvania State University; West Virginia University; and the College of Environmental Science and Forestry, State University of New York at Syracuse. Research conducted or sponsored by the Hammermill Paper Company, Tg Forest Products (formerly Armstrong Forests), and Glatfelter Pulp Wood Company has been important also.

In 1976, the Northeastern Forest Experiment Station and the Cooperative Extension Service of The Pennsylvania State University organized several training sessions to explain and demonstrate the silvicultural prescription system to practicing foresters. Since then, two to four sessions have been held each year, with 20 to 30 participants at each session. The sessions are updated periodically as new research information becomes available. In 1985, a new classroom facility was built at Kane and in 1987 the sessions were lengthened from 3 to 4 days each. In addition, some supplementary 1-day sessions were added to provide in-depth coverage of techniques outlined in the basic sessions.

The sessions have been attended by representatives from nearly every forest management organization in the region: Allegheny National Forest, Monongahela National Forest, other Eastern Region national forests and headquarters offices, State and Private Forestry, Northeastern Forest Experiment Station, Pennsylvania Bureau of Forestry, Pennsylvania Game Commission, New York Department of Environmental Conservation, forestry faculty of eight or nine eastern universities, Hammermill Paper Co., International Paper Co., Tg Forest Products Inc., Kane Hardwoods Division of Collins Pine Co., National Fuel Gas, Westvaco, Charmin Paper Division of Proctor and Gamble, Glatfelter Pulp Wood Co., 15 to 20 forestry consulting firms and others. Ontario Ministry of Natural Resources has participated and others have come from as far away as Chile, Italy, Holland, and New Zealand.

The sessions provide excellent feedback on research needs. Some 60 to 80 participants each year provide candid evaluations on the applicability of the research, and help to identify areas needing further study or refinement. The result is an improved research product as well as an effective technology transfer process.

About half of the time in each training session is devoted to classroom lectures in which results of research and basic principles of silvicultural technique are presented. The remaining time is devoted to practical field exercises in which participants have an opportunity to apply the techniques under the guidance of course instructors. The sessions represent an exceptional collection of practical information on the systematic and scientific application of silviculture to a particular forest region.

Acknowledgments

Lectures presented here were prepared by scientists at the U. S. Department of Agriculture, Forest Service, Forestry Sciences Laboratory, Warren, Pennsylvania. A number of other scientists have contributed immeasurably to these lectures, or to the research leading to the silvicultural knowledge on which the guidelines are based. Some of these include: Ashbel F. Hough, Carl E. Ostrom, Thomas W. Church, Ted J. Grisez, Harold J. Huntzinger, Benjamin A. Roach, John C. Bjorkbom, Kurt W. Gottschalk, John A. Stanturf, David S. deCalesta, Coleman Holt, and Nancy G. Tilghman. For their contributions, we are especially grateful.

Ash Hough deserves special mention as a pioneer researcher who initiated -- and kept alive during nearly 30 years of official neglect -- the many long-term studies that have since helped tremendously to verify responses of forest stands to treatment. Likewise, Ben Roach deserves special mention for his early efforts in formulating systematic silvicultural prescription procedures in the Central States. His guide served as a model for the Allegheny system.

Special thanks also to the dedicated group of forest technicians of the Forestry Sciences Laboratory in Warren. Without these skilled assistants, the research leading to these guidelines could not have been completed: Virgil L. Flick, Vonley D. Brown, John A. Crossley, David L. Saf, and Harry S. Steele.

Pesticide Precautionary Statement

This publication reports research involving pesticides. It does not contain recommendations for their use, nor does it imply that the uses discussed here have been registered. All uses of pesticides must be registered by appropriate State and/or Federal agencies before they can be recommended.

CAUTION: Pesticides can be injurious to humans, domestic animals, desirable plants, and fish or other wildlife--if they are not handled or applied properly. Use all pesticides selectively and carefully. Follow recommended practices for the disposal of surplus pesticides and pesticide containers.

The computer program described in this publication is available on request with the understanding that the U.S. Department of Agriculture cannot assure its accuracy, completeness, reliability, or suitability for any other purpose than that reported. The recipient may not assert any proprietary rights thereto nor represent it to anyone as other than a Government-produced computer program.

Thinning Principles and Practices: Control of Stand Density, Structure, and Species Composition During Thinning in Hardwood Stands in the Alleghenies

David A. Marquis

THINNING

1. The SILVAH stand analysis and prescription technique provides a systematic procedure for analyzing data from forest stands to decide on a silvicultural prescription. In immature stands managed under an even-age system, thinnings often will be prescribed by the SILVAH system when stand density is high enough to warrant it, and the volumes to be removed will at least pay the cost of the thinning. This paper describes the underlying principles behind thinning practices recommended by the SILVAH system.

THINNINGS

- Salvage Mortality
- Concentrate Growth on the Best Trees
- Reduce Rotation

2. Thinnings are made in even-aged stands to:

Increase yield by salvaging trees that would die

Concentrate growth on the best trees in the stand, thereby increasing value

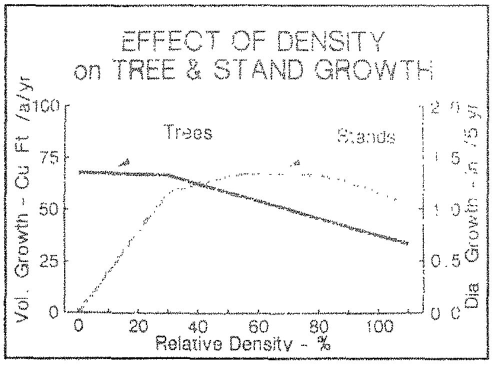
Reduce the time required for the stand to reach maturity

STAND DENSITY

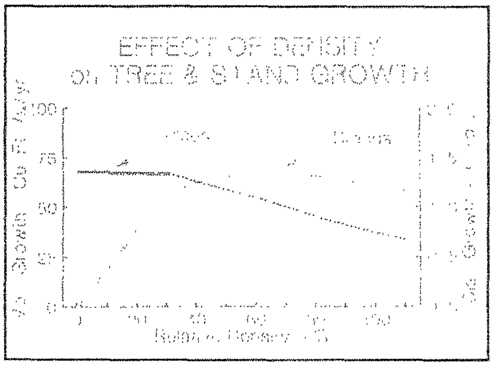
STAND STRUCTURE

SPECIES COMPOSITION

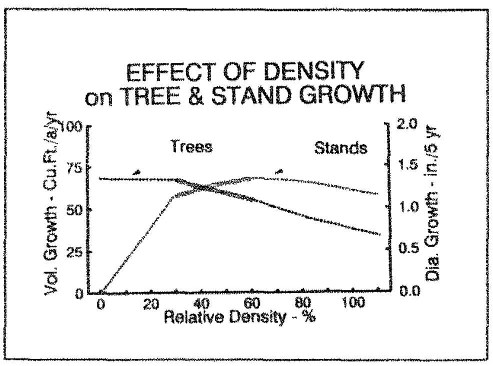
3. To achieve these goals, you must regulate stand density, stand structure, and species composition in appropriate ways. First look at the responses of individual trees and entire stands to various levels of stand density.



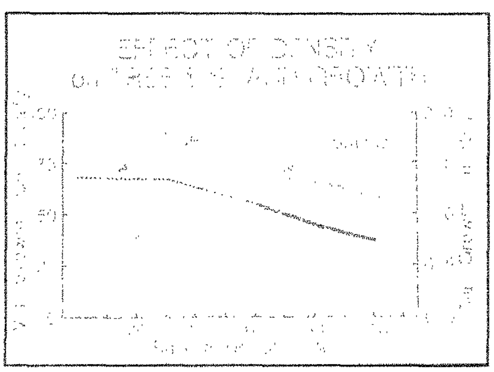
4. In general, volume growth of individual trees and entire stands is affected by density as shown here.



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



6. Between 30 and 60 percent stocking, trees are close enough to each other that growth rate is affected by the competition. Thus, individual tree growth declines as density and the amount of competition exceed 30 percent. Individual trees, nevertheless, have considerable room, and tree growth is rapid. Stand growth continues to increase because the amount of capital--or growing stock--increases, but at a slower rate than in the 0 to 30 percent density range.

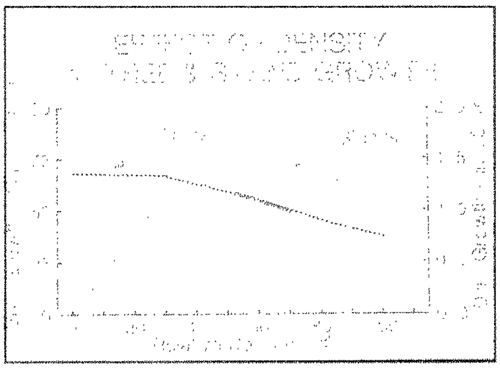


7. Above 50 to 60 percent stocking, competition among trees begins to have a major influence on individual tree growth rate and tree growth declines as density increases.

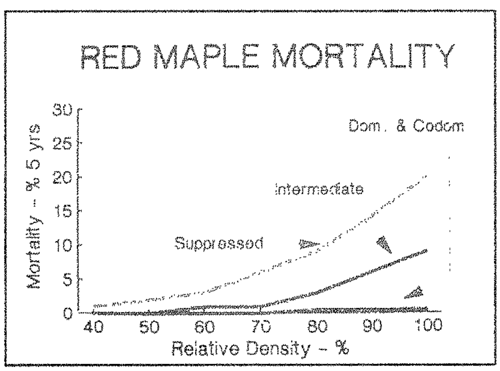
At some point in this range--usually somewhere between 50 and 80 percent relative density--stand growth reaches a maximum. At higher densities, both net stand growth and individual-tree growth decline due to excessive crowding. At very high densities, the stand may actually stagnate.

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

Within this range of densities foresters can manipulate the growth of individual trees without losing any total stand growth. The usual objective of thinning is to keep the growing stock within this optimum range.

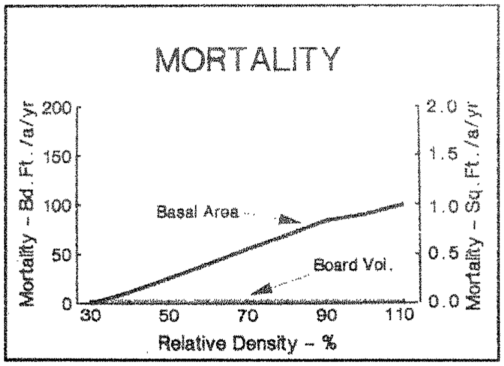


9. The breaking points mentioned are not sharp ones. Although we think of 60 percent as the point of full site occupancy (the point above which total gross growth is nearly constant), research has shown that differences in stand growth around that point (for example, between 50 and 70 percent) are usually small. So, if you miss the desired residual density by 5 percent in your marking, you need not be overly concerned about total stand volume growth.

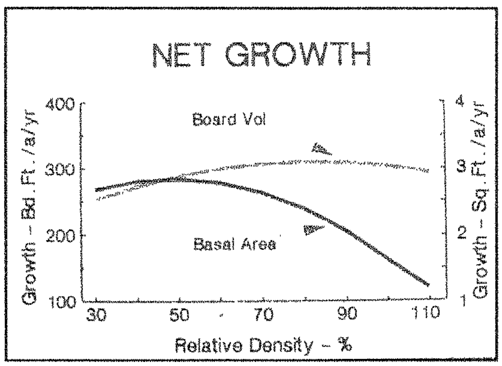


10. Mortality is another concern because one of the objectives of thinning is to utilize the volume in trees that would die from crowding if the stand were not thinned. Mortality is strongly influenced by stand density, increasing dramatically above densities of 60 to 70 percent.

But this mortality from crowding is usually concentrated in the lower crown class trees in the stand. If the trees that die are too small to be merchantable, their loss is relatively unimportant.

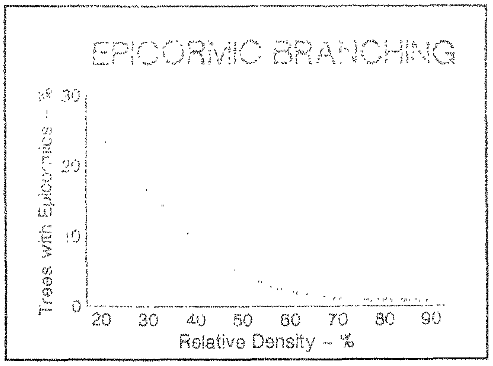


11. For example, mortality in basal area (which include trees as small as 1 inch d.b.h.) may represent 50 percent of net growth at high densities, while mortality in board-foot volume in the same stand is relatively insignificant.



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

13. Tree quality is also affected by stand density and can have a major effect on ultimate value yields. Epicormic branching, forking, and slow pruning of live branches can cause a loss in quality at low densities.



14. Our studies show that the number of epicormic branches that form on the lower bole can be excessive when density drops below 60 percent. Studies on Central States oak stands also show significant quality and value losses over the rotation if thinnings reduce density below 60 percent.

15. Understory vegetation of all kinds--tree seedlings and non-woody plants--respond to the increased availability of light, moisture, and nutrients when density is reduced. Even a small decrease in stand density will produce a response in some understory plants. Below 50 percent density, the undergrowth may become lush and dense, signifying that a significant amount of the site resources are not being used by overstory trees. Thinnings on some sites may result in the invasion of ferns and other plants that interfere with regeneration establishment, and may require herbicide treatment when it is time to harvest the existing stand and regenerate a new one.

Residual Density is a

COMPROMISE

among

Stand Growth, Tree Growth,

Tree Quality, and Understory

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

Recommended

RESIDUAL DENSITY

60 %

17. We recommend that residual density be reduced to 60 percent during thinnings. Cutting stands to this density will provide near maximum stand growth, good individual-tree growth with low mortality due to crowding, and it will minimize undesirable effects such as reduced tree quality due to epicormic branching and forking.

Relative Density

100
90 THIN
80 ------------------------------
70
60 DON'T THIN
50

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

EXCEPTION

Fully-stocked Stands

(Over 92 % Rel. Den.)

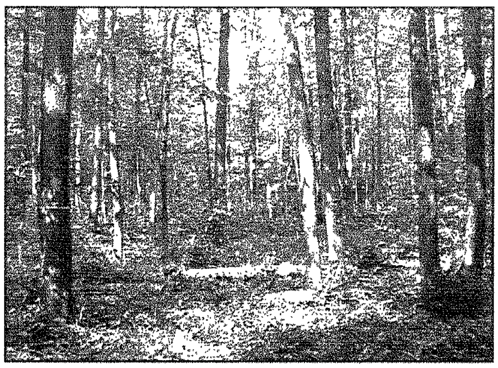
19. Fully stocked stands are the one important exception to the general rule that stand density should be reduced to 60 percent during thinnings and other partial cuts. Fully stocked stands with maximum crowding will contain many trees with small crowns. When thinned to 60 percent in one cut, more growing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

Do not remove more than 35 % of the Relative Density in any one Cut

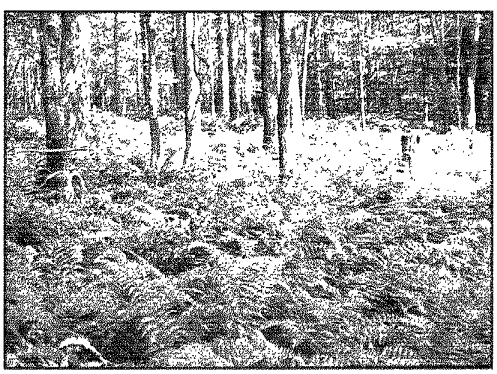
20. The rule in all situations is not to remove more than 35 percent of the relative density in any one thinning. If this rule is observed, excessive exposure and other detrimental effects of making the first thinning too heavy will be avoided. So, in some stands, the first thinning will reduce relative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

21. Here is a 50-year-old Allegheny hardwood stand at 100 percent stocking. Mortality due to crowding is high in this stand, especially among the small trees. As a result, net growth in basal area is low. Individual tree growth is slow, especially among the small trees. There is very little undergrowth.

22. Here is a section of that stand thinned to 60 percent relative density. There is virtually no mortality in this stand, and net volume growth is considerably higher than that in the uncut stand as a result. Also, individual tree growth is good, and there has been a modest increase in the number and size of advance seedlings.

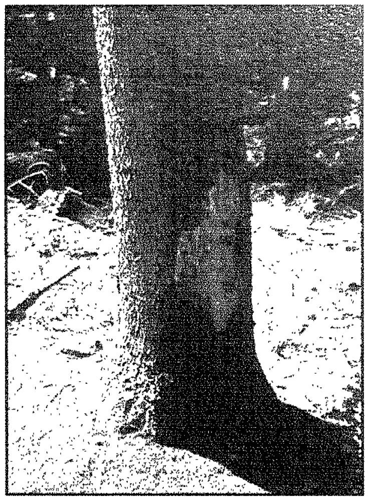


23. This stand was thinned to 40 percent relative density 5 years before the photo was taken. Note how the understory has developed. Invasion by herbaceous plants, especially ferns, is much more likely at densities below 60 percent. Individual-tree diameter growth is excellent in this stand, but there are relatively few trees present. While stand basal area growth is still near the maximum, sawtimber volume growth is lower than it might be. Also, epicormic branching has increased on some trees, especially the intermediate crown-class maples and beeches.



24. There are several real dangers in any partial cutting that you should always bear in mind. Thinnings tend to increase understory density, as already pointed out. This may be desirable if that understory is advance seedlings, but undesirable if they are interfering plants that will persist and become a problem when it is time for regeneration. Especially on the Allegheny Plateau of Pennsylvania where deer populations are high, thinning almost certainly will result in the development of fern understories in many stands. Therefore, thinning often obligates you to perform an herbicide treatment in the future.

Several years ago, we felt that you might minimize problems with fern encroachment by thinning more lightly. But this has not been effective. Any thinning tends to produce a response in the undesirable understory plants. So, the question is whether to thin and risk the need for an herbicide at the end of the rotation, or not to thin at all.



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

Thinning Entries at

15 to 20 Year

Intervals

26. By using our 60 to 80 percent density rule, the interval between thinnings in most stands will be 15 to 20 years. This seems to be a practical and biologically desirable interval.

Okay, now that we know the effect of stand density, we can readily decide what level of stocking to maintain in the residual stand. Great! We're all ready to go out and thin a stand to achieve our goals of maximizing volume and value yield. Right? Wrong!

The manner in which the thinning is done will determine the extent to which these goals are actually achieved. Too often, thinnings are made in such a way as to work against these goals, because the forester marks to some density without any understanding of how stand growth and yield are also affected by stand structure and composition. A high-grading, a thinning, and an individual-tree selection cut may all leave a residual stand at 60 percent relative density. Do you REALLY understand how differences in structure and composition make these cuttings entirely different? If not, you may well be pushing your stands in a direction you do not want them to go.

Ben Roach, a well-known researcher from the Central States and Northeastern Forest Experiment Stations, used to recite an experience from the early years of his career that illustrates this problem very well:

(The following is transcribed from a tape recording made during a lecture by Ben Roach. It describes his "Seat-of-the-Pants-Forestry" experience on the Kaskaskia Experimental Forest in Illinois.)

"In my early years, I had a very interesting and educational job. I was the superintendent of a moderately large and very active experimental forest. Unfortunately, there were no timber markets in the area, so the only way we could get our cutting experiments installed was to cut the trees ourselves, so we developed our own logging crew. Now the only way we could pay the crew was to sell timber and the only way we could sell timber was as lumber, so we got our own sawmill and the logging crew was expanded and doubled as the mill crew. Then the problem was to keep the crew together, and the only way we could keep it together was to furnish year-round employment. So, this meant that we had a substantial annual payroll, which meant a substantial annual cut, which meant many cutting experiments with many replications. There were a few times there when that operational tail wagged that research dog pretty hard, but we did do quite a lot of cutting.
Now for some years I was responsible for the whole operation, except designing the specific cutting treatments, and I had quite a bit of input there. When it came time to put in another study, the four of us would sit around the table and dream up new methods of cutting. Unfortunately, our treatments generally consisted of varying the cutting cycle and the amount of volume to cut at a particular time, so we didn't learn as much from that effort as we should have. But that's another story in research administration and I won't go into that.

But anyway, after the cutting treatments had been decided, then I had the whole show. I'd select the study areas, inventory the stands, mark each stand according to the general principles that we'd agreed on, lay out and put in the skid roads, take the logging crew out, cut, skid, load, and haul the logs; then cut them into lumber, then sort, grade, stack, and dry the lumber, and then find a market and sell the lumber, and then haul it. Fortunately I had a crackerjack of an assistant and he was pretty good at finding markets and selling the stuff, which was my weak point.

On top of that, I had the task of keeping all the business records and seeing that there was enough money in the kitty to pay the crews and maintain and replace the equipment. Plus, of course, keeping all research records of treatments, stand response and growth. Now fortunately, we were located quite a ways out in the woods and so I didn't have much time to waste on hanging around street corners and pool halls and things like that. This was before the days of television, so I could work in the evenings a lot. But anyway, this proved to be an extremely valuable experience. I learned a great deal, and I marked a fair amount of timber.

Now at this time, I'd been trained in, and was a firm believer in and supporter of, what I would now call the uneven-age management syndrome. In fact, in that era, all foresters in the country were trained in this. The basic characteristics of this syndrome were that you would inventory a stand at the same time you would make a growth study, or make an estimate of the net annual board-foot growth. Then you would multiply this annual growth rate by the length of the cutting cycle you wanted, in years. This would give you the prospective volume to cut per acre.

Then we went in to mark the stand. We'd take out the mature trees, and the poor trees, and leave good growing stock. Then after logging, we would go back through, kill the obvious culls among the sawtimber sizes, and sometimes even kill some culls amongst the poles. Now these cuts were referred to, in the terminology of those days, as combined rehabilitation-improvement cuttings. Stand improvement was presumed to be automatic, each cut resulting in improved growth and increasingly better quality. This was good forestry, and in those days it was often referred to as intensive forestry. It left us practitioners in a very noble and self righteous frame of mind. The rest of the world might be raping their woods, but by golly, we were practicing good honorable forestry, perpetuating improved stands for posterity, and even showed you could make a modest profit at the same time. Just made you feel good all over.

Now as I said, I was responsible for making the periodic inventories and compiling the records of stand development and growth to prove just how good our forestry practice was. Fortunately, we had a number of treatments with short cutting cycles and fairly heavy cuts. Also our stands were generally understocked. After a few cuts, it became clearly and painfully evident that I was running out of operable volume.

Now when I first began to suspect that I was running out of timber, I used our standard excuse that we probably over-estimated our growth rate a little bit. After all, our growth studies were fairly crude and maybe our volume tables were a little bit over-optimistic. We tended to estimate merchantable heights to very small and really inoperable top diameters, for example. But I checked and rechecked a number of periodic stand inventories, and I could show on paper that the stands had about the same volumes as when we started. Often they had grown more than what we predicted.

The trouble was, that when I took off my researcher's hat and put on my timber operator's hat, (which in those days was one of those big old heavy fiberglass, Bullard WWI-type helmets) and go out to the woods to mark the volumes for the next cut, I couldn't find it. It was all in what we called the good growing stock trees, the 11-, 12-, 13-, and 14-inch small sawtimber trees that we wanted to save to put on more growth and which, although they were merchantable according to our sawtimber specifications, just weren't operable on a practical basis. Particularly in those days, there was just no way you could get a commercial or economic sawtimber cut out of 11-, 12-, and 13-inch trees, regardless of the fact that we didn't want to cut them anyway.

Now this came as something of a shock to me. Here I was a decent Christian boy of good morals and honorable intentions doing my best to practice honest intensive forestry and I was running out of timber. It just didn't seem fair. Now all I could think of was that I must be doing something wrong, and I hoped that I could figure out what this something was and correct it before other people, and especially the boss, discovered I was obviously a pretty lousy forester.

The most likely place where I was going wrong was in my marking, so I began to get a little gun shy about marking timber. And often thereafter, when I finished marking a stand, I'd sit down on a fallen tree at the edge of it and light up a cigarette and look back at my paint marks (or in those days, the blazes) and I'd wonder what have I done to this stand. Have I cut too little or too much? Have I changed the composition? If so, in what direction? And how much? And what difference is that going to make in growth rates? What have I done to the stand structure? And there was the problem.

We could measure stand density in terms of basal area or volume per acre, but we had no way to put it in terms of relative growing stock. We could monitor the change of composition at our next inventory, but we had no good way to predict what that change was in advance, or what effect it might have, nor how we could control it. And as for stand structure, well, nobody paid much attention to it, and even if it were important, what could you do about it, anyway?

Now since those early days, I've spent a large part of my career working on these problems, and eventually, I came to realize that it was not just a case of recognizing these things. We had to have some way to measure them, to put numbers on them. And then we had to have some way to manipulate them, some measured amount to be able to predict the response in terms of physical quantities, over some length of time. Until we could do that, our silvicultural system, which we called rehabilitation-improvement cutting, should more accurately have been called, the mark-by-the-seat-of-the-pants-silvicultural-system and, the I-sure-do-hope-the-Lord-will-continue-to-provide-system of management planning. And unfortunately, these two methods are still in somewhat rather wide use today.

Well, to continue my story and shorten it somewhat, I eventually learned that there were basically two things wrong with my marking, or for that matter, with our basic assumptions. First, we were dealing with stands that were already understocked-- not too badly understocked, but we didn't help them any by making them more so. The second, and the more important thing, was that we were playing hob with stand structure without actually realizing it, and especially without realizing the consequences. Let me show you how it works.

	10"-13" DBH		14"-18" DBH		TOTAL	
	Trees	Vol	Trees	Vol	Trees	Vol
Initial Stand	26	1436	11	1812	37	3248

27. Let's consider a typical stand of those days which our growth study has shown to grow 200 board feet per acre per year. We'll use a 5-year cutting cycle, so that will give me a cut of 1,000 board feet every 5 years. Ok, now these figures are developed from actual stand data. A typical stand in those days of the kind I was working with had 26 trees per acre in a 10 to 13-inch d.b.h. class with 1,436 board feet. The larger sawtimber, the 14 to 18-inch class, might have had 11 trees per acre, 1,812 board feet. So, the total stand then had 37 trees per acre, about 3,250 board feet.

That's not much of a stand compared to our present stands that we work in around here, but for that period and location, that was not a bad stand.

	10"-13" DBH		14"-18" DBH		TOTAL	
	Trees	Vol	Trees	Vol	Trees	Vol
Initial Stand	26	1436	11	1812	37	3248
1st Cut	0	0	5	1020		

28. So, we'll go through and we'll cut our 1,000 board feet per acre. Now I don't want to cut these good growing stock (small sawtimber) trees, so I'll take my cut out of the mature big trees. I can get my 1,000 board feet in just five trees.

	10"-13" DBH		14"-18" DBH		TOTAL	
	Trees	Vol	Trees	Vol	Trees	Vol
Initial Stand	26	1436	11	1812	37	3248
1st Cut	0	0	5	1020		
Residual	26	1436	6	792	32	2228

29. Now that leaves me a residual stand of 26 good growing stock trees, 1,436 board feet. I've got six big trees left and about 800 board feet per acre. My residual stand totals 32 trees per acre and 2,228 board feet.

	10"-13" DBH		14"-18" DBH		TOTAL	
	Trees	Vol	Trees	Vol	Trees	Vol
Initial Stand	26	1436	11	1812	37	3248
1st Cut	0	0	5	1020		
Residual	26	1436	6	792	32	2228
After 5 Yrs.	28	1680	11	1630	39	3310

30. *Ok, we've made our first cut. Wait 5 years and go back, and I find I've got 28 trees in this small sawtimber class, and 1,680 board feet. Hey that's not bad you know, we're really bringing those small trees right up in there. I find that five of these trees have grown up into the 14 to 18-inch class, and by golly, I've doubled my volume there, from 800 board feet to 1,600. Who says we can't practice good forestry. I find that the total stand has 39 trees per acre, 3,310 board feet. Boy look at that! I've got more than I started with. Beautiful! Go home and get your paycheck, and say by golly I earned that one.*

	10"-13" DBH		14"-18" DBH		TOTAL	
	Trees	Vol	Trees	Vol	Trees	Vol
Initial Stand	26	1436	11	1812	37	3248
1st Cut	0	0	5	1020		
Residual	26	1436	6	792	32	2228
After 5 Yrs.	28	1680	11	1630	39	3310
2nd Cut	0	0	6	998		

31. *Ok, I'll go back and make a second cut. I'm not going to cut the small sawtimber, good growing stock. I'll take my 1,000 board feet up here in the large sawtimber again.*

	10"-13" DBH		14"-18" DBH		TOTAL	
	Trees	Vol	Trees	Vol	Trees	Vol
Initial Stand	26	1436	11	1812	37	3248
1st Cut	0	0	5	1020		
Residual	26	1436	6	792	32	2228
After 5 Yrs.	28	1680	11	1630	39	3310
2nd Cut	0	0	6	998		
Residual	28	1680	5	632	33	2312

32. *Now I've got a residual stand left. Look at that - I've made two cuts. I've got more left now that I had the first time. Put on good quality, good growth. This forestry really works out.*

	10"-13" DBH		14"-18" DBH		TOTAL	
	Trees	Vol	Trees	Vol	Trees	Vol
Initial Stand	26	1436	11	1812	37	3248
1st Cut	0	0	5	1020		
Residual	26	1436	6	792	32	2228
After 5 Yrs.	28	1680	11	1630	39	3310
2nd Cut	0	0	6	998		
Residual	28	1680	5	632	33	2312
After 5 Yrs.	30	1720	9	1270	39	2990

33. *Okay, go back 5 years later. By golly, see I did it again - I've got more trees coming up in the small sawtimber size class. Got more volume too. Of course, I'd expect some of these small trees to have moved up into large sawtimber, and they have. Ah hah, I don't have quite as many as the last time, but probably better quality. Gee, my board-foot volume is down a little bit too, but I still doubled what I left. Add up the figures for the stand, I got 39 trees per acre, that looks pretty good. Uh oh, now what happened? My volume is down. Now how come I got such good growth that period and such poor growth this time. Well, maybe it's bad weather, you know; maybe I got a period of dry years in there and they just didn't grow as much as they ought to.*

	10"-13" DBH		14"-18" DBH		TOTAL	
	Trees	Vol	Trees	Vol	Trees	Vol
Initial Stand	26	1436	11	1812	37	3248
1st Cut	0	0	5	1020		
Residual	26	1436	6	792	32	2228
After 5 Yrs.	28	1680	11	1630	39	3310
2nd Cut	0	0	6	998		
Residual	28	1680	5	632	33	2312
After 5 Yrs.	30	1720	9	1270	39	2990
Plan 3rd Cut	0	0	7	1000		

34. *Well what would happen if I made my planned third cut? Not going to cut anymore of these small sawtimber trees. If I'm going to get a 1,000 board feet out of large sawtimber. I've got to cut seven trees this time. See what's happening, I cut five, then six, and now I have to cut seven, to get the same volume.*

	10"-13" DBH		14"-18" DBH		TOTAL	
	Trees	Vol	Trees	Vol	Trees	Vol
Initial Stand	26	1436	11	1812	37	3248
1st Cut	0	0	5	1020		
Residual	26	1436	6	792	32	2228
After 5 Yrs.	28	1680	11	1630	39	3310
2nd Cut	0	0	6	998		
Residual	28	1680	5	632	33	2312
After 5 Yrs.	30	1720	9	1270	39	2990
Plan 3rd Cut	0	0	7	1000		
Residual	30	1720	2	270	32	1990

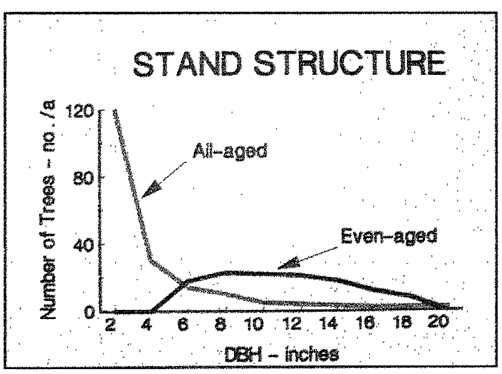
35. *If I made that cut, my residual stand is going to come out looking like this. Still have 32 trees per acre but I'm losing volume rapidly. Only got 2 trees in the large sawtimber class-only 270 board feet. There's no way that those 2 trees can grow 1,000 board feet in the next 5 years. And that's what I ran into.*

Now as I mentioned, these figures come from actual stand tables, but I did exaggerate the cutting a little bit. In order to show what happened in this process, in just a few cuts, I concentrated all my cutting up in the large sawtimber class. In actual practice we'd have taken a few trees down in the small sawtimber just for improvement purposes. When you do take some of that out of the smaller diameter classes, it delays the end result somewhat, especially if you start out with well-stocked stands and you stick to light cuts. But as long as you cut relatively more heavily among the larger trees than you do among the smaller ones, the end result is going to be the same every time. And believe it or not, it doesn't make a bit of difference whether you do that in the name of even-age or uneven-age management. You're going to end up in the same place.

Now, the thing is, when you cut one big tree, you take out a big chunk of volume all at one time. This volume can be recaptured through growth providing you leave enough stocking to use all the growing space. But the growth is distributed in much smaller chunks, among many smaller trees; or it's distributed in slightly larger chunks as ingrowth. But furthermore, as you continue to cut the larger trees, you're cutting generally the faster growing ones. The remaining trees grow, but at progressively slower rates. So sooner or later, you're either going to have to reduce the cut to where you are cutting less than the total stand growth, or else you are going to end up with all your volume clustered in a narrow range of diameters just above the threshold of *merchantability. And again, I say this doesn't matter whether you do it in the name of even-age or uneven-age management, it's going to happen.*

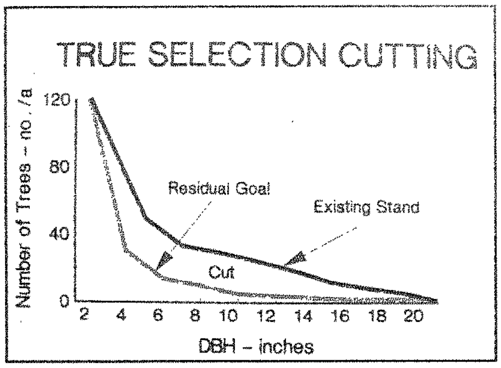
But this does point up a facet of selection cutting that has been almost totally ignored in this country. It would seem to be perfectly obvious that if you cut only the amount that the stand grows, you should have sustained yield forever. But this is one of those obvious facts, like the old one about the sun revolving around the earth, that's true only in one very special case. In the case of the sun revolving around the earth, the special case is, if you happen to be living on Earth and don't look up at the sky too often. Then you can believe that the sun revolves around the earth if you want to, and it doesn't make a whole lot of difference. But if you're an astronaut, heading out for Jupiter or Mars, you better change your assumptions in a hurry.

Now in the case of cutting only the growth in the stand and getting perpetual yields forever, the special case in which this holds true is if you cut that growth <u>from each diameter class in direct proportion to the amount of growth that occurs there.</u> And if you also continue to get reproduction. Otherwise, you are going to change the stand structure, you are going to change the rate of growth, and you are going to change the volumes that are available for cutting. So, so much for the hope-the-Lord-will-continue-to-provide-system-of-forestry. If we are actually going to manage timber, that is, to grow timber according to plan to meet a specific production schedule or to meet a specific product goal, then we are going to have to regulate stand structure."



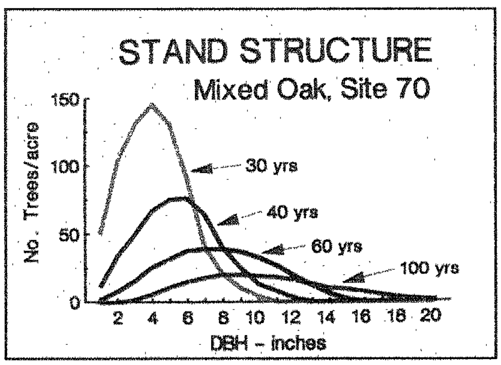
36. As Ben indicated, there are two proven silvicultural systems that have been designed specifically to regulate stand structure so as to grow timber according to a specific, planned production schedule: even-age and uneven-age management.

    When numbers of trees are plotted over diameter class, a stand with a balanced uneven-aged structure has an inverse J shaped distribution. There are many ages of trees present in the stand, with large numbers of young (small) trees and relatively few older (large) trees. By contrast, the diameter distribution of typical even-aged stands plots as a bell-shaped curve. All trees are the same age, and hence, approximately the same diameter.

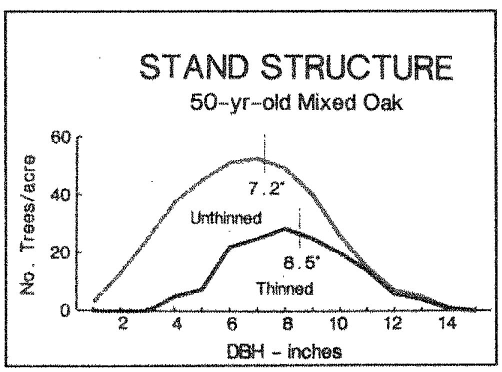


37. In uneven-age silviculture, we attempt to constantly maintain the same stand structure. We decide on the exact form of inverse J structure we want, cut in such a way as to get that structure established, and then--in each succeeding cut--remove the excess trees that have shown up in each diameter class. If the structure we have chosen is within the silvical capability of the species, we should have sustained yield thereafter in relatively equal amounts of both products and non-products.

We will consider uneven-age systems in detail in another chapter. But for now, we will concentrate on the control of stand structure in even-aged thinnings.

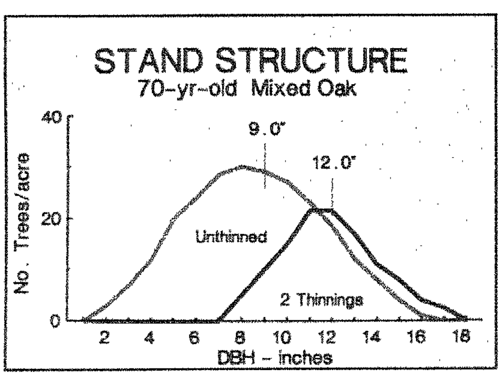


38. In even-age silviculture, stand structure changes over the life of the stand. The bell-shaped curve is narrow and high in young stands, when there are many trees in a few (small) diameter classes. As the stand gets older, the bell-shaped curve moves progressively to the right on the chart, signifying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



39. In even-age silviculture, we use thinning to speed up the natural changes in stand structure over time--that is, to increase stand diameter and move the stand to the right on the chart, toward maturity. One way we do this is by removing trees from the small diameters, thus raising the average diameter.

For example, an oak stand was thinned to 60 percent relative density by taking two-thirds of the cut basal area in trees smaller than the average stand diameter. The cutting alone increased the average diameter by 1.3 inches, and moved the bell-shaped curve to the right on the chart.



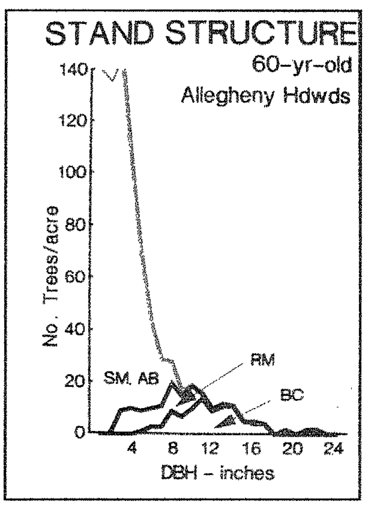
40. Thinning also gives the remaining trees more growing space and increases their individual growth rates. The combined effect of these two factors can be very significant.

In a 70-year-old stand that has had two thinnings, stand diameter was increased 3 inches by the thinning--9 inches versus 12 inches. For management purposes, the thinned stand can be considered equivalent to a 90-year-old natural stand.

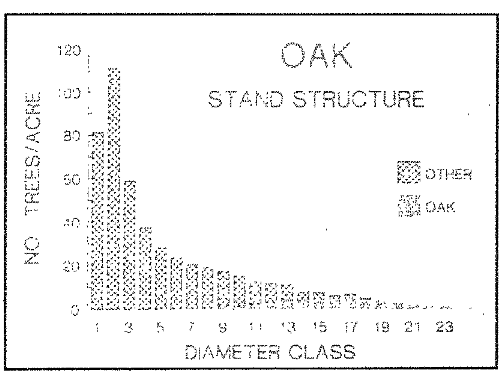
41. When managing stands for the purpose of growing timber, we want to end the rotation with a proper number of big trees properly spaced on every acre.

This is the ideal, and of course we rarely, if ever, achieve it. But we want to come as close to it as we can, and we would like to do it as soon as we can. Every thinning should be carried out with this goal in mind. We want to save the trees that come closest to meeting this goal. Therefore, we want our residual stand to contain the biggest and best quality trees that are now in it. The thinning should remove the bigger and better quality trees only if something is wrong with them, or if they need to be removed to adjust spacing--to provide needed growing space for other equally good trees. Otherwise, they should be saved for the final harvest when the big payoff for the rotation is obtained.

Thus is the theoretical goal of thinning. With stands of a single species, or group of similar species, it can be shown that this sort of cutting from below to push the large trees to maturity as quickly as possible will produce the greatest value return in the long run.



42. However, most mixed species hardwood stands do not follow typical even-age theories very well--the species in the mixture often have markedly different growth rates and tolerances to shade. As a result, many mixed hardwood stands have naturally occurring diameter distributions closely approaching the classic inverse J-shaped curve. This is the result of the mixture of species, and the presence of shade-tolerant stems in the small size classes and understory crown positions. Those small trees are the same age as the larger overstory trees in most cases. Once overtopped by faster growing stems, the tolerant saplings survive in large numbers without making much growth. They form the tail of the inverse J-shaped curve, but do not represent younger age classes. By contrast, the shade-intolerant species such as black cherry or northern red oak or yellow-poplar do not survive once overtopped, so they are not present in the smaller diameter classes. The diameter distribution for intolerant species alone forms a bell-shaped curve typical of even-aged stands.



43. The similarity between stand structure in these mixed stands and the classic all-age structure is only superficial. If we are to manage these stands by traditional even-age techniques, we must somehow convert the J-shaped diameter distribution to a bell-shaped distribution. But how does one deal with all those small trees in the lower end of the inverse J-shaped distribution?

44. If cutting is done strictly from below, the cut would be almost entirely noncommercial saplings, even in stands 50 to 60 years old. Several such pre-commercial cuts would be required in most stands to develop a bell-shaped diameter distribution.

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

Average Diameter at 80 Years

Cherry	18"
Sugar Maple	12"

46. Another complexity in managing these mixed-species hardwoods is that the several species in a stand will not mature at the same time. In Allegheny hardwood stands, for example, sugar maple averages only 12 inches in d.b.h. when the black cherry reaches financial maturity at an average d.b.h. of 18 inches.

ROTATION AGES

Cherry	80 - 90
Red Maple, Red Oak	90 - 100
Sugar Maple, Beech	120 - 150

47. So, it may be desirable to manage the faster growing species on an 80- to 90-year rotation, whereas the slower growing ones may require 120 to 150 years to reach the same stage of development.

Thinning in mixed-species,
stratified-canopy hardwood stands
is

COMPLEX

When in wonder or in doubt,
run in circles, scream and shout !

48. As a result, thinnings in these mixed hardwood stands can be very complex. Simple, textbook types of thinnings often do not work, and a wide variety of thinning practices and schedules may be needed.

THINNING

STRATEGIES

49. Many of the possible options have not been tested, and we still have much to learn. But, I will describe several thinning schemes and rotation strategies that we have tested on our computer simulator that seem to be both biologically and economically sound for use in mixed hardwood stands in the Alleghenies.

SIMULATOR EVALUATIONS

Data base largely 50-80 yr cherry-maple

Economic criteria - maximization of annual income

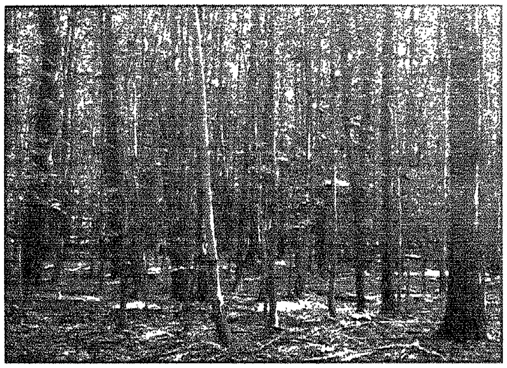
Financial maturity - culmination of MAI in $/a/yr

50. Our simulator correlations are based on the original SILVAH computer simulator, in which the data base is primarily 50- to 80-year-old cherry-maple stands. Economic analyses are based on the maximization of mean annual income, not on present net worth or internal rate of return.

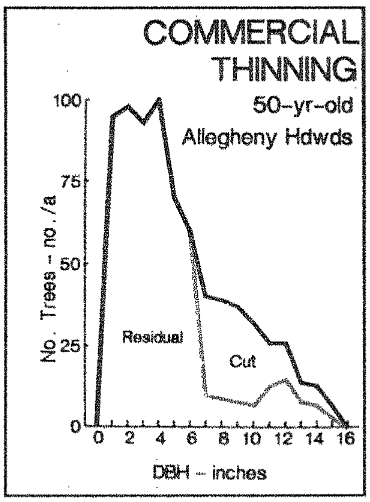
SMALL TREES

How do we deal with them ?

51. First, consider the question of the small trees and how we deal with them.



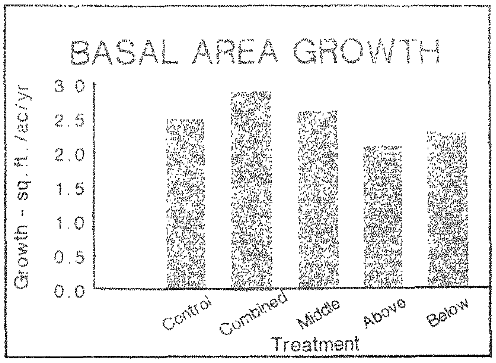
52. We have found that in stands with a high percentage of basal area in the sapling size class, it is impossible to make a commercial thinning without high-grading the stand. Even if the thinning is concentrated in the smaller poles, so much of the good growing stock must be removed that future stand values are reduced considerably.



53. To illustrate, a 54-year-old stand containing 30 square feet per acre of basal area in saplings was thinned to 60 percent relative density without removing any saplings. Two-thirds of the cut basal area came from trees below the average merchantable diameter, so the trees cut averaged only about 8 inches d.b.h. The largest and best trees were retained. So, the middle size classes in the stand--the good growing-stock trees--were nearly eliminated, and a large percentage of the stand growing space became occupied by slow-growing, shade-tolerant saplings.

STRUCTURE
THINNING TREATMENTS
Control
Combined
Middle
Below
Above

54. In this same stand, we compared growth rates after other kinds of thinnings that varied stand structure in dramatically different ways, but left stand density the same (60%). The thinning from the middle treatment was an attempt to get a commercial cut without removing any saplings. Most of the cut in that treatment came from the pole class, plus a few sawtimber trees as illustrated previously. Thinning from above was a typical high-grading, removing all the larger trees and faster growing species. Thinning from below removed ONLY saplings and small poles and was a strictly noncommercial cut. The combined thinning was a commercial thinning in the merchantable size classes combined with noncommercial removals in the sapling class.



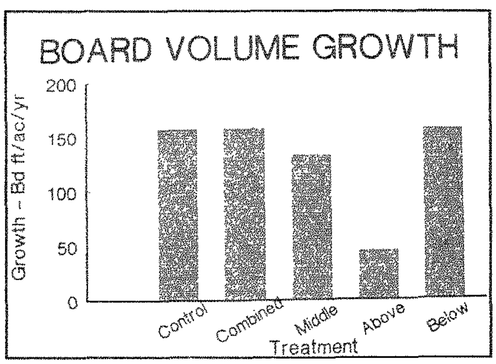
55. Total stand growth in basal area over the 10-year period after cutting was nearly as good in the thin from the middle as in the control or combined treatments which were better than that in the high-grading and precommercial thinning.

It is not surprising that total stand basal-area growth in the control treatment is nearly as good as that in the three moderate thinnings. Remember that total stand growth does not vary widely across the range of densities between 50 and 80 percent. The distribution of that growth--whether on many or few trees, or on primarily small or large trees--does vary, but not the overall total growth.

BASAL AREA GROWTH

	Combined Thin	Thin from Middle
Total Stand	2.8	2.6
% on Saps	11	33

56. In the thin-from-the-middle treatment, for example, a very large proportion of growth (one-third of the total) was on sapling-size trees that will not reach merchantable size within the normal even-age rotation period.

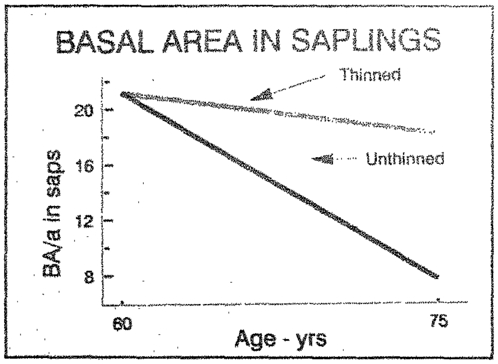


57. As a result, sawtimber growth (and therefore value growth) 10 years after cutting was much better in the combined thin and the control. In the thin-from-the-middle treatment, our simulator projects total yield at age 100 to be reduced dramatically compared to the combined thin and the control. Since this thinning yielded only a marginal return from the pulpwood-size trees cut, the thinning was detrimental both in total volume yield and economic returns.

Sapling Basal Area

20 sq.ft./a

58. Our computer simulation-runs on a variety of stands suggest that this negative effect of commercial thinning occurs when the stand contains more than approximately 20 square feet per acre of basal area in the sapling size class. If there is less than 20 square feet, a commercial thinning usually can be made without non-commercial cutting in the sapling class, and long-term yields will be greater than if the thinning is not done. But if there are more than 20 sqaure feet in the sapling class, any thinning attempted should include noncommercial removal of some of the saplings.



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

For example, in one 60-year-old stand that we examined, there were 21 square feet of saplings at age 60. With no thinning, mortality from crowding reduced sapling basal area to 8 square feet by age 75. But when a commercial thinning was applied, the same stand still contained 18 square feet of saplings at age 75.

RECOMMENDATION

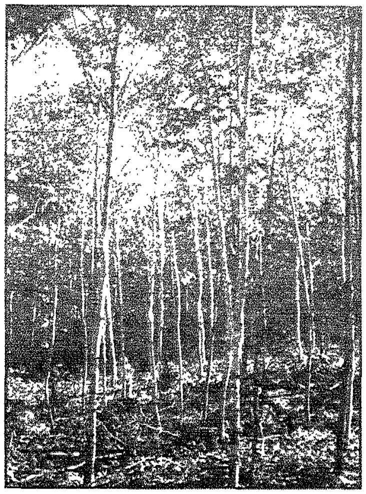
Postpone Thinning
in Young Stands
Until Commercial Thinning
can be used
without TSI in saplings

60. So, our recommendation is to stay out of younger stands that contain more than 20 square feet per acre of sapling basal area, and let natural mortality solve the sapling problem. This avoids the need for investment in precommercial sapling removal, and produces similar long-term yield.

COMBINED THINNING

Commercial Thinning
plus TSI

61. Sometimes stands with large numbers of saplings also have sufficient volume to permit noncommercial cutting of saplings and commercial removal of merchantable trees too. Generally, the products removed are small-diameter material suitable primarily for pulp or even firewood. This combined commercial thinning plus-TSI (timber stand improvement) operation is recommended where the merchantable products will at least pay the cost of the thinning.



62. When the products to be removed will not pay the cost of thinning, the economic returns from an investment in precommercial thinning are questionable. Simulation-runs to date do not show that such investments are universally beneficial. These early thinnings do increase diameter growth of the crop trees.

EARLY THINNING CAN:

- Increase Taper
- Increase Forking
- Delay Natural Pruning
- Reduce Yield

63. But, they also have some negative effects such as:

Increased taper of crop trees (lower sawtimber volume for the same diameter)

Increased forking

Delay of natural pruning

Reduced total volume yields and later initiation of commercial thinnings in some situations.

PRE-COMMERCIAL THINNING

Use it only where:
SPECIES COMPOSITION
or
STAND QUALITY
can be significantly improved

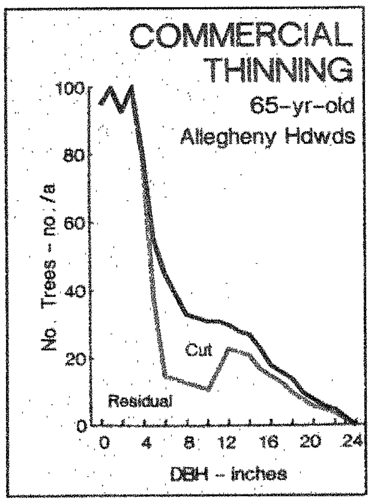
64. So, in general we recommend no precommercial thinnings unless there are many good-quality stems of high-value species being overtopped by poor-quality trees or undesirable species.

COMMERCIAL THINNING

Cut from below

in merchantable sizes only

65. In stands with less than 20 sqaure feet of basal area in saplings, our simulation- runs suggest that the saplings can be ignored in marking for commercial thinnings. In such stands, cutting is concentrated in the smaller merchantable size classes, though sufficient volume also is removed from sawtimber sizes to make an operable cut.



66. We recommend that commercial thinnings be designed to create a bell-shaped structure among the merchantable size classes. This is achieved by removing about two-thirds of the cut basal area from below the average merchantable diameter and one-third from above that diameter. Although the sapling class is unregulated and remains a part of the stand that eventually will have to be removed at final harvest, it does not significantly interfere with stand growth during the intermediate culture period.

EFFECT ON ROTATION

	DIA.	MATURITY
Before Thinning	13.9"	26 yrs
After Thinning	14.8"	20 yrs

67. Such cuts guarantee that the usual objectives of thinning are met: an increase in average diameter and a shorter rotation. In the stand illustrated, this thinning increased merchantable stand diameter from 13.9 to 14.8 inches, and reduced the time to maturity by 6 years.

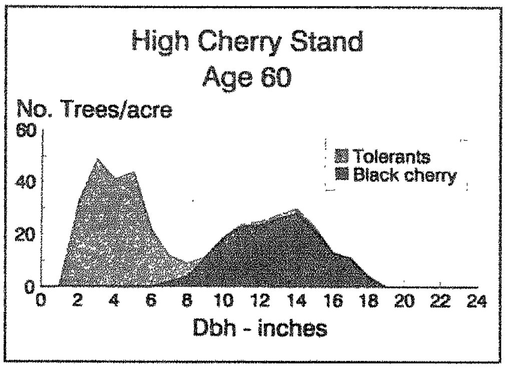
THINNING STRATEGIES

depend on

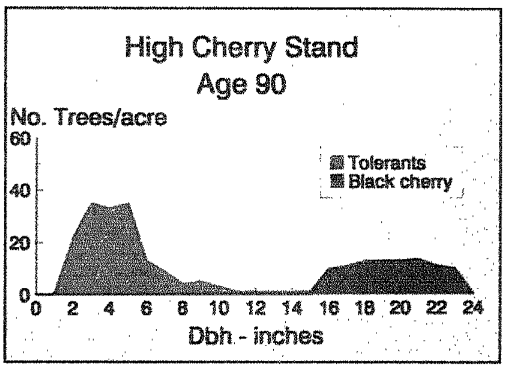
Species Composition

Size Distribution

68. In our simulation runs, we have found that different strategies are needed to maximize financial returns. The appropriate strategy depends upon the species composition and size distribution of the particular stand.

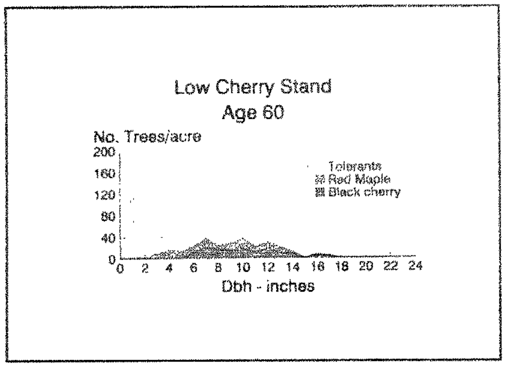


69. In stands such as this one, high-value black cherry dominates the stand even though there is a large number of saplings in the lower canopy and smaller diameters. In the stand illustrated, black cherry represented 81 percent of the stand basal area at age 60, when stand diameter averaged 12.6 inches.



70. At age 90, after two commercial thinnings that reduced density to 60 percent and removed two-thirds of the cut basal area from below the average merchantable diameter, the diameter reached 18.2 inches. At that point, the stand was financially mature by our calculations. This cutting strategy and rotation length of 80 to 90 years based upon a stand diameter of 18 inches produced the best financial returns of any of the several cutting alternatives and rotation lengths tested.

Remember that this stand was dominated by high-value, fast-growing black cherry. Also note that the 6 or 8 square feet of sapling basal area remained pretty much unchanged during the 30-year period. The saplings did not die because the thinning gave them enough light and moisture to survive. But they did not grow much either, so most of them are still present and must be treated at final harvest. Removing them earlier during the thinnings did not justify the expense.



71. In another stand, the simulator-run gave different results. This stand, also 60 years old, contained only 36 percent black cherry and had a stand diameter of 10 inches. There was a considerable amount of red maple which was smaller than the cherry, but larger than the sugar maple and beech.

AT AGE 90

Component	Diameter
Entire Stand	16.1"
Black Cherry	20.1"

72. At age 90, after two thinnings just like those in the previous stand, the black cherry was mature, but the stand as a whole was not, with an average diameter of only 16 inches. The most profitable strategy in this stand was to harvest the black cherry at age 90 but carry the balance of the stand for another 30 years until the red maple and larger sugar maple reached maturity.

BASAL AREA AFTER CHERRY HARVESTED

Medium Saw	Small Saw	Poles	Saps
5	35	22	15

73. This makes good sense, if you consider the basal area and its distribution at age 90, after the cherry is removed. Most of the red maple trees are in the small sawtimber or larger pole class where they are growing into sizes where they will soon qualify for high-value sawtimber and veneer. Thus, they are increasing very rapidly in value at this time. It does not make sense to clearcut such stands when the cherry matures, because there is enough growing stock in other species to make a fully stocked stand that will increase in value rapidly.

However, regeneration could be a problem if all the cherry seed sources are removed at age 90. So, this cherry harvest should actually be spread over the remaining cuts, and attempts made to regenerate and hold cherry advance seedlings until the end of the rotation.

EXTENDED HARVEST

If slower-growing group will:

Equal at least 50 % Density

Mature within 30 years

74. As a general rule, our simulations suggest that this extended harvest or double rotation is profitable if the stocking in the slower growing species size group is at least 50 percent, and if that group will mature within 30 years of the faster growing group.

THIN - HARVEST

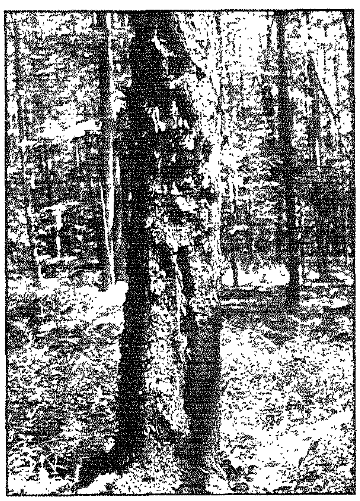
Near end of rotation, to

harvest individually-mature stems

while thinning from below

in the rest of the stand

75. Actually, our simulations show that economic returns in nearly all stands will benefit if the last thinning in the rotation shifts from a strict thinning-from-below to include the removal of those individual stems that have reached large sawtimber size and are individually mature. This captures their yield earlier while avoiding undue risk from natural catastrophes that become more common on larger, mature trees. However, such thin-harvests must be used with care as they can easily turn into high-grading. And, as before, care must be taken to ensure that adequate seed sources of the faster maturing and more valuable species are retained to permit regeneration of these species in the next stand. With care, all of these objectives can be achieved.



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

MARKING PRIORITIES

1. Stand Density
2. Tree Quality
3. Stand Structure

77. In order of priority, we attempt to control density first: that is, we do not overcut or undercut to achieve some structural goal or remove all the unacceptable quality trees. Within the limits of the density to be removed, we give priority to removal of poor-quality trees. Achievement of structural goals is last priority.

EFFECT ON QUALITY

	AGS	UGS
Before Thinning	75	25
After Thinning	100	0

78. Using our guides will automatically improve quality, as the guides call for removal of unacceptable growing stock trees (UGS) before removal of acceptable growing stock (AGS).

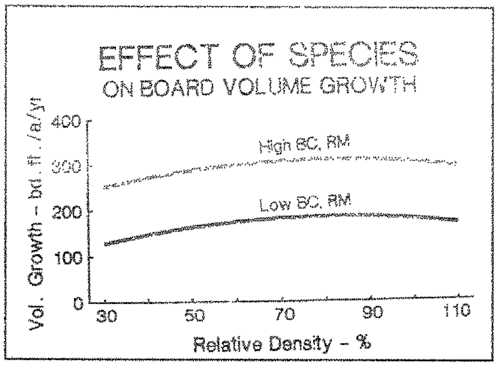
SPECIES COMPOSITION and STAND STRUCTURE are closely related

79. The procedures described for manipulating stand structure automatically favor the faster growing species and individuals in the stand. These usually are the shade-intolerant and more valuable species.

EFFECT ON SPECIES

	% BL. CHERRY
Before Thinning	41
After Thinning	48

80. In the example mentioned earlier, the proportion of black cherry was increased from 41 to 48 percent using these guides.



81. The manipulation of species composition can be one of the most important factors affecting stand yields. For example, in our Allegheny hardwood stands, board-foot volume growth of the entire stand can be 50 percent higher in stands that contain a high percentage of black cherry, than in comparable stands with little cherry. Northern red oak and yellow-poplar often perform in a similar way in oak-hickory or transition stands.

STUMPAGE PRICES

Black Cherry	$ 750
Red Oak	$ 500
White Ash	$ 350
Sugar Maple	$ 125
Beech	$ 50

82. When this faster growth is coupled with the significantly higher stumpage values of cherry or northern red oak,

83. and with the fact that stands with a high percentage of cherry can carry higher volumes,

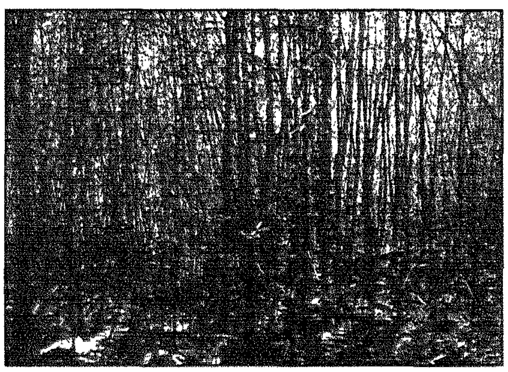
AT AGE 100:

% Cherry	Mbf	Value
Low	9.1	$ 791
Medium	15.2	$ 3091
High	22.9	$ 6702

84. the end result may be a very large increase in economic returns over the rotation from stands with a high percentage of fast-growing, shade-intolerant, high-value species. For example, Allegheny hardwood stands containing a high percentage of black cherry yield nearly 10 times as much as stands with a low percentage of cherry.

EVEN-AGE TREATMENT SCHEDULES

85. Let me summarize some of this discussion about stand structure, species composition, and our general strategy for thinning and rotation length in mixed-species, even-aged hardwoods.



86. It is our belief that these hardwoods generally should be grown in dense stands when they are young; this produces clean, straight boles with little taper. It also provides for high mortality among the slower growing tolerants in the lower canopy, helping to minimize the problem later on of using even-age thinning techniques in stands with an inverse J-shaped diameter distribution. Although diameter growth is less than the maximum in these dense stands, it is still very good on the dominants and codominants during this period. So, during the period of rapid height growth, while sapling size stems still represent a major proportion of stand basal area (the first 40 to 50 years), we recommend that you stay out of these stands and allow them to develop naturally, unless they need a weeding to eliminate poor species or low-quality stems.

Early Commercial Thinnings:

Yield primarily pulpwood.

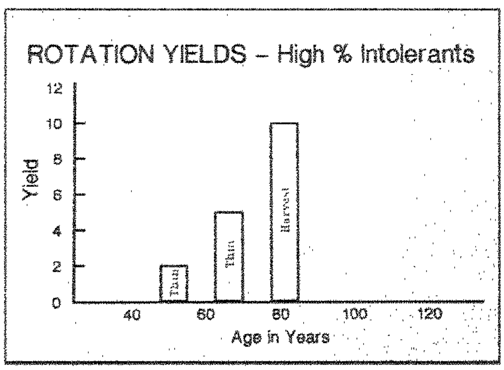
Later Commercial Thinnings:

Yield both sawlogs and pulpwood.

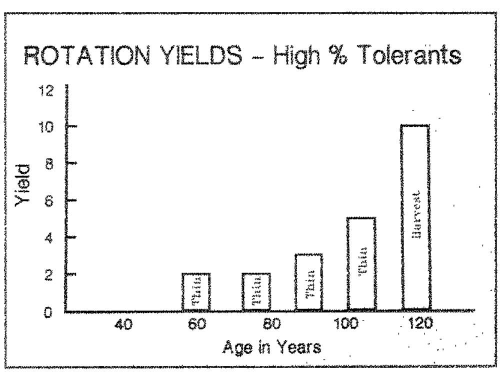
87. Once height growth begins to slow down and the basal area in saplings drops below about 20 square feet per acre, commercial thinnings can begin. The first one or two cuts will yield mostly small diameter products--pulpwood with perhaps a few smaller sawlogs. These thinnings should be primarily from below, to establish the start of the bell-shaped diameter distribution and increase average stand diameter.

Later in the rotation, as the stand approaches maturity, the thinnings will change slightly in character. Cutting will continue to be heavy in the small size classes (the poles), but by now some of the faster growing species and individuals will be mature and can be removed. This narrows the bell-shaped distribution from both ends and makes the stand more nearly even-sized. It also maximizes value yield by harvesting those individuals and species that are no longer increasing rapidly in value. This concentrates growth on the small sawtimber sizes that are increasing most rapidly in value due to both diameter increase and grade improvement.

So, the final partial cuttings are really part of the harvest cutting, which may extend over several cuts rather than just one. They are a combination harvest of mature stems and thinning among smaller stems. There is some danger in allowing these thin-harvests to become high-gradings that deplete the stand and leave genetically inferior seed sources for establishment of the next stand. But, if used only at the very end of the rotation, they can improve economic returns substantially without causing the silvicultural problems usually associated with repeated high-grading.



88. Rotation lengths and number of thinnings will vary depending upon the mix of species present. In stands with a high percentage of black cherry, white ash, red oak, and yellow-poplar, we might expect the first commercial thinning at age 50, a second one at age 65, and final harvest at age 80.



89. In stands with more sugar maple, beech, white oaks, hickory, and other slow-growing species, thinnings might occur at ages 50, 70, 90, 110, and a final harvest at 120 or 125 years. The thinning prior to final harvest would undoubtedly be a thin-harvest, and even the one at age 90 would include moderate amounts of large trees. Care would have to be taken during the last few cuts to ensure retention of enough of the faster growing species to provide seed for regeneration at the end of the rotation.

THINNING PRESCRIPTIONS

90. In the article "Development of a Silvicultural Prescription," Ernst discusses the use of our prescription (decision) charts. I will review quickly the decisions involved in preparing a prescription for thinning.

THINNING PRESCRIPTIONS

- Defer Cutting
- Commercial Thinning
- Thin-Harvest
- Combined Thinning
- Precommercial Thinning

91. We recognize five major thinning prescriptions:

Defer cutting

Commercial thinning

Thin-harvest

Combined thinning

Precommercial thinning

THINNING is appropriate if:

- Stand is NOT mature
- AGS density › 35 %
- Visual goal permits even-age mgmt.

92. Thinning of all types is appropriate in stands that are not yet mature; that is, stands in which the featured species-size group is less than 18 inches d.b.h., and in which there are enough good quality stems to be worth managing the stand. Thinning is also an even-age practice, so visual goals must not preclude even-age culture.

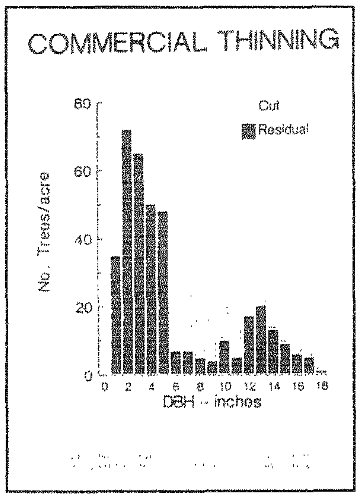
Relative Density	
100	THIN
90	
80	----------------
70	DON'T THIN
60	
50	

93. Regardless of other stand characteristics, if relative stand density is less than 80 percent, there is no need for thinning. Growth and mortality should be adequate, and there is not likely to be enough volume available to warrant a commercial cut without overcutting. So, the prescription for stands at less than 80 percent density is to defer cutting now, examine again in 10 to 15 years.

COMMERCIAL THINNING

- Density > 80 %
- Sapling BA < 20 sq. ft.
- Stand immature

94. Commercial thinning is used when relative density is above 80 percent, the stand is not close to the end of the rotation, and the basal area in saplings is less than 20 square feet.



95. Commercial thinnings should cut heavily in the pole sizes, lightly to moderately in the small and medium sawtimber sizes. Most sawtimber trees that are cut should be ones that are of low quality, are in danger of dying, or must be removed to provide growing space for better quality stems of similar size. The effect of applying this distribution of cut to a typical cherry-maple stand averaging 14 inches (medial diameter in merchantable trees) is illustrated here. Notice that most of the cut has occurred in the 6- to 12-inch diameter classes. In this example, the cut produced about 1600 board feet of sawtimber and 6 cords of pulpwood, or 8.5 cords if it all goes into pulp. Notice that the residual stand has begun to assume a bell-shaped curve in the merchantable size classes, rather than the inverse J-shaped curve it had before. Subsequent thinnings would reinforce this distribution.

DISTRIBUTION OF CUT

Table 1, Appendix

% cut from each size class

96. To provide objective and easily followed guidelines for distribution of cut among size classes, we have prepared a table showing the percentage of the cut that should come from each size class for stands of varying stand diameter (Table 1 in the Appendix). To use this table, you must know the diameter of the merchantable size trees. We use the average diameter of only merchantable trees because we are ignoring the saplings and working only with the merchantable sizes.

EVEN-AGE CUTS

2/3 of cut BA or 3/4 of cut RD — from below the ave. diameter

97 . We are currently testing a wide variety of even-age structures to learn which will produce the best yield over the rotation. Until that information is available, we simply work in the direction of creating a bell-shaped diameter distribution within the portion of the stand that we will feature in our management. We do this by cutting more heavily below the average diameter than above--two-thirds of cut basal area or three-fourths of cut relative density comes from below the average diameters.

FEATURED STAND

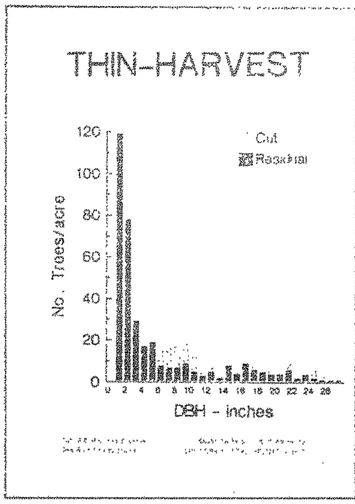
Type Cut	Component
Combined	Entire Stand (D)
Commercial	Merch. Stand (DM)
Commercial HV Sp	Merch Stand (HV DM)
Thin-Harvest	Immature Merch. Stand (DM)

98. The particular average diameter used depends upon the type of cut--that is, the portion of the stand to be featured in management.

THIN - HARVEST

- Density › 80 %
- Sapling BA ‹ 20 sq. ft.
- Stand near maturity

99. Thin-harvests are used toward the end of the rotation, as the last regular thinning in most stands. As with other commercial thinnings, the stand should be above 80 percent density and sapling basal area less than 20 square feet.

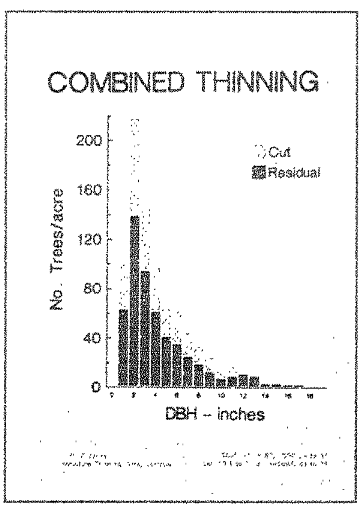


100. Notice in this chart that the thin-harvest distribution looks very similar to the commercial thinning shown earlier, except for slightly less cutting in the small sawtimber and slightly more cutting in the large sawtimber sizes. So, it is primarily a thinning, but modified for the special purpose described. Unlike commercial thinnings, the thin-harvest may slightly reduce stand diameter and proportion of fast-growing species rather than increase them. But, a final harvest about 15 years later will still be appropriate, and the overall yields will be improved over those obtainable from a more conventional thinning (thin from below) at this time

COMBINED THINNING

- Density > 80 %
- Sapling BA > 20 sq.ft.
- Cut Volume Operable

101. Combined commercial thinning with TSI in the sapling class is appropriate in young stands with density greater than 80 percent, that have more than 20 square feet in basal area, but also have enough merchantable volume to warrant a commercial sale.



102. The distribution of cut for a combined thinning is handled in the same manner as with a commercial thinning, except that cutting is extended into the sapling class, and the diameter of all sizes (not just merchantable sizes) is used in distribution of the cut. Density and quality considerations are identical to the commercial thinning. Notice that cutting in the sapling class is aimed only at reducing that class to a level where it does not dominate residual stand stocking. If these guides are applied to a stand that has less than 20 square feet of basal area they result in removal of all saplings--which is neither necessary nor economical.

PRE-COMMERCIAL THIN

- Density > 80 %
- Sapling BA > 20 sq.ft.
- Cut Volume Inadequate

103. Precommercial thinning is appropriate in stands with density greater than 80 percent that contain more than 20 sqaure feet of basal area and have too little volume to support a commercial thinning.

PRE-COMMERCIAL THINNING

Use it only where:
SPECIES COMPOSITION
or
STAND QUALITY
can be significantly improved

104. This treatment requires an investment. We do not recommend precommercial thinning investment except in those unusual cases where either species composition or stand quality can be significantly improved.

PRE-COMMERCIAL THIN

Pole stands -- Area-wide thinning

Sapling stands -- Crop tree thinning

105. If used, precommercial thinnings in pole-size stands can be done on an area basis using the same distribution of cut procedures as the combined thinning.

In younger--sapling-size--stands, precommercial thinning is more easily handled as a crop tree release, where 50 to 200 of the best trees are selected per acre, and thinning is done to remove only those trees competing with the crop trees. This reduces cost and provides better results than area-wide treatments at this age.

THINNING

106. Thinnings in mixed hardwood stands can increase yields significantly by concentrating growth on the most valuable stems in the stand, by increasing their growth rate, and by capturing some of the yield earlier in the rotation. To achieve these goals, thinning must include regulation of stand density, structure, and composition. The SILVAH prescription system provides a precise way of regulating thinning to achieve these results.

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Trimble, G. R. 1974. Response to crop tree release by 7-year-old stems of red maple stump sprouts and northern red oak advance reproduction. Res. Pap. NE-303. Upper Darby, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 6 p.

Table 1. -- Cut relative density to come from and relative density to be retained in various size classes, in percent.

DIAMETER	SAPS	POLES	SSAW	MSAW	LSAW[1]
	EVEN-AGE SILVICULTURE CUT RELATIVE DENSITY TO COME FROM VARIOUS SIZE CLASSES				
MDM	Commercial Thinning and Shelterwood Cutting[2]				
8	--	100	0	0	0
9	--	96	4	0	0
10	--	88	12	0	0
11	--	81	19	0	0
12	--	74	24	2	0
13	--	68	26	6	0
14	--	63	27	10	0
15	--	58	28	13	1
16	--	54	28	14	4
17	--	51	27	15	7
MD	Combined TSI - Commercial Thinning				
4	91	9	0	0	0
5	82	18	0	0	0
6	74	26	0	0	0
7	67	29	4	0	0
8	61	30	9	0	0
9	55	31	14	0	0
10	51	31	15	3	0
	Precommercial Thinning				
--	100	0	0	0	0
	Thin-Harvest				
--	--	50	5	15	30[3]
	ALL-AGE SILVICULTURE RELATIVE DENSITY TO BE RETAINED IN VARIOUS SIZE CLASSES				
	Standard Selection Cutting (Mgmt Goal 3)				
	--[4]	41	37	22	0
	Single-tree Selection Cutting with Maximum Large Trees (Mgmt Goal 4)				
	--[4]	22	30	27	21

[1] For commercial thinning only, take up 50% of original density in large saws and adjust other sizes proportionally.
[2] Note that shelterwood cuts being made in stands that contain 5 or more square feet of basal area per acre in noncommercial (UGS) saplings and poles should include removal of all noncommercial stems (usually by injection with an herbicide) even though no other cutting will occur in the sapling class.
[3] For thin-harvest only, take up 75% of original density in large saws and adjust other sizes proportionally.
[4] In all-age cuts, all existing sapling density is retained.

Source: Marquis, David, A.; Ernst, Richard L.; Stout, Susan L. 1992. Prescribing silvicultural treatments in hardwood stands of the Alleghenies (revised). Gen. Tech. Rep. NE-96. Radnor, PA: U. S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 101 p.

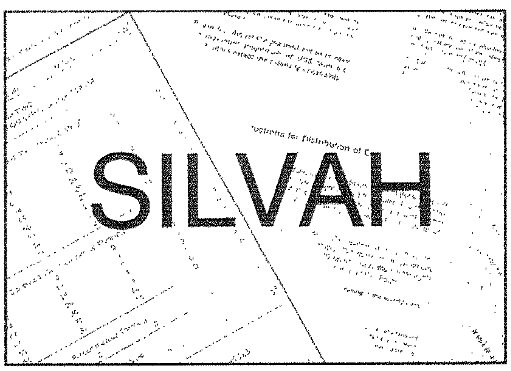
Distribution of Cut
Under Even-Age Management

Richard L. Ernst

Distribution of cut

Decide which trees to cut

1. If a partial cutting is prescribed in the SILVAH system, there must be a plan regarding species, sizes, quantity, and quality of trees to be removed. This article concentrates on thinnings under even-age silviculture and works through the mechanics of developing the cutting plan. Refer to the forms in Appendix C and D. Procedures for distributing the cut under all-age silviculture are slightly different and are described later by Stout in, "Uneven-age Management Principles and Practices".



2. This entire process of distributing the cut among species, size, and quality classes is part of the three step SILVAH process, and has been automated in the SILVAH computer program. The procedures for the manual distribution of cut described here essentially duplicate the algorithm in the computer program.

Phases of Distribution of Cut Procedures

- Prepare worksheet and determine density and structure
- Adjust the structure to fit distribution of actual stand
- Adjust the planned cut to remove maximum proportion of UGS
- Translate planned cut to marking guides

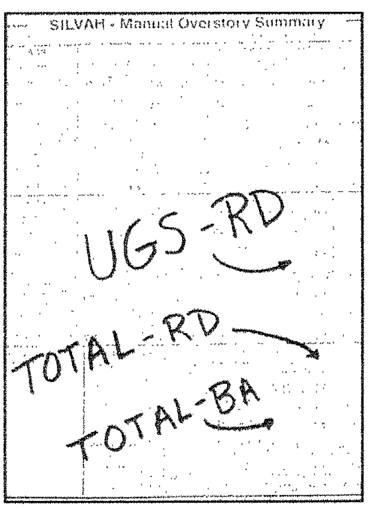
3. The procedures for distribution of cut can be divided into four phases. These phases are described in detail in Appendix A. We will discuss each phase for an even-age intermediate thinning and will use the same sample stand as that in the analysis article.

Distribution for COMMERCIAL THINNING

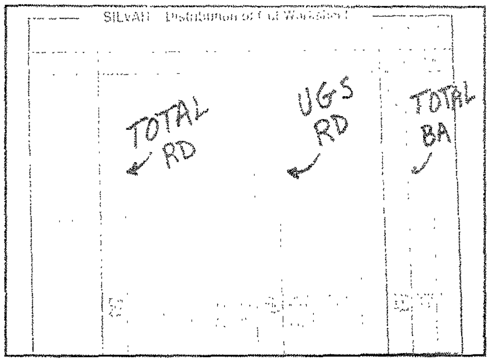
4. The inventory, data summary and analysis, and prescription have been completed for the sample stand previously. The recommended prescription is a commercial thinning; the distribution of cut for a commercial thinning is discussed here.

Distribution in RELATIVE DENSITY

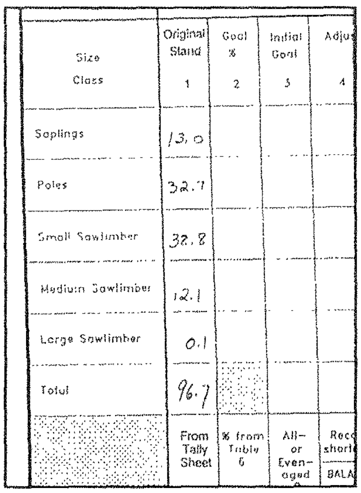
5. The distribution of cut calculations are made using relative density rather than basal area or number of trees. This makes it easy to achieve the desired residual density goal. At the end of the procedure, we convert to basal area/acre and cut ratios for field implementation.



6. The first phase is to copy values from the stand summary and to determine the density and structure parameters. Copy three columns of data from the Manual Overstory Summary worksheet (Appendix D) to the Distribution of Cut worksheet (Appendix C). Copy the original stand density, original stand density in unacceptable growing stock (UGS density), and original stand basal area

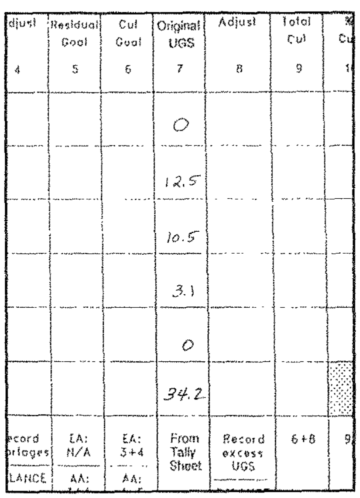


7. to the Distribution of Cut worksheet, columns 1, 7, and 12, respectively.



Size Class	Original Stand 1	Goal % 2	Initial Goal 3	Adju 4
Saplings	13.0			
Poles	32.7			
Small Sawtimber	38.8			
Medium Sawtimber	12.1			
Large Sawtimber	0.1			
Total	96.7			
	From Tally Sheet	% from Table 6	All- or Even-aged	Rec short BALA

8. Copy the original relative density sums for all species and all qualities to column 1, for each size class and the total. In our example, these numbers are 13.0, 32.7, 38.8, 12.1, 0.1, and 96.7.



djust 4	Residual Goal 5	Cut Goal 6	Original UGS 7	Adjust 8	Total Cut 9	% Cu 1
			0			
			12.5			
			10.5			
			3.1			
			0			
			34.2			
ecord ortages LANCE	EA: N/A AA:	EA: 3+4 AA:	From Tally Sheet	Record excess UGS	6+8	9

9. Then copy the original relative density in unacceptable growing stock (UGS density) for all species, for each size class to column 7. This is a commercial thinning, so there will be no cutting in the sapling class. Even though there may be UGS in the sapling class, they will not be removed. So, put a zero in the sapling class. For this example, the numbers are 0, 12.5, 10.5, 3.1, and 0, with a total of 34.2, or a total of 26.1 UGS in commercial size classes.

...ol ...ut	% Cut	Cut Ratio	Original Stand	Cut	Residual
9	10	11	12	13	14
			11.1		
			37.4		
			73.1		
			35.8		
			0.5		
			158.0		
...48	9/1		From Tally Sheet	$\frac{10 * 12}{100}$	12 − 13

10. Finally, copy the original basal area per acre of all species and qualities to column 12 for each size class and the total. In our example, the numbers are 11.1, 37.4, 73.1, 35.8, and 0.5, a total of 157.9. We now have the required stand data on our worksheet, and are ready to begin the distribution of cut calculations.

Thinning Priorities

- Stand density
- Tree quality
- Stand structure

11. In a thinning, we want to control three conditions in the residual stand: stand density, tree quality, and stand structure in that order of priority. However, it is easier to perform the density and stand structure calculations first, then adjust for quality.

Residual density

RD * 0.65

must be >= 60

12. So, begin by calculating the desired residual stand density (Phase I, step 5). The goal is to reduce the relative density in the stand so the remaining trees can grow faster. This is the first priority. For thinnings, we recommend a residual relative density of 60 percent, but we suggest you never remove more than 35 percent of the relative density in any one cut. To determine the residual density, multiply the original relative density of the stand by 0.65 (the complement of 35 percent). If the result is greater than 60, use the calculated value; if the result is less than 60, use 60.

The desired residual density for shelterwood cuttings may be either 50 or 60 percent. For shelterwood cuts, reduce density to the desired level even if that results in removal of more than 35 percent at one time.

RD * 0.65

96.7 * 0.65 = 62.9

13. The sample stand has a density of 96.7, as shown in the total row of column 1. So, multiply that total density, 96.7, by 0.65 to get a residual density of 62.9. It is above the recommended minimum density of 60 for commercial thinnings, so use 62.9 as the goal. Multiplying by 0.65 prevents removing more than 35 percent of the relative density that is there. Taking it all the way back to 60 percent relative density in this stand would have removed more than the limit of 35 percent.

Small Sawtimber	38.7						10.5
Medium Sawtimber	12.1						3.1
Large Sawtimber	0.1						0
Total	96.7		* 0.	65 =	62.9		34.2
	From Tally Sheet	% from Table 6	All- or Even-aged ?	Record shortages — BALANCE	EA: N/A — AA: 3+4	EA: 3+4 — AA: 1-5	From Tally Sheet

14. Record the desired residual density of 62.9 in the total row of column 5.

CUT is

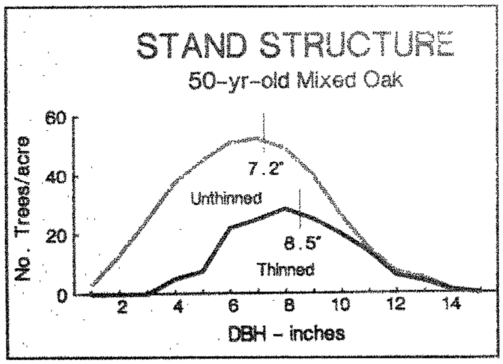
original - residual

96.7 - 62.9 = 33.8

15. The total density to be cut can now be calculated (Phase I, step 6). It is the original relative density minus the residual, or the total from column 1 minus the total from column 5. For this stand, it is 96.7 - 62.9 = 33.8.

Small Sawtimber	38.7						10.5
Medium Sawtimber	12.1						3.1
Large Sawtimber	0.1						0
Total	96.7		←MI	NUS →	62.9	33.8	34.2
	From Tally Sheet	% from Table 6	All- or Even-aged ?	Record shortages — BALANCE	EA: N/A — AA: 3+4	EA: 3+4 — AA: 1-5	From Tally Sheet

16. Record the 33.8 to be cut in the total row of column 6. Fill in only the TOTAL row of this column at this time. We have now completed our calculations of total stand residual and cut density.



17. The next calculations deal with stand structure, or the distribution of cut among size classes (Phase I, step 7). We know how much we want to cut, but we must decide from which sizes to take the cut. In even-age thinnings and shelterwood cuts, we want to cut more heavily from below the stand diameter than from above.

DISTRIBUTION OF CUT

Table 6, GTR-NE-96 (Revised)

% cut from each size class

18. As a general rule, we like to remove 2/3 of the cut basal area from below the average stand diameter and 1/3 from above. This is equivalent to removing 3/4 of the relative density from below, and 1/4 from above. Appendix B shows the proportion of the total cut relative density that should come from each of the major size classes, based on the average stand diameter. For a typical stand, these tabulated values achieve the cut from below. For commercial thinning, where cutting is confined to merchantable size trees, use the average diameter of merchantable trees (MDM) to select the appropriate row in this table.

Commercial Thinning

Cut RD from size classes
(from Table 6, GTR-NE-96)

MDM	SAPS	POLES	SSAW	MSAW	LSAW
12	--	74	24	2	0
13	--	68	26	6	0
14	--	63	27	10	0
15	--	58	28	13	1

19. For this stand, look up the cut factors in the commercial thinning section of the table for a stand with an average diameter (merchantable sizes) of 14 inches.

This table also accommodates other types of thinnings. If the prescription were for a combined thinning/timber stand improvement or a pre-commercial thinning; we would use the average diameter (DM) instead of average merchantable diameter (MDM) in the appropriate section of the table. Combined and pre-commercial cuts include all tree sizes, including saplings. There are also sections in the table for thin-harvest cuts and for selection cuts.

The factors for a commercial thinning in a stand with an average merchantable diameter (MDM) of 14 inches are: 0, 63, 27, 10, and 0 for saplings to large sawtimber. Most of the cut, 63 percent, is concentrated in the pole class, which is below the average stand diameter.

Size Class	Original Stand 1	Goal % 2	Initial Goal 3	Adjust 4
Saplings	13.0	0		
Poles	32.7	63		
Small Sawtimber	38.8	27		
Medium Sawtimber	21	10		
Large Sawtimber	01	0		
Total	96.7			
	From Tally Sheet	% from Table 6	All- or Even-aged ?	Record shortages BALANCE

20. Record these values in column 2 in the rows for the appropriate size classes.

	Relative Density					
Size Class	Original Stand 1	Goal % 2	Initial Goal 3	Adjust 4	Residual Goal 5	Cut Goal 6
Saplings	13.0	0	—	—	—	—
Poles	32.7	63				
Small Sawtimber	38.8	27				

21. The percentage of the cut that will come from the saplings is zero since this is a commercial cut. So there is no need to record calculations for this row. Just mark out the sapling row from column 3 to 11 to avoid using it in any of the calculations.

% of CUT from size class

NOT

% of class to cut

22. Remember that these proportions represent the percentage of the cut that should come from each size class. It is not the proportion of each class to cut. That will be determined later.

Phases of Distribution of Cut Procedures

- Prepare worksheet and determine density and structure
- Adjust the structure to fit distribution of actual stand
- Adjust the planned cut to remove maximum proportion of UGS
- Translate planned cut to marking guides

23. The next phase of the procedure is to adjust the structure to fit the actual stand.

Total cut of 33.8,

63% from poles,

33.8 * 0.63 = 21.3

24. In the example, the total cut will remove 33.8 relative density units. That number is found in the total row of column 6. Sixty-three percent of the total cut needs to come from the poles; therefore, the cut in the poles will be: 0.63 times 33.8 = 21.3 relative density units. Remember, take 63 percent of the total 33.8 cut; do not take 63 percent of the 32.7 that is present in the pole class.

Poles	32.7	.63	21.3				
Small Sawtimber	38.8	27					
Medium Sawtimber	12.1	10					
Large Sawtimber	0.1	0					
Total	96.7					62.9	33.8

Times

25. Record the pole cut of 21.3 in the pole row of column 3.

Saplings	12.0	0	--	--	--	--
Poles	32.7	63	21.3			
Small Sawtimber	38.8	27	9.1			
Medium Sawtimber	12.1	10	3.4			
Large Sawtimber	0.1	0	0			
Total	96.7				62.9	33.8

26. Similarly, 27 percent of the 33.8 total cut relative density, or 9.1 relative density units should come from the small sawtimber; and 10 percent of the 33.8 total cut relative density, or 3.4 relative density units from the medium sawtimber. The key here is to remember that the proportions in column 2 apply to the total cut in column 6.

Size Class	Stand 1	2	3	
aplings	13.0	0	--	
oles	3[illegible].7	63	21.3	
mall Sawtimber	3[illegible].8	27	9.1	
ledium Sawtimber	12.1	10	3.4	
arge Sawtimber	0.1	0	0	
otal	96.7		33.8	
	From Tally	% from Table	All-	Re

27. Check to see that the cuts in each size class sum to the total you wanted to cut; that is, the total of column 3 equals the total in column 6. In the example they do, within the limits of rounding.

Cutting more than you have ?

(compare col. 1 and col. 3)

28. Usually, this distribution can be met without any trouble, but sometimes the initial distribution may call for cutting more from a class than is actually there. If that is the situation, there needs to be an adjustment. Compare the initial estimates of the cut in column 3 with the actual density present in column 1 for each size class.

Record deficiencies as negatives in Col. 4

29. Record any deficiencies -- the amount by which the trial cut exceeds the actual density present -- in column 4 for each size class. Record these deficiencies as negative numbers, since any adjustment would need to reduce the cut in that size class.

Adjust to increase removals of mature. (up to 50 % LSaw)

30. Another adjustment could be made to remove a portion of any large sawtimber (24+ inches) present, because large trees may be considered individually mature. So, you may increase the amount to be cut in the large sawtimber class in accordance with the footnotes in Appendix B. In commercial thinnings, the recommendation is to remove up to 50 percent of the large sawtimber class; in thin-harvest cuts, remove up to 75 percent of this class. Just record the amount of relative density by which you want to increase the cut in column 4, for large sawtimber. Record these adjustments as positive numbers, since we are increasing the cut in the large sawtimber size class.

Balance any adjustments

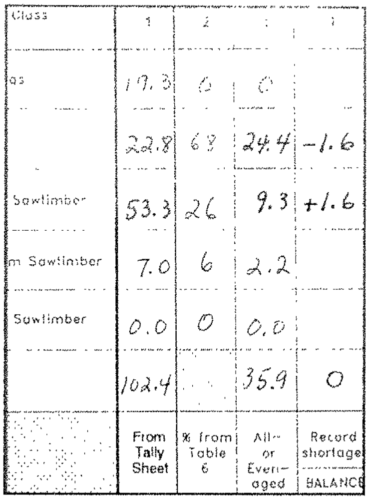
31. If you have recorded any negative numbers (that is, deficiencies requiring a decrease in the cut) or positive numbers (that is, increases in large sawtimber cut) in column 4, then you need to complete the adjustment process. Any adjustments in one size class must be compensated for by adjusting other classes so the density goal is maintained. That is, the sum of the adjustments should be zero.

Size Class	Stand 1	Goal % 2	Initial Goal 3	Adjust 4
s	13.0	0	—	—
	32.7	63	21.3	
Sawtimber	38.8	27	9.1	None
Sawtimber	12.1	10	3.4	
Sawtimber	0.1	0	0	
	96.7		33.8	
	From	% from	All-	Record

32. In the sample stand, there are no deficiencies, and the amount of relative density in large trees is so small that you really could not take half of it. So, no adjustments are necessary.

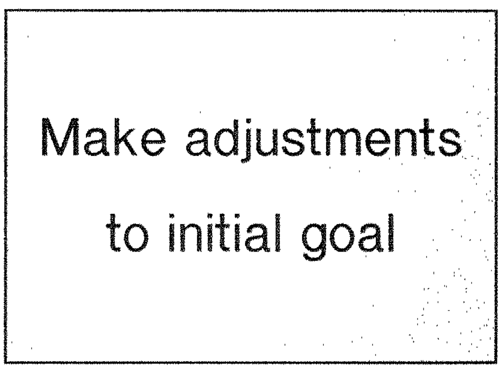
33. Examining a stand where an adjustment is necessary if the initial cut calls for cutting more than is present (a negative in column 4), decrease the cut in the class that has the deficiency, and balance it by increasing the cut in some other class. In this example, we have a deficiency of 1.6 in the pole class. So, we need to reduce the cut in that class by 1.6, and balance it by increasing the cut in the small sawtimber by 1.6. This balance can be done using your best judgment, or it can be done in proportion to the initial cut goal percentage from column 2. The computer program adjusts the cut using the proportions, but the common sense approach is recommended when calculations are done manually. The adjustments are usually minor, so differences between the manual approach and the proportion approach will be insignificant.

If an adjustment is needed, write down compensating adjustments to other size classes (either increasing the cut with positives or decreasing it with negatives) until the total is in balance. That is, the increases in any size classes are offset by decreases in others, resulting in a zero total in the adjustment column.

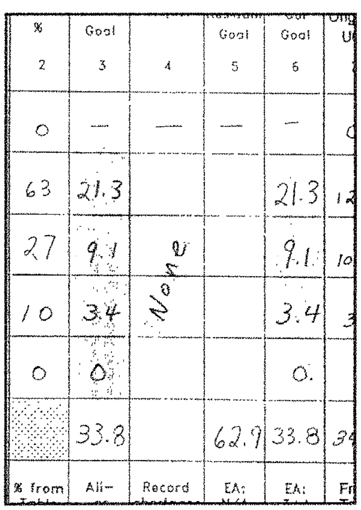


Class	1	2	3	4
as	19.3	6	0	
	22.8	63	24.4	-1.6
Sawtimber	53.3	26	9.3	+1.6
m Sawtimber	7.0	6	2.2	
Sawtimber	0.0	0	0.0	
	102.4		35.9	0
	From Tally Sheet	% from Table 6	All- or Even-aged	Record shortage BALANCE

34. Make adjustments recorded in column 4 by adding the values in columns 3 and 4 for each size class, and record the new values in column 6. Check to be sure the total cut equals the planned cut, within rounding error.



35. If there are no adjustments, as in the original sample, the new cut goal is the same as the original. Copy the values from column 3 to column 6.



%	Goal		Goal	Goal	Orig U
2	3	4	5	6	
0	—	—	—	—	0
63	21.3			21.3	1
27	9.1	None		9.1	10
10	3.4			3.4	3
0	0			0.	
	33.8		62.9	33.8	34
% from	All-	Record	EA:	EA:	Fr

Phases of Distribution of Cut Procedures

- Prepare worksheet and determine density and structure
- Adjust the structure to fit distribution of actual stand
- Adjust the planned cut to remove maximum proportion of UGS
- Translate planned cut to marking guides

36. The third phase of the procedure is to adjust the structure for quality.

QUALITY:

Don't cut AGS while leaving UGS

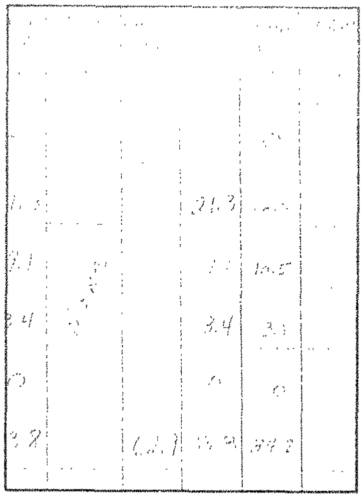
37. Up to this point, you have been dealing with two of the three priorities: stand density and structure. Now it is necessary to account for quality in the distribution of cut. It makes very little sense to cut acceptable growing stock (AGS) in one size class, while leaving unacceptable growing stock (UGS) in another simply to meet the structure goal. The importance of recording the AGS/UGS during the inventory is apparent, because we strive to remove all UGS in thinning. So, an adjustment may be needed for quality. Begin by comparing the UGS present in the stand with the cut goal just calculated.

Compare CUT (Col. 6) with UGS (Col. 7)

CUT > UGS -- cutting AGS

CUT < UGS -- leaving UGS

38. For any size class, if the value for the cut, column 6, is larger than the UGS, column 7, then all of the UGS in that size class is scheduled for removal in addition to the AGS that is cut. If on the other hand the cut is less than the UGS, then UGS is left in that size class.



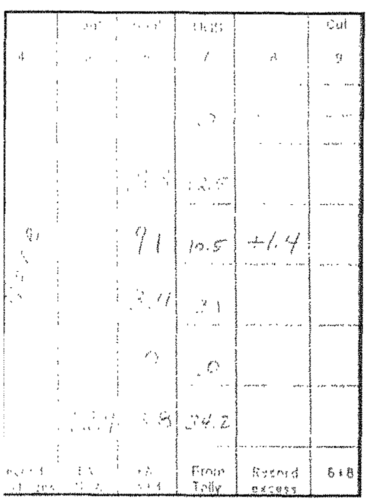
39. For example, in the sample stand we plan to remove 21.3 relative density units from the pole class. There is 12.5 relative density units of UGS in that class. So, all of the UGS will be cut along with some acceptable growing stock poles as well.

We also plan to remove 9.1 relative density units from the small sawtimber class. But there are 10.5 in UGS, which is more than the cut. So, this would leave some UGS in the small sawtimber class after the cut while cutting AGS in the pole class. In such instances, the cut should be increased in the small sawtimber class to remove all the UGS there, and the cut in the pole class should be reduced by a similar amount to compensate.

Distributions of Quality

- Remove all UGS
- Entire cut is UGS
- Cut AGS, leave UGS

40. Three situations can exist in our initial plan for cutting that is based on structure alone. If the stand is of high quality, that is, the cut removes all of the UGS in every size class, then there are no problems, and there is no adjustment to be made. If the stand is uniformly poor and there is more UGS than can be cut in every size class, then the entire cut in every size class is UGS and again there is no adjustment needed. In such stands, it may take more than one cut to remove all the UGS. But some stands will have UGS being left in one class, while AGS is being cut in other classes. It is in this situation that an adjustment can be made.



41. To make this adjustment, compare columns 6 and 7; if there is more UGS in any size class than that which is being cut from the class, record the excess in column 8.

This stand does have some excess UGS in the small sawtimber, while AGS is being cut in poles and medium sawtimber, so an adjustment is possible. There is only one class, the small sawtimber class, where UGS is being left uncut. Take all of them; that is, increase the cut in that class by 1.4. Record this adjustment with a positive sign since we are increasing the cut. If you increase the cut in the small saw size class, then you need to decrease the cut in other classes so that the total being removed is not changed.

BALANCE:

Increase cut of UGS

Reduce cut other classes

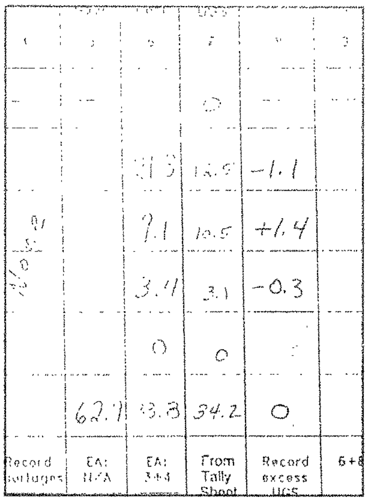
42. This adjustment is a balancing act which can be done using common sense by adding some to one class and taking away some from another class or by doing it in proportion to the percentages of cut recorded in column 2. The computer program redistributes the cut using those proportions; in most situations the differences in the adjustment procedure between the common sense procedure and the mathematical procedure will be minimal. Increasing the cut in a class to remove more UGS, requires a decrease of the cut in another class to compensate. As a rule, decrease the cut in a class where we were removing AGS.

	Goal	Goal	Original UGS		
4	5	6	7	8	9
			0		
		21.3	12.5		
[illegible]		9.1	10.5	+1.4	
		3.4	3.1	-0.3	
		0	0		
	62.9	33.8	34.2		
Record [illegible]	EA: N.A.	EA: [illegible]	From Tally	Record [illegible]	

43. The medium sawtimber has the potential for value increase, so in this stand reduce the cut in that class. But reducing the cut by the whole 1.4 relative density percent would result in the same predicament: leaving UGS in the medium sawtimber class. So, reduce the cut as much as possible. Reducing it by 0.3 avoids cutting any AGS, but gets all the UGS. Since you are reducing the cut, record a negative 0.3 for this class.

Adjust	Residual Goal	Cut Goal	Original UGS	Adjust	Total Cut
4	5	6	7	8	9
			0		
		21.3	12.5	-1.1	
[illegible]		9.1	10.5	+1.4	
		3.4	3.1	-0.3	
		0	0		
	62.9	33.8	34.2		
Record	EA:	EA:	From	Record	6

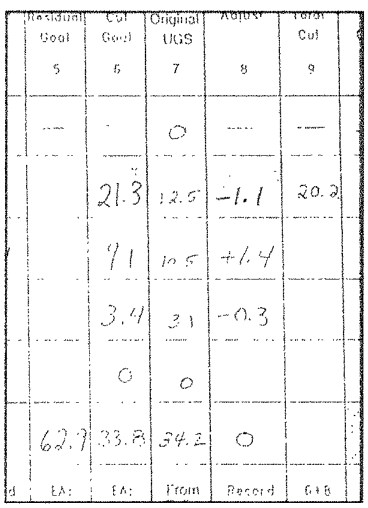
44. That leaves 1.1 relative density units, and the only other class that can be adjusted is the pole class. So, reduce the cut by 1.1 in the poles.



45. The bookkeeping works out, since the adjustments written in column 8 sum to zero.

More UGS than you can get in one cut?

46. Some stands will have so many UGS that you cannot get them all in one cut. If that is so, make as many adjustments as possible (so that you are not cutting AGS in any class), and do not worry about the rest. Just cross out the excess UGS and write down as much as you actually can remove. The procedures to make the adjustment in this situation are described in detail in Appendix A.



47. Make these adjustments by adding or subtracting (as the sign in column 8 indicates) the values in column 8 to the cut goal values in column 6. Record the result in column 9, the total cut. For this example, reduce the pole cut of 21.3 by 1.1, leaving an adjusted pole cut of 20.2.

Goal	Goal	Original UGS		Cut
5	6	7	8	9
---	--	0	---	---
	21.3	12.5	-1.1	20.2
	9.1	10.5	+1.4	10.5
	3.4	3.1	-0.3	3.1
	0	0		0
62.9	33.8	34.2	0	
EA:	EA:	From Tally	Record	6+8

48. Repeat this for the other size classes resulting in total cuts of 10.5 in the small sawtimber and 3.1 in the medium sawtimber.

Goal	Goal	UGS		Cut	Cut
5	6	7	8	9	10
		0			----
	21.3	12.5	-1.1	20.2	
	9.1	10.5	+1.4	10.5	
	3.4	3.1	0.3	3.1	
	0	0		0	
62.9	33.8	34.2	0	33.8	
EA:	EA: 3+4	From Tally	Record excess	6+8	9/1

49. Be sure that the total cut shown in column 9 is the same as the cut goal in column 6. It is, within rounding, so the adjustments have not changed the residual density; the first priority, density control, has been maintained. This ends the distribution of cut calculations.

Phases of Distribution of Cut Procedures

- Prepare worksheet and determine density and structure
- Adjust the structure to fit distribution of actual stand
- Adjust the planned cut to remove maximum proportion of UGS
- Translate planned cut to marking guides

50. In Phase IV all that remains is to translate this cut into marking ratios that can be used as guides by the marking crew.

% CUT =

CUT / ORIGINAL

51. The figures just calculated are not easily used as a marking guide. It would be a difficult task to go out and mark 20.3 relative density units per acre from the pole class. So, we convert the density values to percentage and finally to marking ratios that are easy to use. For each size class, first calculate the percentages of the original stand density to be removed, by dividing the cut density in column 9 by the original density in column 1. Multiply by 100 to convert to a percentage and record that value in column 10. This is the percentage of the actual density or basal area in each size class to be cut.

% Pole CUT =

20.2 / 32.7 = .62

or 62%

52. For example, in the pole class, cutting 20.2 relative density units from the original 32.7, means we will remove 62 percent of the original density.

Size Class	Original Stand 1	Goal % 2		Total Cut 9	% Cut 10	Cut Ratio 11
plings	13.0	0		--	--	—
les	32.7	63	1	20.2	62	
mall Sawtimber	32.8	27	4	10.5		
edium Sawtimber	12.1	10	3	3.1		

53. On the form, calculate the percentage cut by dividing the cut by the original and record this percentage of the pole class being cut in column 10.

	Stand 1	% 2	#	Total Cut 9	% Cut 10
	13.0	0		—	—
	32.7	63	1	20.2	62
ber	38.8	27	4	10.5	27
imber	12.1	10	3	3.1	26
ber	0.1	0		0	0
	96.7			33.8	
	From	%	ard	6+8	9/1

54. Repeat by size class, and record these values in column 10. For the example, the values are 27 percent of the small sawtimber class and 26 percent of the medium sawtimber class.

Cut Goal 5	Original UGS 7	Adjust 8	Total Cut 9	% Cut 10	Cut Ratio 11	Original Stand 12	Cut 13
—	0	—	—	(62/100)		11.1	—
21.3	12.5	-1.1	20.2	62	3/5	37.4	
9.1	10.5	+1.4	10.5	27		73.1	
3.4	3.1	0.3	3.1	26		35.8	

55. Percentages are easier to implement than actual amounts of relative density, but they are still somewhat difficult to manage. Further simplify these percentages by converting the percentage to a cut ratio. Convert the percentage being cut, column 10, to a ratio (that is, cut percent over 100 and reduce the fraction) for use by the marking crew. Enter the ratio in column 11. For example, cutting 62 percent of the poles, is the equivalent of removing 62/100, which can be reduced to approximately 3/5 of the poles. The marking guide then, is to remove 3 out of 5 poles in this cut to achieve the desired density, structure, and quality distribution.

8	9	10	11	12
—	—	—	—	11.1
-1.1	20.2	62	3/5	37.4
+1.4	10.5	27	1/4	73.1
-0.3	3.1	26	1/4	35.8
	0	0	0	0.5
0	33.8			158.0
Record excess UGS	6+8	9/1		From Tally Sheet

56. Repeat this for each size class. The recommendation is to remove 1 of every 4 small sawtimber and 1 of every 4 medium sawtimber trees.

	Total Cut	% Cut	Cut Ratio	Original Stand	Cut	Resid
	9	10	11	12	13	1
	—	—	—	11.1	—	
1	20.2	62	3/5	37.4	23.2	
4	10.5	27	1/4	73.1		
3	3.1	26	1/4	35.8		
	0	0	0	0.5		
	33.8			158.0		
	6+8	9/1		From	10*12	12

57. A ratio of 3 in 5 means that you should remove 3 out of every 5 trees of that size class. Within any size class, it also means that you will remove 3/5 of the basal area in that size class. Thus, these ratios can be used for marking without tallying the total actual basal area or relative density. But, the markers might like to use a prism to check residual basal area and verify that they are achieving the desired residual density. Or, you may wish to estimate the cut or residual stand averages. So, convert the relative density calculations back to basal area.

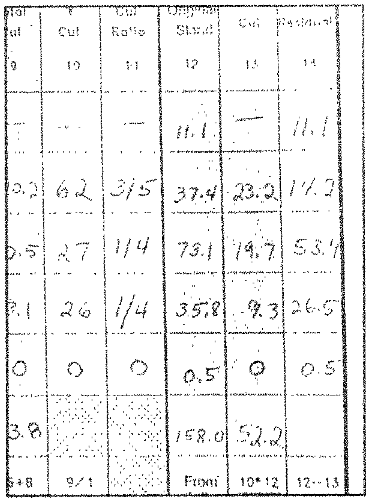
Calculate the basal area to be cut in each size class using the percent cut in column 10 and the original basal area in column 12. Record these values in column 13. For example, in the pole class, removing 62 percent of the 37.4 square feet of basal area means cutting 23.2 square feet.

Cut	Cut	Ratio	Stand		
9	10	11	12	13	14
—	—	—	11.1	—	
20.2	62	3/5	37.4	23.2	
10.5	27	1/4	73.1	19.7	
3.1	26	1/4	35.8	9.3	
0	0	0	0.5	0	
33.8			158.0		
6+8	9/1		From Tally	10*12 / 100	12-13

58. Calculate the cut basal area for the remaining size classes. For the example stand, the figures are 19.7 square feet from the small sawtimber class and 9.3 square feet from the medium sawtimber class.

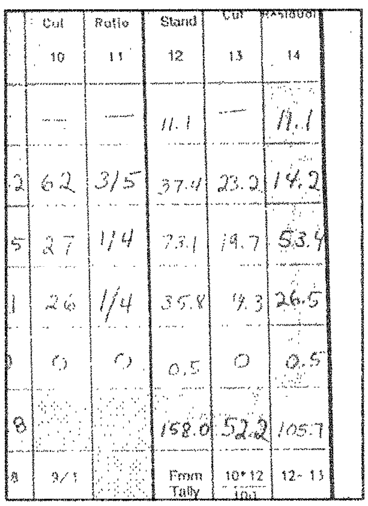
—	—	—	11.1	—	
20.2	62	3/5	37.4	23.2	
10.5	27	1/4	73.1	19.7	
3.1	26	1/4	35.8	9.3	
0	0	0	0.5	0	
33.8			158.0	52.2	
6+8	9/1		From Tally Sheet	10*12 / 100	12-13

59. The sum of the five size classes is the total basal area cut. These basal area values can be converted to volumes using the conversion factors from the Overstory Manual Summary worksheet (Appendix D), as was done for the original stand.



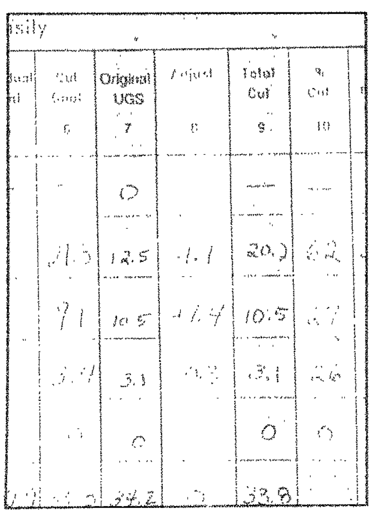
Total Cut 9	% Cut 10	Cut Ratio 11	Original Stand 12	Cut 13	Residual 14
—	—	—	11.1	—	11.1
2.2	62	3/5	37.4	23.2	14.2
0.5	27	1/4	73.1	19.7	53.4
3.1	26	1/4	35.8	9.3	26.5
0	0	0	0.5	0	0.5
3.8			158.0	52.2	
6+8	9/1		From	10*12	12−13

60. Calculate the residual basal area by subtracting the cut basal area, column 13, from the original basal area, column 12, and enter these values in column 14.



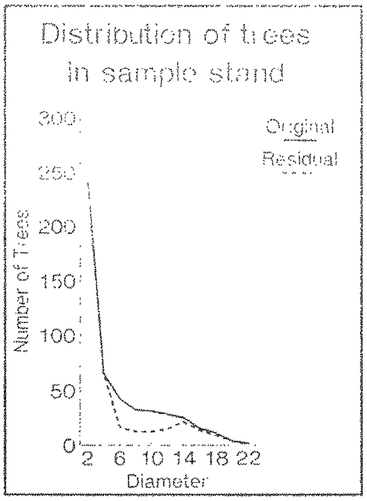
% Cut 10	Ratio 11	Stand 12	Cut 13	Residual 14
—	—	11.1	—	11.1
62	3/5	37.4	23.2	14.2
27	1/4	73.1	19.7	53.4
26	1/4	35.8	9.3	26.5
0	0	0.5	0	0.5
		158.0	52.2	105.7
9/1		From Tally	10*12 (10)	12−13

61. Again, sum the values in column 14 to get the total residual basal area.



Cut Good 6	Original UGS 7	Adjust 8	Total Cut 9	% Cut 10
—	0		—	—
21.5	12.5	-1.1	20.2	62
7.1	10.5	+1.4	10.5	27
3.4	3.1	[illegible]	3.1	26
0	0		0	0
[illegible]	34.2	[illegible]	33.8	

62. One additional piece of useful information is a comparison of the total cut in column 9 with the UGS in column 7. In the example, just about all of the cut in the sawtimber sizes will be UGS and about half of the poles will be UGS. So, our cut in this stand will clean up the sawtimber by removing most of the UGS, and hitting the poles fairly hard, including removing some good quality poles.



63. These data provide a basis on which to judge the proposed cut and its effect on the residual stand. Implementing such a cut, would remove most of the pole size class from this stand and start creating a desired bell-shaped curve in the small and medium sawtimber sizes. The residual stand would be dominated by good quality trees in the small and medium sawtimber sizes where we want to concentrate the growth. And because we have thinned throughout all size classes and opened the crown canopy, we should increase the growth on these residual trees.

It is possible to try a variety of cutting alternatives, and evaluate the impact on volumes to be cut, and residual stand characteristics. This provides a powerful means of testing alternative cutting schemes, in addition to providing guidance for stand marking to ensure that the prescription is applied to the stand in the manner intended.

Selected References

Ernst, Richard L.; Stout, Susan L. 1991. Computerized algorithms for partial cuts. In: McCormick, Larry H.; Gottschalk, Kurt W., eds. Proceedings. 8th central hardwood forest conference.; 1991 March 3-6; University Park, PA. Gen. Tech. Rep. NE-148. Radnor, PA: U. S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station: 132-147.

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Roach, Benjamin A. 1977. A stocking guide for Allegheny hardwoods and its use in controlling intermediate cuttings. Res. Pap. NE-373. Upper Darby, PA: U. S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 30 p.

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APPENDIX A

Distribution Of Cut

In any partial cutting, trees should be selected for cutting or retention to achieve the desired density, structure, and quality in the residual stand. The desired structure, in particular, varies with the type of partial cutting prescribed. To decide which trees should be cut, use the following guidelines.

First priority is to maintain the desired residual stand density. Second priority is to remove all unacceptable growing stock trees before better quality trees are cut. And third priority is to cut so as to achieve the desired stand structure (size-class distribution). Species composition--a factor in both stand quality and structure--may also be altered by cutting. All else being equal, stand markers should generally favor the most valuable species, or with all-aged cuttings, the most valuable shade-tolerant species. However, no special consideration is given to species composition in distributing the cut, since the procedure used automatically favors the larger trees, which are usually the more valuable species in the stand.

In selection cuts and thinnings, residual stand density should be 60 percent, except where this would mean removal of more than 35 percent of the relative density in one cut. In these cuts, residual stand density should be 65 percent of the existing density. Residual densities in even-aged regeneration cuts are not subject to the above limitation. Seed cuts should be made to leave the prescribed 50 or 60 percent relative density regardless of how much must be removed to achieve it. The first harvest cut of a three-cut shelterwood should likewise reduce relative density to 30-35 percent all at one time to achieve desired results.

Stand structure goals in thinnings and shelterwood cuts are achieved indirectly. We do not know exactly what stand structure we should try to create in these mixed hardwood stands, many of which do not exhibit the textbook type of even-aged bell-shaped curve. So, we attempt to move the structure toward the theoretical ideal by cutting more heavily from the smaller trees than the larger ones. This increases stand diameter, reduces time to maturity, and reduces the diversity of diameter classes present, altering the distribution of diameters toward a bell-shaped curve without assuming any particular curve as ideal. A table showing the proportion of the cut that should come from each major size class is used to distribute the cut (Appendix B). The values in this table were calculated using the assumption that two-thirds of the cut basal area (three-fourths of the cut relative density) should come from below the stand diameter, and the rest from above the stand diameter.

Stand structure goals are achieved in selection cuttings by setting up a residual structure goal based on the maximum tree size, q factor, and residual density prescribed. A table of appropriate goals are used for this purpose (Appendix B). Then, any trees that are in excess of those goals (within each major size class) are cut. However, no saplings are cut--the structure goals are set up so as to exclude saplings and achieve the desired structure within the merchantable size classes only.

Quality goals are achieved as an adjustment to the structural goal. After the initial structural goal for a thinning, shelterwood cut, or selection cutting has been established, the goal is compared, by size class, with the inventory data on tree quality. If acceptable quality trees are being cut in one size class while unacceptable quality trees are being left in another, an adjustment that does not alter the residual density is made.

In commercial thinnings, a minor deviation from the procedure above is made in those stands that contain substantial amounts of large sawtimber (trees 24 inches and larger). Since such trees are generally mature, up to 50 percent of them may be removed, allowing more of the smaller sawtimber sizes that are increasing more rapidly in value to remain.

The distribution of cut for commercial thinnings assumes that there is adequate volume of both sawtimber and pulpwood, to make a sale involving both products feasible. In cases where sawtimber volumes are limited and the sale is to include only pulpwood, a redistribution of cut should be made. The density of good quality (AGS) sawtimber that would have been removed should be taken instead from the poletimber-size class.

The stand diameter to be used in the distribution of cut depends upon the prescription. In combined TSI-Commercial Thinnings, sapling-size trees are to be cut, so the diameter of the entire stand (MD) is the appropriate one to distribute the cut around. In commercial thinnings, and shelterwood cuts, no saplings are cut, so the diameter of only the merchantable-size trees (MDM) is used.

The cut in Precommercial Thinnings and Thin-Harvests is not distributed as above, but is special. Since no commercial sale is involved in a Precommercial Thinning, cutting occurs strictly from the unacceptable growing stock, the noncommercial species, and the smallest trees in the stand. No merchantable trees of good quality are cut, since this might reduce total stand yield over the long term.

In Thin-Harvests, the cutting is very heavy in the large sawtimber and poletimber size classes. Such stands are within 15 years of maturity; the poles will not grow into valuable sawtimber size before final harvest so there is little reason to save them. The large sawtimber trees are already mature and might as well be harvested. This preserves for the final harvest the maximum number of small and medium sawtimber trees that are increasing in value most rapidly.

In all partial cuttings, unacceptable growing stock trees are removed first, even if this means that the structure goals cannot be met. Within this limit, the cutting is done so as to come as close to the desired structure as possible. Mechanics of distributing the cut follow.

Instructions for Distribution of Cut

The overstory data and guidelines on partial cutting can be used to calculate how much of each size and quality class should be cut to achieve the prescribed effect. This distribution of cut provides the information that timber markers need to achieve the desired structure in the residual stand. The calculations can be done by computer or by hand, using the Distribution of Cut Worksheet (Appendix C). Calculations for intermediate cuttings under even-aged silvicultural systems and those for selection system cuts are made using the same worksheet. The steps described below are easiest to follow if Appendix C is consulted as an example.

The distribution of cut occurs in four major phases. The first is selection of stand density and structure parameters based on the prescription selected. Next, structure parameters are adjusted to fit the actual size distribution in the particular stand. This step is slightly different for even-age and all-age prescriptions. The third phase adjusts the structure once again to remove the maximum proportion of UGS possible within the relative density constraints already established. The final phase translates the result into marking guides (ratios), and into basal area for cut and residual stands. We recommend carrying these calculations to one decimal place.

In Phases I, II and III there are several alternate paths, depending on the prescription and conditions in the particular stand. In the explanations below, these alternate paths are written in smaller type; be certain to select the appropriate path from the several alternatives listed. The several choices are identified by statements that begin: ***"If this is a . . ."*** or ***"If the total of Column 6 is . . ."***.

Phase I. Prepare worksheet and determine density and structure parameters.

1. *Transfer the original relative density* from the Manual Overstory Summary Form (Appendix D)(totals block in the lower right corner) to Column 1, Distribution of Cut Form (Appendix C), for each size class and for the total. Include saplings, even if none are to be cut.

2. *Transfer UGS relative density* from the Manual Overstory Summary form (summary block of the UGS section, near the center right) to Column 7, Distribution of Cut Form.

> If there will be no cutting in the sapling class, . . .
> . . . record no saplings.
>
> If this is the seed cut of a shelterwood sequence, and the stand contains 5 or more square feet of basal area per acre in noncommercial saplings and poles, . . .
> . . . include these noncommercial sapling UGS in Column 7.
>
> **If there will be cutting in the sapling class, . . .**
> . . . record sapling UGS.

3. *Total the UGS recorded.*

4. *Transfer the original basal area per acre* from Manual Overstory Summary form (total block in the lower right hand corner) to Column 12, Distribution of Cut Form, for each size class and for the total.

5. *Determine the residual density for this treatment.*

> If this is a thinning or selection cut . . .
> . . . multiply the original relative density (Total, Column 1) by 0.65. If this number is 60% or more, record it in the total row of Column 5. If it is less than 60%, record 60%.
>
> **If this is a shelterwood seed cut in an area with moderate to high deer pressure, . . .**
> . . . record 60%.
>
> **If this is a shelterwood seed cut in an area with low deer pressure, . . .**
> . . . record 50%.
>
> **If this is the second cut (first removal cut) of a three-cut shelterwood** sequence, . . .
> . . record 35%.

Record the desired residual density in the Total row, Column 5.

6. *Determine the density to be removed in this treatment.* Subtract the desired residual density (Total, Column 5) from the original relative density (Total, Column 1). Record this value in the Total row, Column 6.

7. *Determine the size class distribution for this treatment.* Copy the goal percents for each size class from Appendix B (Cut relative density to come from and relative density to be retained in various size classes, in percent) to Column 2, Distribution of Cut Form, by size classes. Use the line on Appendix B for the appropriate prescription and stand diameter. Record the percents as proportions; that is, divide each by 100 and record.

Phase II. Adjust the structure to fit the size class distribution of the actual stand.

If this is an even-aged treatment .

1. Multiply the proportions in Column 2 by the Cut Density in the Total Row of Column 6. Record these values in Column 3.

2. Total Column 3 to be certain that the total cut goal is the same as the Total of Column 6.

3. For each size class, subtract the values in Column 3 (density to be cut) from the values in Column 1 (original density). Record only negative answers in Column 4.

If there are no negatives, . . .
. . . copy the numbers from Column 3 to Column 6 and proceed to **Phase III.**

If there are negatives, . . .
. . . an adjustment is required. Negatives occur in Column 4 when the original stand has less density in a particular size class than the planned cut. Increase the cut in other classes by writing positive numbers in those rows where the cut is to be increased. Make these increases in the smaller size classes to the extent possible. Do not increase the cut in any size class to more than is available (the value in Column 1).

Check to be sure that the adjustments balance; that is that the sum of the positive and negative numbers in Column 4 is zero.

Calculate the adjusted cut for each size class by summing Column 3 and Column 4. Record the answers in Column 6. Check to be certain that the total of the values in Column 6 equals the total already written there. Proceed to **Phase III.**

If this is an all-aged treatment . . .

1. Since no saplings will be cut in these treatments, transfer the original relative density of the sapling class from Column 1 to Column 3.

2. Determine the residual density of the merchantable size classes by subtracting the sapling density from the total Residual Density (Total, Column 5). Record the answer in the space above Column 3.

3. Determine the distribution of this merchantable residual among the size classes. Multiply the proportions already written in Column 2 by the merchantable residual above Column 3. Record each answer in the appropriate size class in Column 3.

4. Total Column 3 and be certain that the total residual goal is the same as the total of Column 5.

5. For each size class, compare the planned residual structure with the existing structure by subtracting the values in Column 3 from the values in Column 1. Record negatives only in Column 4.

If there are no negatives,. . .
. . . the cut can be implemented as planned. Copy the values for each size class in Column 3 to Column 5, Residual Goal. Calculate the Cut Goal by subtracting Column 5 from Column 1 for each size class. Record the answers in Column 6. Proceed to Phase III.

If there are negatives, . . .
. . . an adjustment is required. Negatives in Column 4 reflect deficiencies in the current stand compared to the desired residual. Increase the residual in other classes to ensure that the correct residual density is left. Do not increase the residual in any class above the density in the original stand, or the value in Column 1. Record increases as positive numbers in Column 4. In general, increase the residual in smaller classes. The best trees in these classes will grow faster and smooth out the deficiencies prior to the next cut.

Be certain that the adjustments balance; that is, that the sum of the positive and negative numbers in Column 4 is zero.

Determine the actual residual goal by summing the initial goal in Column 3 and the adjustments in Column 4 for each size class. Record the answers in Column 5. Be certain that the sum of the values in Column 5 is equal to the total already written there.

Determine the cut goal for each size class by subtracting Column 5 from Column 1 and recording the answers in Column 6. Proceed to Phase III.

Phase III. Adjust the planned cut to remove the maximum proportion of UGS from the stand within established density constraints.

1. *Determine the quality effects of the planned cut.* Subtract the original relative density of UGS (Column 7) from the planned cut (Column 6). Record the answers in Column 8. Positive values in Column 8 represent AGS being cut, and negative values represent UGS being left in the stand.

2. *Determine whether an adjustment is required and possible.*

If all the answers have the same sign (positive or negative), . . .
. . . adjustment is either not required or not possible. Copy all values from Column 6 to Column 9 and proceed to **Phase IV**.

If some of the differences are positive and some negative, . . .
. . . an adjustment to increase the UGS removed is required. The nature of the adjustment depends on the totals of Column 6 and Column 7.

3. *Make the adjustment, if required.*

If the total of Column 6 is greater than the total of Column 7 (that is, the planned cut exceeds the UGS) . . .

1. Erase or strike out the positive numbers in Column 8.

2. Change the negative numbers to positives. Because the relative density of the planned cut exceeds the relative density of UGS in Column 7, all the UGS in Column 7 can be removed in this treatment. The numbers just made positive represent increased cuts in those classes where UGS were to be left.

3. Decrease the cut in the remaining classes to balance the increases recorded in Step 2. Record the decreases as negative numbers in Column 8. Be sure not to decrease the cut so far as to leave UGS in these classes--that is, be certain that Column 6 minus your adjustment in Column 8 is greater than or equal to the value in Column 7.

4. Be certain that the adjustment is balanced; that is, that the sum of the positive and negative numbers in Column 8 is zero.

5. Determine the adjusted cut by summing the values in Column 6 and the values in Column 8 for each size class. Record the answers in Column 9. Be certain that the sum of Column 9 equals the Total, Column 6. Proceed to **Phase IV.**

If the total of Column 6 is less than the total of Column 7 (that is, the UGS exceed the planned cut) . . .

1. Erase or strike out the negative numbers in Column 8.

2. Change the positive numbers to negatives. Because the relative density of the UGS exceeds the planned cut, the entire cut should be UGS. The numbers just made negative represent decreased cuts in those classes where AGS were to be cut.

3. Increase the cut in the remaining classes to balance the decreases recorded in Step 2. Record the increases as positive numbers in Column 8. Be sure not to increase the cut in any size class so far as to cut AGS in that class; that is, be certain that the sum of Column 6 plus these adjustments in Column 8 is less than or equal to the value in Column 7 for each size class.

4. Be certain that the adjustment is balanced; that is, that the sum of the positive and negative numbers in Column 8 is zero.

5. Determine the adjusted cut by summing the values in Column 6 and the values in Column 8. Record the answers in Column 9. Be certain that the sum of Column 9 equals the total of Column 6. Proceed to **Phase IV.**

Phase IV. Translate the planned cut to a marking guide and to basal area.

1. *Calculate the percent cut* in each size class: Divide Column 9 by Column 1 and multiply by 100. Record the answers in Column 10.

2. *Determine the cut ratio* by translating the percents in Column 10 to proportions and reducing these to simple fractions. For example, if 52% of the poles are to be cut, this is the same as 52/100, which can be reduced to approximately 1/2 of the poles. Avoid fractions finer than 5ths. Record the ratios in Column 11.

3. *Determine the cut basal area* for each size class by multiplying the percents in Column 10 times the basal areas in Column 12 and dividing by 100. Record these values in Column 13. The sum of these values is the total basal area cut. These values can be converted to crude volumes using the basal area factors from the Manual Overstory Summary Form (Appendix D).

4. *Determine the residual basal areas* for each size class by subtracting the cut values in Column 13 from the original stand values in Column 12. Record the answers in Column 14.

The distribution of cut ratios described above are all calculated automatically by the computer program, and they are printed in the narrative section of the computer printout as marking instructions. Data on the residual and cut stands are also included.

APPENDIX B

Cut relative density to come from and relative density to be retained in various size classes, in percent.

DIAMETER	SAPS	POLES	SSAW	MSAW	LSAW[1]
	EVEN-AGE SILVICULTURE CUT RELATIVE DENSITY TO COME FROM VARIOUS SIZE CLASSES				
MDM	Commercial Thinning and Shelterwood Cutting[2]				
8	--	100	0	0	0
9	--	96	4	0	0
10	--	88	12	0	0
11	--	81	19	0	0
12	--	74	24	2	0
13	--	68	26	6	0
14	--	63	27	10	0
15	--	58	28	13	1
16	--	54	28	14	4
17	--	51	27	15	7
MD	Combined TSI - Commercial Thinning				
4	91	9	0	0	0
5	82	18	0	0	0
6	74	26	0	0	0
7	67	29	4	0	0
8	61	30	9	0	0
9	55	31	14	0	0
10	51	31	15	3	0
	Precommercial Thinning				
--	100	0	0	0	0
	Thin-Harvest				
--	--	50	5	15	30[3]
	ALL-AGE SILVICULTURE RELATIVE DENSITY TO BE RETAINED IN VARIOUS SIZE CLASSES				
	Standard Selection Cutting (Mgmt Code 3)				
	--[4]	41	37	22	0
	Single-tree Selection Cutting with Maximum Large Trees (Mgmt Code 4)				
	--[4]	22	30	27	21

[1] For commercial thinning only, take up to 50% of original density in large saws and adjust other sizes proportionally.
[2] Note that shelterwood cuts being made in stands that contain 5 or more square feet of basal area per acre in noncommercial (UGS) saplings and poles should include removal of all noncommercial stems (usually by injection with an herbicide) even though no other cutting will occur in the sapling class.
[3] For thin-harvest only, take up to 75% of original density in large saws and adjust other sizes proportionally.
[4] In all-age cuts, all existing sapling density is retained.

Source: Marquis, David L.; Ernst, Richard L.; Stout, Susan L. 1991. Prescribing silvicultural treatments in hardwood stands of the Alleghenies (revised). Gen. Tech. Rep. NE-96. Radnor, PA: U. S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 101 p.

SILVAH - Distribution of Cut Worksheet

Stand ID

	Relative Density											Basal Area		
Size Class	Original Stand	Goal %	Initial Goal	Adjust	Residual Goal	Cut Goal	Original UGS	Adjust	Total Cut	% Cut	Cut Ratio	Original Stand	Cut	Residual
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Saplings														
Poles														
Small Sawtimber														
Medium Sawtimber														
Large Sawtimber														
Total														
	From Tally Sheet	% from Table 6	All- or Even-aged ?	Record shortages / BALANCE	EA: N/A / AA: 3+4	EA: 3+4 / AA: 1-5	From Tally Sheet	Record excess UGS / BALANCE	6+8	9/1		From Tally Sheet	10*12 / 100	12-13

SILVAH - Distribution of Cut Worksheet

USDA, Forest Service, NEFES, Warren, PA 1/91

Stand ID Comp 171, Stand 23 - Commercial Thinning

Size Class	Relative Density: Original Stand 1	Goal % 2	Initial Goal 3	Adjust 4	Residual Goal 5	Cut Goal 6	Original UGS 7	Adjust 8	Total Cut 9	% Cut 10	Cut Ratio 11	Basal Area: Original Stand 12	Cut 13	Residual 14
Saplings	13.0	0	—	—	—	—	0	—	—	—	—	11.1	—	11.1
Poles	32.7	63	21.3			21.3	12.5	-1.1	20.2	62	3/5	37.4	23.2	14.2
Small Sawtimber	38.8	27	9.1	None		9.1	10.5	+1.4	10.5	27	1/4	73.1	19.7	53.4
Medium Sawtimber	12.1	10	3.4			3.4	3.1	-0.3	3.1	26	1/4	35.8	9.3	26.5
Large Sawtimber	0.1	0	0			0	0		0	0	0	0.5	0	0.5
Total	96.7		33.8		62.9	33.8	26.1	0	33.8			158.0	52.2	105.7
	From Tally Sheet	% from Table 6	All- or Even-aged ?	Record shortages / BALANCE	EA: N/A / AA: 3+4	EA: 3+4 / AA: 1-5	From Tally Sheet	Record excess UGS / BALANCE	6+8	9/1		From Tally Sheet	10*12 / 100	12-13

SILVAH - Manual Overstory Summary

Stand ID

USDA, Forest Service, NEFES, Warren, PA 1/91

AGS		BC-WA-YP			RM-NRO-EH-Oth			SM-AB-StM-OO			All Species AGS		
Size class		BA	RD	BdFt	BA	RD	BdFt	BA	RD	BdFt	BA	RD	BdFt
Saplings	value												
	f		1.44			1.21			1.17				
Poles	value												
	f		0.60			0.76			0.99				
Small Saws	value												
	f		0.39	84		0.57	64		0.94	64			
Medium Saws	value												
	f		0.31	128		0.49	106		0.92	106			
Large Saws	value												
	f		0.27	148		0.44	120		0.91	120			
All Sizes AGS	value												

UGS		BC-WA-YP			RM-NRO-EH-Oth			SM-AB-StM-OO			All Species UGS		
Size class		BA	RD	BdFt	BA	RD	BdFt	BA	RD	BdFt	BA	RD	BdFt
Saplings	value												
	f		1.44			1.21			1.17				
Poles	value												
	f		0.60			0.76			0.99				
Small Saws	value												
	f		0.39	42		0.57	32		0.94	32			
Medium Saws	value												
	f		0.31	64		0.49	53		0.92	53			
Large Saws	value												
	f		0.27	74		0.44	60		0.91	60			
All Sizes UGS	value												

Multiply factor (f) by basal area (BA)

AGS + UGS		All Species							
Size class		MDM	MD	BA*f	BA*f	Cords	BA	RD	BdFt
Saplings	value								
	f				3.0		4		
Poles	value								
	f			8.5	8.5	0.18			
Small Saws	value								
	f			14.5	14.5	0.22			
Medium Saws	value								
	f			20.5	20.5	0.24			
Large Saws	value								
	f			26.5	26.5	0.28			
All Sizes	value	1/(3-4)	2/3	1	2		3		

SILVAH - Manual Overstory Summary

Stand ID

USDA, Forest Service, NEFES, Warren, PA 1/91

AGS Size class		BC-WA-YP BA	BC-WA-YP RD	BC-WA-YP BdFt	RM-NRO-EH-Oth BA	RM-NRO-EH-Oth RD	RM-NRO-EH-Oth BdFt	SM-AB-StM-OO BA	SM-AB-StM-OO RD	SM-AB-StM-OO BdFt	All Species AGS BA	All Species AGS RD	All Species AGS BdFt
Saplings	value	0	0		1.0	1.2		3.2	3.7		4.2	4.9	
	f		1.44			1.21			1.17				
Poles	value	3.1	1.9		9.0	6.8		11.6	11.5		23.7	20.2	
	f		0.60			0.76			0.99				
Small Saws	value	30.0	11.7	2520	19.5	11.1	1248	5.8	5.5	371	55.3	28.3	4139
	f		0.39	84		0.57	64		0.94	64			
Medium Saws	value	25.8	8.0	3302	2.1	1.0	227	0	0	0	27.9	9.0	3529
	f		0.31	128		0.49	106		0.92	106			
Large Saws	value	0.5	0.1	74	0	0	0	0	0	0	0.5	0.1	74
	f		0.27	148		0.44	120		0.91	120			
All Sizes AGS	value	59.5	21.7	5896	31.6	20.1	1475	20.6	20.7	371	111.6	62.5	7742

UGS Size class		BC-WA-YP BA	BC-WA-YP RD	BC-WA-YP BdFt	RM-NRO-EH-Oth BA	RM-NRO-EH-Oth RD	RM-NRO-EH-Oth BdFt	SM-AB-StM-OO BA	SM-AB-StM-OO RD	SM-AB-StM-OO BdFt	All Species UGS BA	All Species UGS RD	All Species UGS BdFt
Saplings	value	0	0		1.1	1.3		5.8	6.8		6.9	8.1	
	f		1.44			1.21			1.17				
Poles	value	0.5	0.3		3.7	2.8		9.5	9.4		13.7	12.5	
	f		0.60			0.76			0.99				
Small Saws	value	6.8	2.7	286	6.8	3.9	218	4.2	3.9	134	17.8	10.5	638
	f		0.39	42		0.57	32		0.94	32			
Medium Saws	value	4.7	1.5	301	3.2	1.6	173	0	0	0	7.9	3.1	474
	f		0.31	64		0.49	53		0.92	53			
Large Saws	value	0	0	0	0	0	0	0	0	0	0	0	0
	f		0.27	74		0.44	60		0.91	60			
All Sizes UGS	value	12.0	4.5	587	14.8	9.6	391	19.5	20.1	134	46.3	34.2	1112

Multiply factor (f) by basal area (BA)

AGS + UGS Size class		MDM	MD	BA*f	BA*f	Cords	All Species BA	All Species RD	All Species BdFt
Saplings	value				33.3		4 11.1	13.0	
	f				3.0				
Poles	value			317.9	317.9	6.7	37.4	32.7	
	f			8.5	8.5	0.18			
Small Saws	value			1060.0	1060.0	16.1	73.1	38.8	4777
	f			14.5	14.5	0.22			
Medium Saws	value			733.9	733.9	8.6	35.8	12.1	4003
	f			20.5	20.5	0.24			
Large Saws	value			13.2	13.2	0.1	0.5	0.1	74
	f			26.5	26.5	0.28			
All Sizes	value	1/(3-4) 14.5	2/3 13.7	2125.0 1	2158.3 2	31.5	158.0 3	96.7	8854

Marking Ratios and the SILVAH System

James C. Redding

The SILVAH stand analysis and prescription system provides a systematic procedure for collecting, summarizing, and analyzing stand data to arrive at an appropriate silvicultural prescription. If that prescription includes a partial cutting, the system also provides a way to quantify marking instructions. These instructions indicate the desired residual stand density and structure, and provide information on change in species composition and quality expected as a result of cutting.

The final, crucial step is to apply the carefully prepared prescription by marking the stand in the prescribed way. Improper marking wastes all of the time, effort, and considerable expense incurred in the stand inventory and analysis.

Most markers mark stands to a specific residual density and select trees for removal to improve tree spacing, total stand quality, and species composition. The SILVAH system adds another factor--control of stand structure to ensure that the cutting achieves its long-term objective within the framework of the particular silvicultural system being used. This control of stand structure is achieved by removing the desired density within specific tree size classes.

One of the field exercises in our silvicultural training sessions is a marking exercise. The class marks an actual stand and evaluates how close their marking comes to the prescribed density, structure, composition, and quality goals. Most people have difficulty in meeting the stand structure goals.

To improve marking to a prescribed structure, we have developed a procedure that uses cut ratios, by three or four major size classes. In this article, I describe how the ratios are applied, provide some hints on marking stands to a given prescription, and discuss some of the initial reactions to the use of marking ratios.

In the procedures for distributing the cut among size classes, and for calculating the marking ratios, figures are carried to the closet tenth of a square foot of basal area. Then we reduce those precise calculations to broad ratios--1:5 large sawtimber, or 2:3 poles -for marking. We spend time being precise because if you begin rounding off too soon, your ratios are likely to come out much differently due to the accumulation of errors caused by rounding. By not rounding the calculations until the last step, you know that the ratios are based on good, sound figures. The simpler ratio derived from these sound figures is easy to apply in the woods, and is adequately precise for marking.

Once learned and properly applied, use of the ratios considerably reduces the variation among markers. This is particularly important to large forestry organizations because personnel change frequently and continuity in marking quality is a concern.

USING THE RATIOS IN THE WOODS

Using the ratios in the woods is fairly simple. As you progress through the stand, stop at regular intervals and consider the circle of trees immediately around you. Decide which trees are best to leave for the final crop and which must be removed to achieve the residual density goal. Select for removal those trees that are of poor quality, poor risk, or those that are interfering with a better stem. In addition to these usual marking procedures, use the ratios to guide your selections of how many trees to remove in each broad size class.

Within the circle of trees you are considering, choose the best quality sawtimber to leave and using the ratios, mark the appropriate number of sawtimber trees to improve spacing, quality, and species composition of the residual stand. Do the same in the pole size classes. For example, if your ratio in poles is 2:3 and there are six poles in your area of consideration, choose the best two and mark the other four for removal. If you let your marking be guided by the ratios, you will achieve both the desired structure and the desired density in your residual stand.

These ratios automatically help you adjust your marking as conditions within the stand vary. For example, if your ratio in poles is 2:3, you will automatically mark heavier in spots where the poles are numerous, and you will mark lighter where there are fewer poles. The same is true of the other size classes.

But do not ignore traditional marking criteria. Use the ratios as a guide, not as an absolute rule. Cutting 2:3 poles simply means that you want to mark very heavily in the pole size class. Cutting 1:5 small sawtimber simply means that you really do not want to remove very many of that size class at all--mostly those of poor quality or those that must be removed to provide more room for a better tree of the same size.

For example, suppose you examine a circle of trees and find five small sawtimber trees of which two are such poor quality and/or spacing that they need to be removed even though your ratio only calls for taking 1:5. Also suppose your pole ratio is 2:3, and you find six poles of which only one is poor quality. By all means, take out the two poor-quality small sawtimber, and compensate by removing fewer poles. On the other hand, if all the poles are also of poor quality, adhere more closely to the ratios prescribed.

Do not try to compensate from one circle of trees to the next. If you find seven poles instead of six and the ratio is 2:3, mark either 4 or 5 poles, whichever seems most appropriate in terms of quality and spacing. But do not try to remember that you marked one too many or one too few and compensate for it in the next area of consideration--it is too confusing and unnecessary. So, use the ratios as a guide, not as a rigid rule, to determine how heavily you should cut in each size class. Add this guide to those you already use in marking, not as a substitute for the usual attention to quality and spacing.

INITIAL REACTIONS TO USE OF RATIOS

At first a seasoned marker using ratios will probably become frustrated by what seems to be needless complexity, and may return to their usual method of marking. If the prescription and timber type are similar to those with which you usually work, you will be close to what was prescribed anyway. However, if you are asked to mark a stand in a different manner to satisfy some different management goal, you may have a problem. If, for example, you are accustomed to marking even-age thinnings, and you are asked to mark a group-selection cut and do not apply cut ratios, you probably will not achieve the residual stand density goal and almost certainly will not achieve the intended stand structure. This happens when given a prescription you have never marked before because you have no idea what the residual stand should look like. Proper application of cut ratios overcome this problem.

The value of the system became clear to me when I marked a stand for a study designed to compare various management strategies with our traditional even-age strategies. The study consisted of twenty 5-acre plots marked to five very different prescriptions. The residual densities stayed about the same, but the stand structure and species composition changed dramatically. This gave the residual stand of each treatment a very different look even though all plots were cut to the same relative density.

I began marking an even-age thinning since I was used to that type of prescription, and tried to apply the ratios generated by the SILVAH program. I had marked timber on the national forest for a number of years using residual basal area as my guide. At first I resented being locked into the numbers by the new system. After marking one acre, I could not see much difference from what I usually marked, so I stopped using the ratios and finished marking the stand in the usual way. We had 100 percent inventories for each plot, so I could subtract what I had marked from what was there originally to see how close I met my target. In the even-age thinning, I was right on target even though I ignored the ratios for most of the marking.

Feeling confident, I moved onto the next 5-acre plot--an economic selection cut. After marking one acre of this treatment and ignoring the ratios, I looked back at the residual stand I was leaving. To my surprise, it looked just like the residual for the even-age thinning. I knew there should be a difference, but because I had never marked an economic selection cut before, I had no concept of what kind of stand I should be leaving.

I slowly pulled the SILVAH printout from my cruiser's vest and looked at the marking ratios and began applying them. After finishing the plot, I subtracted what I had marked from the original 100 percent inventory and to my surprise I had left the exact residual stand prescribed. I still was not totally comfortable using the ratios, but the results from the economic selection plot made me think that these ratios might be practical in the woods. Sure enough, in a week I had applied the ratios and marked 100 acres in these 5-acre blocks, resulting in the prescribed residual stand each time. Also, after using the ratios for a week, I was comfortable with them, and convinced that I would never go back to my old way of marking. In the 10 years since my introduction to this system of marking, I let the ratios guide my marking with good success.

GUIDES FOR NEW MARKERS

Those who have little or no marking experience are likely to apply the ratios too rigidly and mark trees that should have been left or vice versa. If your crewmate is an experienced marker, you will probably disagree and cease talking to each other halfway through your first strip. The following can help you through the familiarization period.

1. Emphasize the residual stand. As you mark a group of trees, ask yourself, "Am I making the stand more uniform? Are the trees I am leaving well spaced and generally of good quality?"

2. Remember that the stand analysis figures from which you have derived a marking guide are average figures for the stand as a whole. Every circle of trees you consider in the stand is not going to be average. Your prescription may call for removing all of the UGS large sawtimber. What are you going to do if all the UGS material is concentrated in one small area of the stand? Remember too that your inventory is based on a sample cruise that may not have adequately sampled all conditions within a stand. Do not get locked into the numbers--use common sense. If you feel you can justify marking a tree that is not called for, mark it and move on.

3. Density within a stand will vary from point to point. Using traditional marking methods you have to lighten up your marking in open patches and mark more heavily in the dense portions. Applying the ratios does this automatically for you.

4. When marking a large tree, consider how that tree will be felled. If other trees are in its path and will likely be damaged, mark those trees too, even if your ratios do not call for it.

5. When working in stands of sprout origin, thin sprout clumps to one or two of the better stems.

6. Remove all trees that, in your judgment, will not survive 15 years. This may be due to a split crotch, poor vigor of the crown, excessive lean, rot, or insect damage and disease.

7. Favor retaining species that are a minor component in the stand you are working in. These residuals will provide a seed source for that particular species which may improve species diversity in the next forest.

8. Favor retaining trees that are important for wildlife. This may include leaving trees with suitable nesting cavities, coniferous trees for cover, and mast-producing species for food.

9. Try to thin areas where trees are clumped together to improve spacing and growth of the trees that remain. Tree crowns need to have adequate growing space on at least three sides to maximize growth. But, do not hesitate to leave two good trees side by side.

10. Favor, where possible, leaving species that will enhance the management objective for a particular property.

SUMMARY

No matter how much or how little timber marking experience you have had, your first exposure to this system of marking will, like any change, probably make you uncomfortable. Do not give up on it--give it a fair trial.

Keep in mind the advantages of this system. First, it gives prescription writers the assurance that the residual stand will be close to the prescription. For markers, it gives you confidence that you will end up with a residual stand fairly close to the prescription. This is true especially if the prescrition deviates from the normal way you have been marking similar stands.

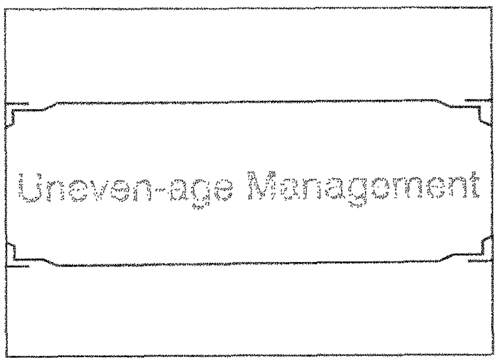
Most of all, recognize the numbers for what they are: guides to aid you in achieving your density, structure, and species composition goals. Exercise your professional skill and judgment each time you pull the trigger of your paint gun.

Selected References

Leak, William B.; Gottsacker, James. 1985. New approaches to uneven-age management in New England. Northern Journal of Applied Forestry. 2:28-31.

Principles and Practices of Uneven-age Management

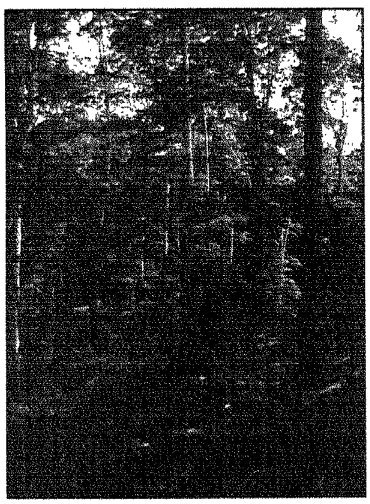
Susan L. Stout



1. The SILVAH system of stand inventory, analysis, and prescription includes prescriptions from both even- and uneven-age silvicultural systems. Uneven-age silvicultural systems are used when management goals, usually aesthetic, require maintenance of continuous high forest cover, even though this usually means a shift to a less valuable species composition over time. In this article, the principles of uneven-age management and their application in the SILVAH system are discussed. This is a shift of focus. Most of the lectures in this series are focused on even-age management.

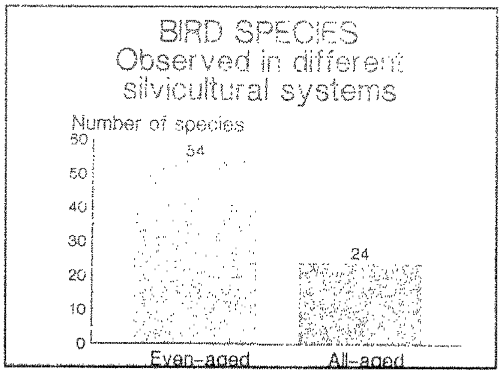
2. Under even-age management we can focus on the often high proportions of less shade-tolerant species such as black cherry, white ash, red maple, yellow-poplar, and red oak. These species grow fast and have high value per unit volume. They also occupy less growing space per tree than their more shade-tolerant associates, so stands with high proportions of these species have higher volumes per acre.

3. Uneven-age management, on the other hand, and particularly single-tree selection cutting, results in a gradual change in species composition toward more shade-tolerant species, and Allegheny hardwood stands managed under this system will eventually consist primarily of sugar maple, beech, and hemlock. So selection cutting and uneven-age management will usually be less profitable than even-age management in Allegheny hardwoods. In forest types where the highest value species are shade-tolerant ones like sugar maple and less valuable competitors are shade intolerant, uneven-age management may be preferable to even-age management for timber production objectives. This is true in some parts of Canada.

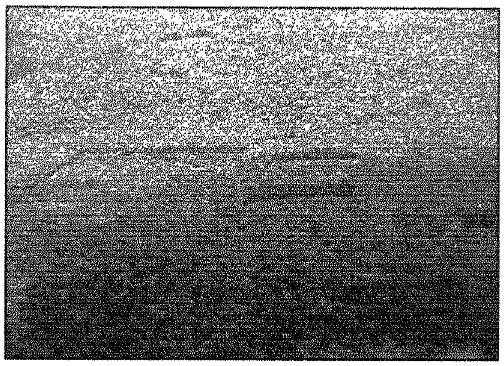


4. In the oaks, the probable outcome of single-tree selection cutting will be more variable. On hot dry sites, such as ridgetops or southerly aspects, oaks may be replaced by noncommercial and very tolerant species such as dogwood and sassafras over many years. On other sites, with low oak site index, more tolerant but sometimes acceptable species such as hickory; red maple; or slow growing white, chestnut, or post oaks may come to dominate the stand. And on some sites, the stand may convert from an oak to a northern hardwood stand over many years of repeated single-tree selection cutting.

5. Uneven-aged forest stands have desirable habitat characteristics for species, such as the pileated woodpecker, that can or must meet all habitat needs in mature forests, with relatively unbroken canopy and many large trees.



6. The mix of vegetative conditions found in a balanced even-aged forest provides for more diversity of wildlife, however. Uneven-age management does not create large blocks of early seedling-sapling stages, with an abundance of accessible foods and low cover. Because forests managed under uneven-age silvicultural systems lack the vegetative and structural diversity of forests managed under even-age systems, the abundance and species diversity of wildlife will be lower, as shown in this graph developed from research done in mixed hardwoods in New England.



7. Forest fragmentation has become an increasingly important biological and political concern for forest managers. Much of the eastern work on forest fragmentation was done in places where the forces fragmenting the forest involved permanent changes, like development or agriculture. The effects of the temporary changes associated with both even- and uneven-age partial cuttings and harvest openings have not been adequately assessed. Preliminary reports about the effects of openings created by forest management on forest interior bird species are encouraging.

8. Uneven-age management, especially single-tree selection cutting, offers a significant advantage over all forms of even-age management. It maintains a more natural, undisturbed appearance than any other cutting method. A high forest canopy is maintained at all times, leaving the appearance of a completely undisturbed forest when viewed from a distance, and absorbing most of the impact of disturbance even when viewed close-up immediately after a cutting. This photo was taken in the first growing season after cutting in this stand.

Selection system useful:

- near travel corridors
- near recreation areas
- on small private woodlands
- to preserve natural appearance

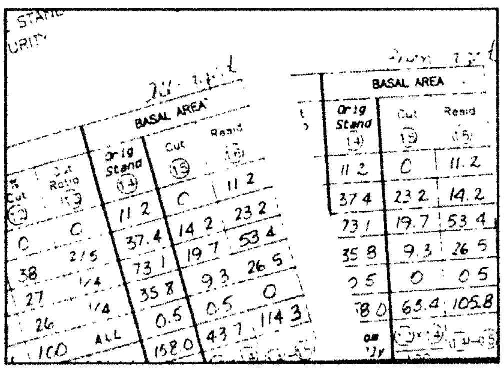
9. For these reasons, selection system silviculture is especially appropriate in heavily traveled zones or areas of high recreation use on public forests. It is often the preferred, and sometimes the only, acceptable cutting method on small, privately owned woodlands where timber production is secondary to the recreation or aesthetic goals of the owner. And it preserves natural appearance in managed forest stands.

10. Selection system also offers an alternative to the three-cut shelterwood on sites with limitations, particularly wetness, that would put them at risk of regeneration failure if seedlings were exposed to the harsh conditions following complete overstory removal under even-age management.

UNEVEN-AGE SILVICULTURE

- Principles
- Research results
- SILVAH Prescriptions
- Application

11. Thus, uneven-age silvicultural systems have specific advantages. Here we begin to explore the application of the SILVAH system in uneven-age management. Specifically, we review the principles underlying uneven-age silviculture and some research results. We also describe SILVAH's uneven-age prescriptions and the application of these prescriptions to actual stands.



12. We take a detailed look at the planning of an actual selection system cut for the sample stand that is used throughout this volume, using one of the uneven-age alternatives within SILVAH.

SELF-SUSTAINING FOREST:

Predictable flow of resource benefits, including wood products, at regular intervals.

13. Uneven-age silviculture attempts to create a self-sustaining forest, within a single stand, in which regeneration, growth, and removals act to maintain a stable population of trees from which a predictable flow of products can be harvested at regular intervals.

At each entry . . .

HARVEST

THIN

REGENERATE

14. Silviculture of a such a stand consists of regular entries during each of which (a) mature and high risk trees are harvested, (b) immature age classes are thinned to concentrate growth on the best stems and ensure the continuous flow of trees to the large size classes, and (c) space and conditions are created for the establishment and development of new regeneration.

Optimum structure depends on:

- Product objectives
- Price structure
- Site quality

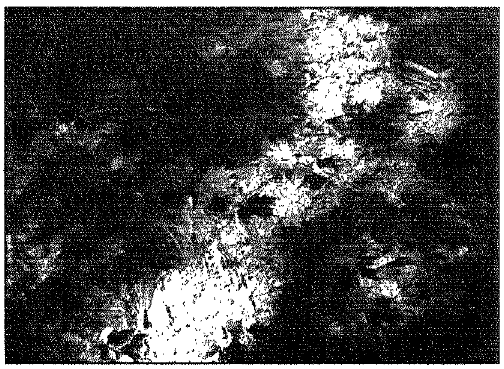
15. Within this conceptual framework, a wide variety of options are available. Options range from the strictest individual-tree selection cuttings through group-selection systems that some might be inclined to call a patchwork of small clearcuts. These options have in common the conscious creation and thinning of several age classes within one forest stand, and silvicultural efforts to mold these age classes into a stable and sustainable size distribution over the area of the stand. Furthermore, trees that develop in an uneven-aged stand will spend at least part of their early development under the influence of older and larger trees in the same stand.

16. Species composition can vary greatly, depending on the size of canopy openings created during silvicultural operations in managed uneven-aged stands. With single-tree selection, 90 percent or more of the regeneration will be of shade tolerant species. In Allegheny hardwoods, these will be sugar maple, American beech, and hemlock. In oaks, as already mentioned, the results may range from white and chestnut oaks through red maple, sassafras, and dogwood.

17. A slightly higher proportion of intolerants can be retained if uneven-age management consists of a mix of single-tree selection cutting with small group selection cutting, in which openings up to half of an acre are created whenever a group of trees growing together could logically be removed. The openings provide more variety of wildlife habitat as well.

SYSTEM	REGENERATION (%) TOLERANT	INTER./ INTOLERANTS
SINGLE TREE	90	10
GRPS TO 1/2 A.	67	33

18. This table, from work on the White Mountain National Forest in New Hampshire, shows the proportions of intermediate and intolerant regeneration obtained using different varieties of uneven-age management. As the size of openings in the canopy increased from single-tree openings to 1/2-acre openings, the proportion of intolerant and intermediate species in the regeneration increased too. Most of the regeneration even under group selection is at the intermediate end of the intermediate/intolerant grouping.



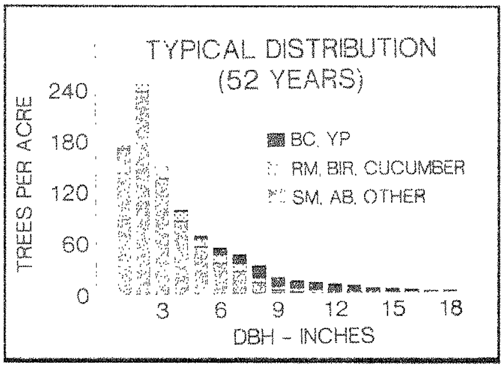
19. We must include one very important warning in our discussion of uneven-age silviculture, however. There is no assurance that uneven-age management can be used successfully in any region where deer populations are high. The success of selection cutting depends on the establishment of a new age and size class at each cut, and the eventual growth of these stems into the main crown canopy. The long period of slow growth in the understory, however,

20. greatly increases the length of time that seedlings are subject to deer browsing compared to those under even-aged management, and the small openings created by group selection are very attractive to deer. In addition, deer seem to browse preferentially on those species that would otherwise be favored by the selection system. There are many locations where reproduction simply CANNOT be obtained. Unfortunately, regeneration failures are not nearly so apparent under selection cutting, and it is possible to apply three or four selection cuts before it becomes obvious that you are running out of trees. So, special care should be taken to monitor the progress of age class replacement if uneven-age management is used in areas of moderate to heavy deer population.

21. Interfering plants further complicate this story. The selection system depends on successfully bringing through an age-class from each entry to the stand. When we treat interfering understories in an even-aged stand, we eliminate existing advance reproduction along with interfering plants. Then we count on the post-cutting conditions to favor germination of numerous seedlings that can outgrow the returning fern, grass, or weed species in the full light after even-aged overstory removal. We cannot afford to eliminate the existing small trees from the last cutting cycle, nor can we expect fast growth from new seedlings in the perpetual partial shade of the selection system. So, interfering plants need to be assessed carefully in selecting stands to be managed under this system.

MANAGING THE TRANSITION FROM EVEN TO UNEVEN-AGED STANDS

22. Remember that almost all existing eastern hardwood stands are even-aged in character. A period of adjustment is required to establish a stable uneven-age condition with the desired distribution of ages and tolerant species; this adjustment period may require two or three cuts spanning 30 to 50 years. So, most uneven-age management practiced during the foreseeable future will involve stands in this transition from an even-age condition to an uneven-age condition.



23. Many even-aged mixed hardwood stands exhibit an inverse J-shaped diameter distribution. This structure is due to the variety of species present and their widely different growth rates. The intolerants are clustered in the large sizes, whereas the tolerants are concentrated in the smaller size classes and lower crown positions. Although this structure is not truly a balanced uneven-age structure, it does make the job of conversion somewhat easier.

24. As the large intolerants are removed during selection cutting, they will be replaced by the tolerants in the smaller size classes, and the stand will eventually be dominated by tolerant species.

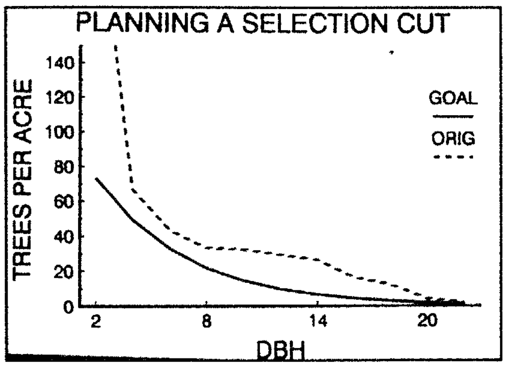
YEAR OF CUT	% OF CUT IN BLACK CHERRY
1990	[illegible]
2010	[illegible]
2030	[illegible]

25. A fully stabilized uneven-aged stand will not be obtained until most of the intolerants have been replaced by new age classes of vigorous tolerant stems in all size classes. However, there is no reason to hurry this adjustment process. The intolerants present now are fast-growing and valuable and retaining some intolerant species for as long as possible will help maximize value from the stand. And because the system for distributing the cut requires that the cut in each size class be proportional to the existing species composition, this will happen automatically over the first two or three cuts under the selection method. The intolerants will "grow out the top" and be replaced by tolerant species growing up from the small size classes.

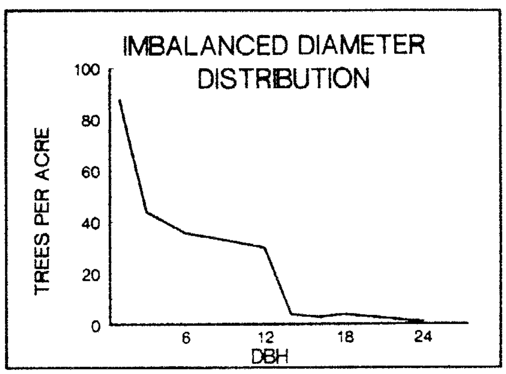
SELECTION PRESCRIPTION

- Stand Density
- Stand Structure
- Species Composition

26. Planning a prescription for selection cutting involves the same factors considered in planning a thinning. You must account for stand density (stocking), stand structure (diameter distribution), and species composition. The type of structure and species composition sought are quite different than those sought under thinning. But once the residual stand has been decided, the mechanics of distributing the cut are quite similar.



27. Fundamental to uneven-age management is the selection of a basic structure for the stand. This will be the residual stand after every cutting cycle. Ideally, this structure should sustain itself. If each cut returns the stand to this structure, the stand will respond with regeneration of a new age class and healthy, vigorous growth on the residual stems.

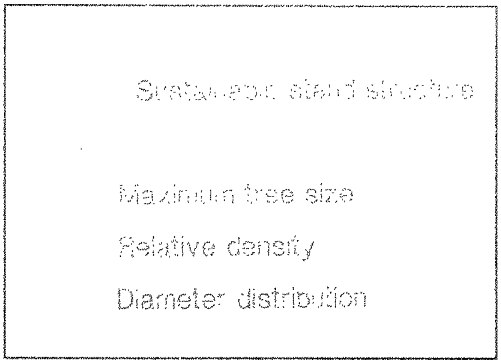


28. Merely matching the volume cut to the volume you believe has grown in the stand since the last cutting does not provide adequate regulation of a stand under the selection system. Even when calculations of volume growth are good, and volume growth exceeds the cut, concentrating the cut in the largest classes can badly imbalance the diameter distribution. The example from the Kaskaskia Experimental Forest provided by Marquis and Roach in the article "Thinning Principles and Practices" illustrates this problem very well.

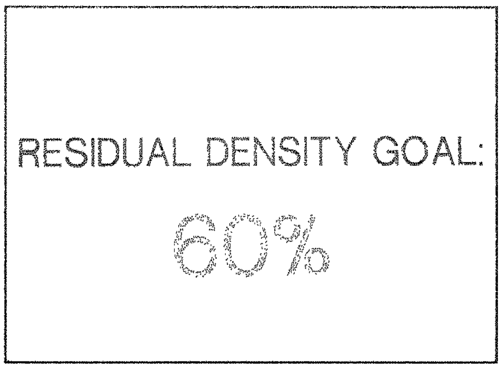
SOLUTION:

CONTROL STAND STRUCTURE

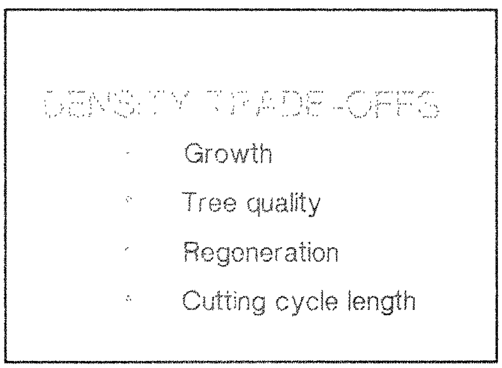
29. The solution is careful selection of a sustainable residual stand structure.



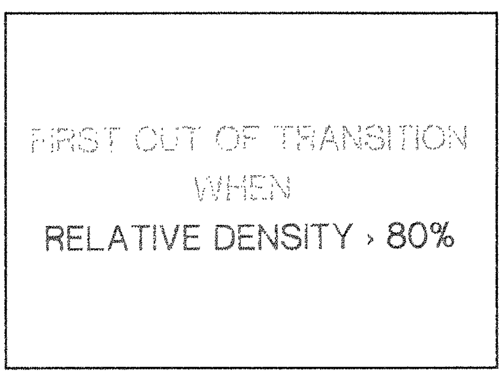
30. The residual stand structure can be defined by three parameters: residual relative density, maximum tree size, and diameter distribution of the residual stand.



31. The choice of residual relative density is handled exactly as in thinning, and for the same reasons. We wish to distribute stand growth among the best residual stems, maintain the quality of those stems, and open the canopy enough to foster the development of a new age class after every cut. Stands should be cut back to 60 percent relative density in each cycle, but no more than 35 percent relative density should be removed in any one cut.



32. Some work done by Ralph Nyland and his students in New York and simulation work done elsewhere suggest that lower residual densities may be appropriate in some situations, such as stands being managed with long cutting cycles. Lower residual densities may have a negative effect on stem quality. Epicormics, in particular are a concern. Work done in the Lake States suggests that residual densities around 60 percent are compatible with natural pruning on pole-size and larger stems. Density also affects regeneration established through selection system cutting. Sixty percent seems to be the appropriate residual density for most situations.



33. When the relative density of a stand to be managed under the selection system is below 80 percent, defer cutting in the stand. More than likely growth on all stems is good, mortality is low, and sufficient volume is not available for a commercial cut. But if relative density is above 80 percent, volume for a commercial cut should be adequate, and the better quality residual stems should respond to such a cut with improved growth.

AVERAGE DENSITY IN STANDS WITH GROUP SELECTION:

50%

34. Density in stands managed by the group selection variant of uneven-age silviculture will average closer to 50 percent, when the zero density openings are included in a standwide average density. Most trees will grow in the same conditions as those in a 60 percent relative density single tree selection cut stand except those on the edge of group openings.

35. The choice of maximum tree size has both visual and economic consequences. Many landowners prefer to have large trees for aesthetic reasons, and the existence of large trees does contribute to the 'natural' appearance that we associate with uneven-age management. But the decision on maximum tree size also influences economic returns from timber.

MAXIMUM SIZE TREES FOR VARIOUS RATES OF RETURN

SPECIES	2 %	4 %	6 %
BLACK CHERRY	32	22	18
RED MAPLE	32	22	18
WHITE ASH	30	22	18
SUGAR MAPLE	32	22	18

36. For example, this rate of return information indicates that sugar maple can be grown only to 18 inches d.b.h. on good sites if a reasonably high rate of return, such as 6 percent, 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 rate of return, such as 2 percent. The lower rate of return and larger trees that result might very well be appropriate for aesthetic reasons, and one of the model stand structures that we suggest reflects this possibility. Twenty-two inches is a better compromise where timber production is more important, and the visual effect of large trees less necessary.

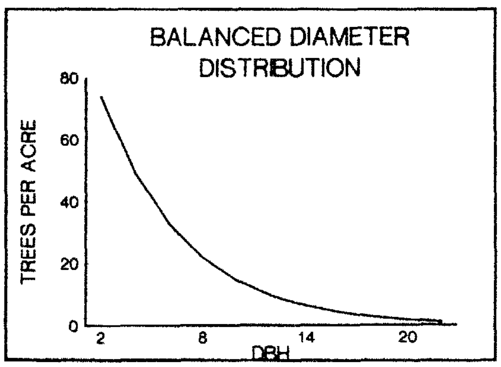
"Q" - THE QUOTIENT OR RATIO BETWEEN NUMBERS OF TREES IN SUCCESSIVE DIAMETER CLASSES.

37. The most widely accepted procedure for setting stand structure goals under selection cutting is to utilize the QUOTIENT (called 'q') between numbers of trees in successive diameter classes as a means of calculating a desired diameter distribution. Recent evidence shows that distributions other than those based on a 'q' may be advantageous under certain circumstances, but these distributions have not been fully evaluated in the forest yet. So, we will base our discussion on the quotient 'q'.

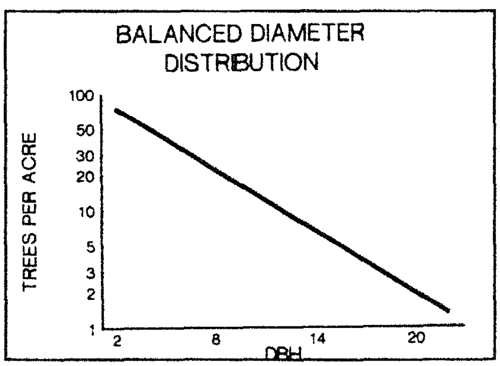
Q = 1.3

DBH	# TREES/ACRE
18	1.69
20	1.3
22	1.0

38. This stand has a 'q' of 1.3. Each diameter class has 1.3 times as many trees as the next larger diameter class. That is, if you divide the number of trees in the 20-inch class, for example, by the number of trees in the 22-inch class, the QUOTIENT would be 1.3.



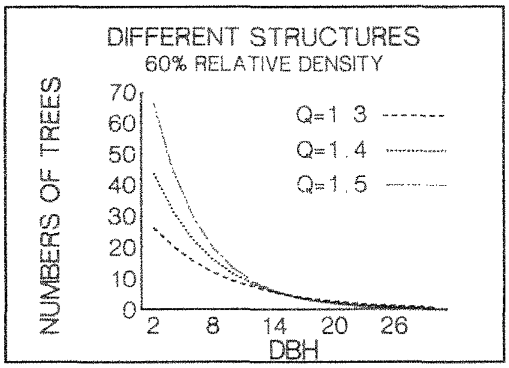
39. When the number of trees is plotted over diameter class for a stand with a 'q' distribution, the plot has a typical inverse J-shape.



40. Or, if the same distribution is plotted on semilog paper, the distribution follows a straight line. 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. For our purposes, a 'q' for 2-inch classes is needed, but the literature contains 'q's for both 1- and 2-inch classes. The 'q' for 2-inch classes is the square of the 'q' for 1-inch classes.

HOW TO CHOOSE 'Q'?

41. This gives some idea of what 'q' is. But what are the consequences of choosing a 'q' value?



42. Quotients ranging between 1.3 and 2.0 for 2-inch classes have all been recommended for various situations. The lower the 'q', the smaller the difference in number of trees between diameter classes. Stands maintained to a low 'q' have a high proportion of the available growing space devoted to larger, more valuable trees and should theoretically produce somewhat higher sawtimber yields (not necessarily greater total volume yields) than stands maintained to a high 'q'. But maintenance of a low 'q' factor means that excess numbers of small stems that usually develop may have to be removed periodically at some expense.

STAND STRUCTURE GOALS FOR VARIOUS 'Q' LEVELS IN ALLEGHENY HARDWOOD STANDS

	Q-LEVEL		
	1 4	1 6	1 8
DBH	NO TREES PER ACRE		
2-6	[illegible]	[illegible]	[illegible]
8-12	59	76	83
14-18	22	19	14
20-30	11	6	3
AVG. DIA	14 6	11.2	9.0

43. For example, consider the numbers of small trees that would be maintained in a stand held at a 'q' of 1.4 versus the number in the same stand if maintained at a 'q' of 1.8. It is obvious that many additional small trees would have to be cut under the 1.4 'q'.

STAND STRUCTURE GOALS FOR VARIOUS 'Q' LEVELS IN ALLEGHENY HARDWOOD STANDS

	Q-LEVEL		
	1 4	1 6	1.8
DBH	SQ FEET OF BASAL AREA ACRE		
2-5	13	24	34
8-12	30	38	40
14-18	20	24	18
20-30	[illegible]	[illegible]	[illegible]

44. On the other hand, compare the basal area in large sawtimber in the two stands. There is much more basal area in large sawtimber where the 'q' is low.

Optimum structure depends on:

- Product objectives
- Price structure
- Site quality

45. A great deal has been written concerning economic optimization of residual stand diameter distributions under the selection system (see "Selected References"). Several principles emerge. The optimum structure depends on what is optimized: growth of large sawtimber volume, total volume, or total value, for example. It also depends on the price structure: the value premium for large logs, for example. There is evidence that good sites can carry lower 'q's than poor sites, and that strategies are workable that allow for a slow adjustment of the 'q', over several cutting cycles, to an optimum appropriate to site and product objectives.

AIM FOR THE LOWEST 'Q'
THAT'S POSSIBLE
WITH THE EXISTING STAND

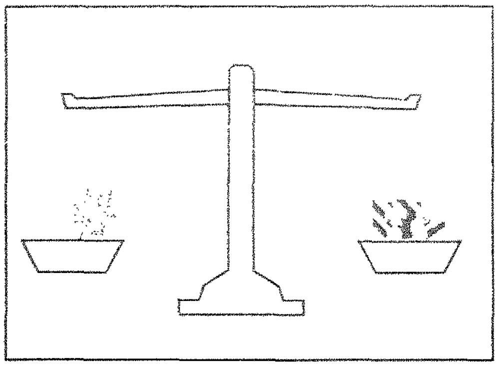
46. This strategy is the one we recommend. As we initiate uneven-age management in a stand, we shoot for the lowest 'q' that seems feasible in terms of markets and money available for cultural work in small trees. The prelogging 'q' level will also be an important factor. In younger, second-growth stands where the existing 'q' level may run over 2.0 and the number of large trees is limited, it would be unrealistic to shoot for a very low 'q'. But in older stands or in stands that have already received several cuts aimed at balancing the diameter distribution, a lower 'q' may be feasible.

ACTUAL
'Q'
MAY CHANGE
OVER TIME

47. When you use the SILVAH computer program, your choice of management goal identifies the 'q' you would like the stand to achieve in the long run. SILVAH automatically adjusts that 'q' during the transition cuts. The actual residual "q" during the period when a stand is first being brought under management may be somewhat higher than the goal 'q' factor. Then you can gradually work toward a smaller 'q' in successive cuts, a process that occurs automatically in the SILVAH computer program.

SILVAH ADJUSTS 'Q'
GOALS TO EXISTING
STANDS

48. That is, with SILVAH, the 'q' of your residual stand reflects a balance between the 'q' of the present stand and the 'q' of the structural goal you have selected. Your structural goal should reflect the visual or aesthetic preferences of management, and will define the target 'q' that SILVAH works towards. But the target will always be modified by the reality of the existing stand, and if you want a stand with many large trees in the long run, but have very few large trees now, SILVAH will adjust accordingly. The distribution of cut practices for manual application of the selection system will achieve this balancing, as well.



49. Although the number of combinations of different maximum tree sizes, residual relative densities, and diameter distributions or 'q' factors is virtually infinite, the final choice of stand structure is really a balancing act between the value of the timber produced and the aesthetic qualities of the managed stand. We have developed two 'prototype' stands from among all these combinations. You are welcome to 'fine tune' your own ideal stand structure, but one of these prototype stands will suffice for the vast majority of situations.

MANAGEMENT GOAL = 3,4

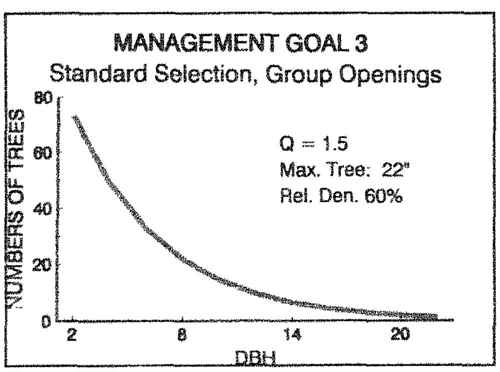
UNEVEN-AGE MANAGEMENT

50. We distinguish between these two stand structures by the management goal associated with each stand. When a landowner specifies a management goal of 3 or 4, even-aged regeneration cuttings of any kind are ruled out for that property.

STANDARD SELECTION CUTTING

- Density of shade tolerants > 35
- Management goal = 3
- Deer pressure < 4
- Relative density > 80%

51. If the management goal is coded as 3, extremely large trees are not required and maximum timber production possible from uneven-age management is desired. If the target stand also has at least 35 square feet of shade tolerant species to provide seed for new age classes, is under low to medium deer pressure, and has a current relative density that exceeds 80 percent, this goal leads to our standard selection cutting prescription of single-tree and group selection cutting combined.



52. The type of residual structure called for by this prescription is illustrated here. A 22-inch maximum tree size is selected as a compromise between desired visual characteristics and timber production, and a 'q' of 1.5 is also selected as a target. Although the single-tree selection between openings will aim for a residual relative density of the traditional 60 percent, the stand average residual density will be closer to 50 percent because of the openings created where whole groups of trees are removed.

STANDARD SELECTION CUTTING

- Density of shade tolerants > 35
- Site limits > 30%
- Deer pressure < 4
- Relative density > 80%

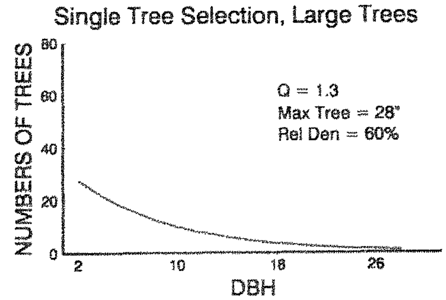
53. This prescription may also be appropriate in stands with site limits detected on over 30 percent of the regeneration inventory plots, depending on management goal. Because continuous overstory cover is maintained, regeneration is never exposed to the drying out of surface soil or the raising of the water table that may occur on some harsh sites after even-aged removals. Here, too, this cutting will only be prescribed if deer pressure is low to medium, if there is a "critical mass" of shade tolerant species, and if the current relative density exceeds 80 percent.

SINGLE-TREE SELECTION CUTTING

- Density of shade tolerants > 35
- Management goal = 4
- Deer pressure < 4
- Relative density > 80%

54. If the management goal is 4, the appearance of a forest of large trees is the primary management concern, and all cutting must help maintain a stand structure that fits that objective. If, in addition to that management goal, a stand has the critical mass of shade tolerant species, is under low to medium deer pressure, and has a current relative density in excess of 80 percent, SILVAH will prescribe strict single-tree selection with a large maximum tree size and low target 'q'.

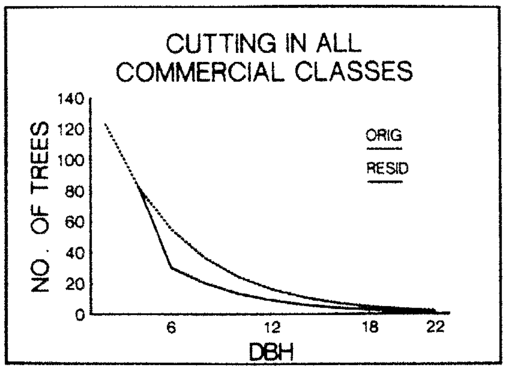
MANAGEMENT GOAL 4
Single Tree Selection, Large Trees



55. This is the target stand for management goal 4. The maximum tree size is 28 inches, the 'q' is 1.3, and the residual relative density is 60 percent. If the 'q' factor of the present stand is appreciably higher than 1.3, SILVAH will adjust the 'q' of the residual for this cut and work toward 1.3 in future cuts.

User may change SILVAH's model stands.

56. These are the basic prescriptions with which SILVAH works. If you are using the computerized version of SILVAH, you may alter the variables that determine the structural goals toward which SILVAH will work. Specifically, you may change the maximum tree size, the 'q,' or the residual relative density for an uneven-age prescription, and SILVAH will do the rest. You may also do these things by hand.



57. The application of any uneven-age prescription should include cutting in all merchantable size classes to avoid unwanted changes in structure. In general, the saplings can be left to thin themselves or to be thinned as they grow into the merchantable size classes. If you find that the saplings greatly exceed your ultimate structural goal, and if money is available for treatment of these stems, you may choose to remove some.

MONITOR

SAPLINGS AND REGENERATION

CAREFULLY !

58. Even though cutting in the sapling class is not required for application of the selection system, this class is of great importance. It must be included in any inventory of the stand, because the population of the sapling class IS the future of the stand. When inventory shows that the sapling class has fallen below the levels of your structural goals, the stand may already be in serious trouble. Researchers in Indiana found such a deficiency in stand structure appearing within 16 years of the initiation of selection system in mixed hardwood stands on good sites.

PRIORITIES FOR ACHIEVING

THE DESIRED RESIDUAL:

1. DENSITY
2. QUALITY
3. STRUCTURE

59. The basic principles underlying the distribution of a selection cut are the same as those underlying an intermediate cut in an even-age system. Trees are selected for cutting or retention to achieve the desired density and structure and to leave a residual stand of the best possible quality. The first priority is to achieve the desired residual relative stand density. The second priority is to remove as many unacceptable growing stock trees as possible within that density constraint. The third priority is to achieve the desired size-class distribution.

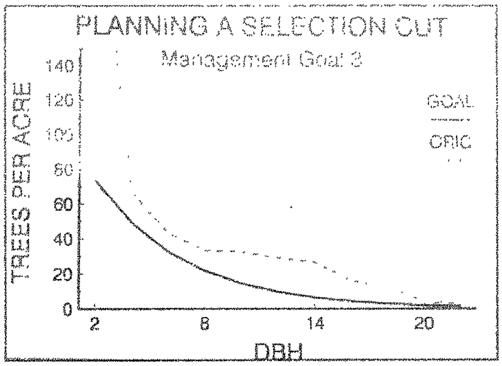
DEVELOP

A MARKING GUIDE

BASED ON

THESE STRUCTURES

60. If computer prescriptions are used, the computer will develop a marking guide for the stand based on these priorities and on the residual stand structure associated with the management goal that was chosen. But it is possible to use the manual distribution of cut procedure developed for intermediate cuttings in even-aged stands with very little modification to develop a marking guide for a selection cut.

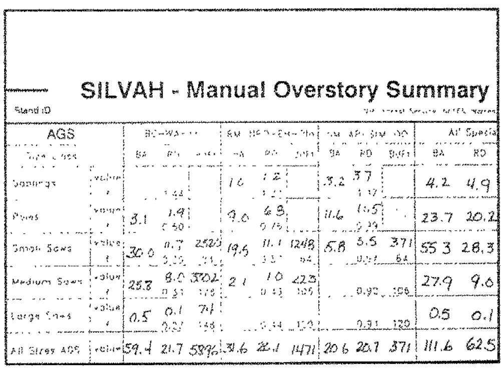


61. Now we review the underlying concepts of a selection cut. Once the basic residual stand structure for the uneven-age management plan has been selected, and the stand has been cruised, we are ready to plan a specific selection cut. We know the structure of the present stand, and the structural goal for the stand. The purpose of the selection cut is to bring the stand closer to that goal, while improving stand quality and maintaining adequate density on the site. This means removing trees that are in excess of the structural goal, except where needed to balance deficiencies, or to improve the overall quality of the stand.

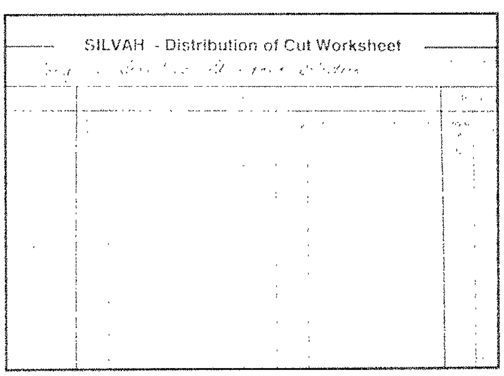
GROWING SPACE GOALS

	M.G. 3	M.G. 4
SAPS	--	--
POLES	41	22
SSAW	37	30
MSAW	22	27
LSAW	0	21

62. Background for the procedures about to be described is given in earlier articles: "Stand Data Summary and Analysis" and "Distribution of Cut." We have characterized the target stand structures by the proportion of the relative density in each of the merchantable size classes. Those are the numbers shown here. For example, in a stand for which we have prescribed a standard selection cut, with a 'q' of 1.5 and a maximum tree size of 22 inches, we would like the relative density of the pole class to be 41 percent of the merchantable residual density. This proportional relationship among the size classes should be the same in any stand with that structural goal.



63. Turn to Appendix A as we review the the mechanics of manually planning a selection cut for a stand with a management goal of 3, timber production with continuous high forest cover and some large trees. As with thinning, the first step in distributing a selection cut is to transfer basic stand data from the Manual Overstory Summary forms



64. to the Distribution of Cut Worksheet.

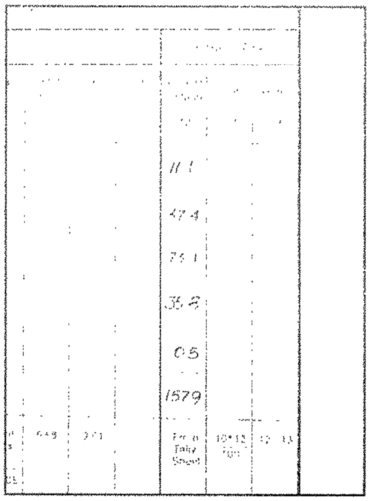
Class	1	2	3
Saplings	13.0		
Poles	32.7		
Small Sawtimber	38.8		
Medium Sawtimber	12.1		
Large Sawtimber	0.1		
Total	96.7		
	From Tally Sheet	% from Table 5	All- or Even-aged ?

65. Relative stand density is transferred to column 1.

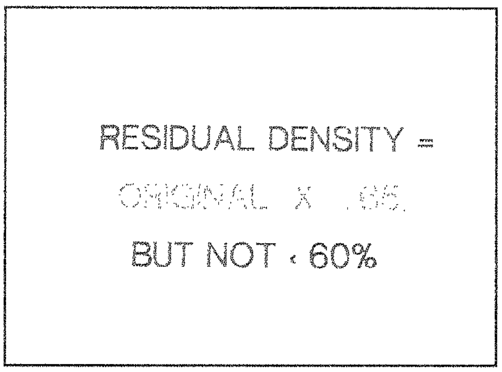
Relative Density

Adjust	Residual Goal	Cut ...	Original UGS	Adjust	Total Cut	% Cut
4	5	6	7	8	9	10
			—			
			12.5			
			10.5			
			3.1			
			26.1			
Record shortages / BALANCE	EA N/A / AA 3+4	EA 3+4 / AA 1−5	From Tally Sheet	Record excess UGS / BALANCE	5+8	9/1

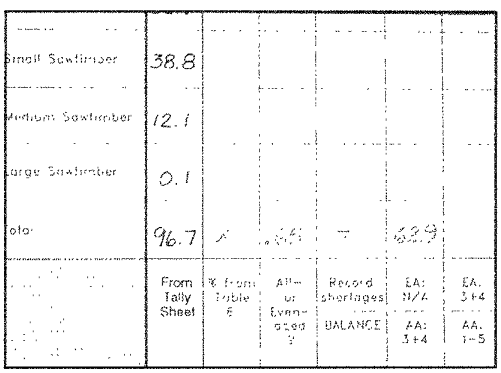
66. Relative density for UGS only is transferred to column 7. Note that we do not transfer the UGS value for the sapling class, since we will not cut saplings. And the total we record is the total for the merchantable classes.



67. Basal area for the total stand is transferred to column 12.

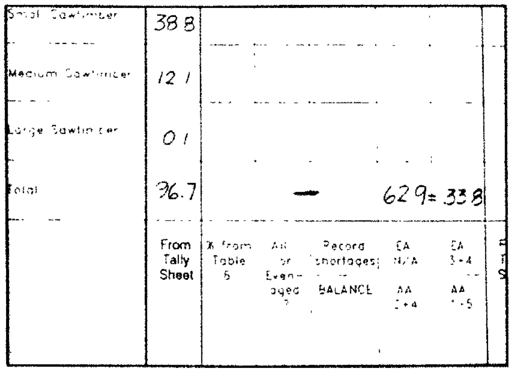


68. The desired residual relative density is the relative density of the original stand times 0.65, but not less than 60 percent.



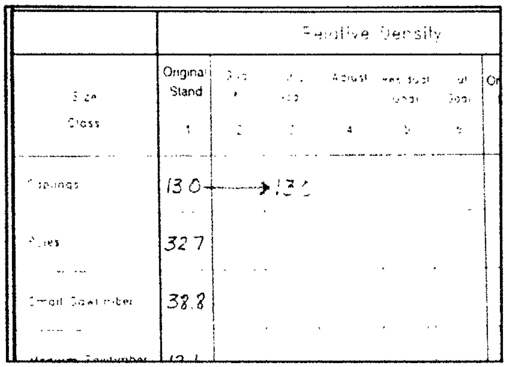
	From Tally Sheet	% from Table 6	All- or Uneven-aged Y	Record shortages BALANCE	EA: N/A AA: 3+4	EA: 3+4 AA: 1-5
Small Sawtimber	38.8					
Medium Sawtimber	12.1					
Large Sawtimber	0.1					
Total	96.7	x	.65	=	62.9	

69. Record this value in the total row of column 5.



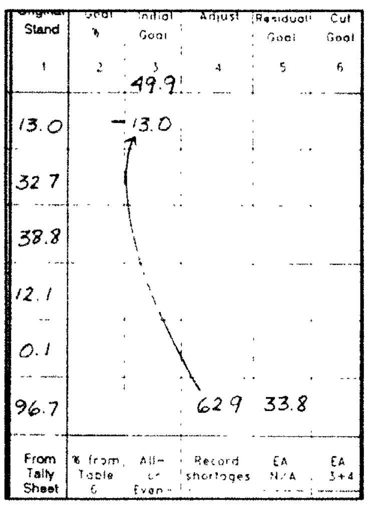
Small Sawtimber	38.8	
Medium Sawtimber	12.1	
Large Sawtimber	0.1	
Total	96.7	— 62.9 = 33.8
	From Tally Sheet	

70. The relative density to be cut is the original stand relative density (total, column 1) minus the residual stand relative density (total, column 5); record this as the cut goal (column 6) in the total row.



Size Class	Original Stand 1	2	3	4	5	6
Saplings	13.0 →		13.0			
Poles	32.7					
Small Sawtimber	38.8					

71. We now know the total residual relative density that we would like to have. Because we are not working in the saplings, the entire cut must come from the merchantable sizes. All of the saplings will remain in our residual stand. So, we record the relative density of the sapling class in the sapling row in column 3, just transferring it from column 1. Notice that column 3 is the residual stand, the inverse J-shaped structure that will begin to create a self-sustaining unit.

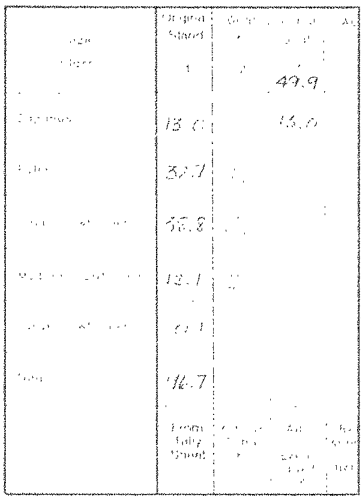


Original Stand 1	Goal % 2	Initial Goal 3	Adjust 4	Residual Goal 5	Cut Goal 6
		49.9			
13.0		− 13.0			
32.7					
38.8					
12.1					
0.1					
96.7				62.9	33.8
From Tally Sheet	% from Table 6	All- or Even-		Record shortages	EA N/A, EA 3+4

72. To find the residual in the merchantable sizes, we subtract the sapling relative density from the residual stand relative density (total, column 5 minus sapling row, column 3), and jot it down above column 3.

	GROWING SPACE GOALS	
	M.G. 3	M.G. 4
SAPS	--	--
POLES	41	22
SSAW	37	30
MSAW	22	27
LSAW	0	21

73. Use the table in Appendix B to fill in the desired residual structure. Choose the structure appropriate to the prescription. With a management goal of 3, we refer to the line for a Standard Selection Cut. These percentages are 41 percent in the pole class, 37 percent in the small sawtimber class, and 22 percent in the medium sawtimber class. For uneven-age silviculture, these numbers are percentages of the merchantable residual that will be left in each size class. The percentages in the top of this table, for even-aged silviculture, are percentages of the cut.



74. Record these values in column 2.

RESIDUAL IN EACH SIZE CLASS =
TABLE PROPORTION OF MERCHANTABLE RESIDUAL

COL. 3 = COL. 2 × MERCH. RESID.

75. The residual goal in each of the merchantable size classes is equal to the percentage from the table, now entered in column 2, times the desired residual relative density in the merchantable classes, the number jotted above column 3.

Size Class	Original Stand 1	Goal % 2	Initial Goal 3 49.9	Adjust 4
ngs	13.0		13.0	
	32.7	41	20.4	
l Sawtimber	38.8	37	18.4	
um Sawtimber	12.1	22	11.0	
Sawtimber	0.1	—	—	
	96.7			
	From Tally Sheet	% from Table 6	All- or Even-aged ?	Record shortages BALANCE

76. Enter these values in column 3. For this stand, these values are [20.4] in the pole class, [18.4] in the small sawtimber class, and [11.0] in the medium sawtimber class. The note below column 3 reminds you that these numbers are calculated differently for uneven- and even-aged cuts.

Original Stand 1	Goal % 2	Initial Goal 3 49.9	Adjust 4	Residual Goal 5	Cut Goal 6
13.0		13.0			
32.7	41	20.4			
38.8	37	18.4			
12.1	22	11.0			
0.1	—	—			
96.7		62.8 ←→		62.9	33.8
From Tally Sheet	% from Table 6	All- or Even-aged ?	Record shortages BALANCE	EA N/A AA 3+4	EA: 3+4 AA: 1-5

77. Sum column 3 and check to see that its total is the same as that in Column 5, within rounding error.

Size Class	Original Stand 1	Goal % 2	Initial Goal 3 49.9	Adjust 4
ngs	13.0		13.0	
	32.7	41	20.4 ✓	
Sawtimber	38.8	37	18.4 ✓	
m Sawtimber	12.1	22	11.0 ✓	
Sawtimber	0.1			
	96.7		62.8	
	From Tally Sheet	% from Table 6	All- or Even-aged ?	Record shortages BALANCE

78. Differences between the original stand in column 1 and the desired residual values you have just written in column 3 are the excesses and deficiencies of the stand distribution when it is compared to the desired stand structure. Record any DEFICIENCIES, or negative values, in column 4. No adjustments are required in the sample stand. This means that the original stand structure has no deficiencies compared with the desired residual stand structure.

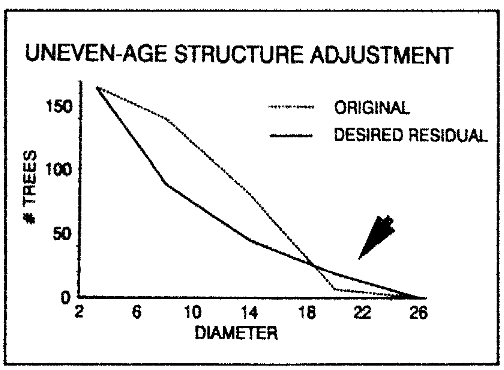
WHAT IF PRESENT STRUCTURE HAS DEFICIENCIES?

79. For many stands in this transition period from even- to uneven-age management, however, there will be deficiencies, particularly in the sawtimber classes. So we will look at the adjustment procedure--and its meaning--in a stand in that transition.

Stand ID PLOT 5B

[illegible] Class	Original Stand	[illegible]	[illegible]	Adjust
	1	2	3 58.3	4
Saplings	9.6		9.6	
Poles	44.2	41	23.9	✓
Small Sawtimber	46.0	37	21.6	✓
Medium Sawtimber	4.6	22	12.8	-8.2
Large Sawtimber	0			
Total	104.4		67.9	
	From Tally Sheet	[illegible]	[illegible]	[illegible]

80. The original or existing relative density in medium sawtimber in this stand is 8.2 relative density units BELOW what we would like to leave in that size class in a well-structured residual stand. This is shown by the negative in column 4.



81. This graph helps us visualize the meaning of negatives, or deficiencies. The dotted red line is the residual we would like to leave and the black line is the present stand. We cannot leave the amount of medium sawtimber that we would like to, because it is not there.

	Original Stand 1	Goal % 2	Initial Goal 3 58.3	Adjust 4	Residual Goal 5
	9.6		9.6		
	44.2	41	23.9	+4.0	
ber	46.0	37	21.6	+4.2	
imber	4.6	22	12.8	-8.2	
ber	0	—	—		
	104.4		67.9		
	From Tally Sheet	% from Table 6	All- or Even-aged ?	Record shortages BALANCE	EA: N/A AA: 3+4

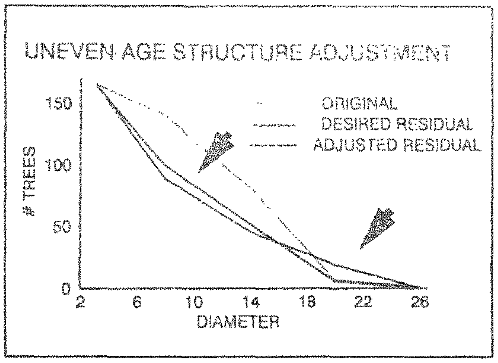
82. So, we increase the residual in the pole and small sawtimber classes to balance this deficiency. This helps to achieve two objectives: we keep the residual relative density we wanted, and we provide "excess" in the smaller size classes that can grow faster and "fill in" the deficiency.

	Original Stand 1	Goal % 2	Initial Goal 3 58.3	Adjust 4	Residual Goal 5
	9.6		9.6		
	44.2	41	23.9	+4.0	
ber	46.0	37	21.6	+4.2	
imber	4.6	22	12.8	-8.2	
ber	0				
	104.4		67.9	0	
	From Tally Sheet	% from Table 6	All- or Even-aged ?	Record shortages BALANCE	EA: N/A AA: 3+4

83. Be sure that your excesses balance your deficiency. That means that the sum of column 4, with its pluses and minuses, should be zero.

	Stand 1	Goal % 2	Initial Goal 3 58.3	Adjust 4	Residual Goal 5
	9.6		9.6		9.6
	44.2	41	23.9	+4.0	27.9
	46.0	37	21.6	+4.2	25.8
er	4.6	22	12.8	-8.2	4.6
	0				↓
	104.4		67.9	0	67.9
	From Tally Sheet	% from Table 6	All- or Even-aged ?	Record shortages BALANCE	EA: N/A AA: 3+4

84. Column 5 is the adjusted residual goal. Since column 4 contains your corrections to the theoretical residual in column 3, you calculate the adjusted residual by summing column 3 and column 4. Be sure that the total of column 5 is still equal to the relative density you wanted to leave, already recorded in the total row of that column, within rounding error.



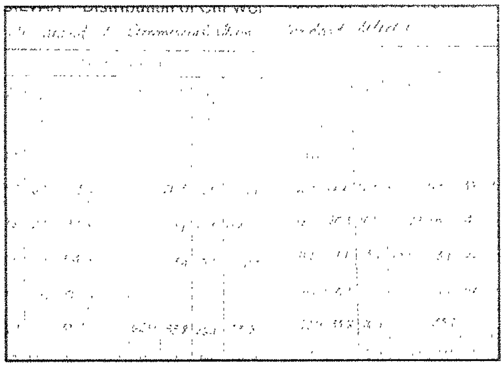
85. What have we done to the stand and to our cut? We have purposely created excesses in the classes immediately below the existing deficiency that can grow and result in a smoother, more desirably structured stand the next time around.

Original Stand 1	Goal % 2	Initial Goal 3	Adjust 4	Residual Goal 5
		49.9		
13.0		13.0		13.0
32.7	41	20.4		20.4
36.8	37	18.4		18.4
12.1	22	11.0		11.0
0.1				
96.7		62.8		62.9
From Tally Sheet	% from Table 6	All or Even-aged ?	Record shortages BALANCE	EA: N/A AA: 3+4

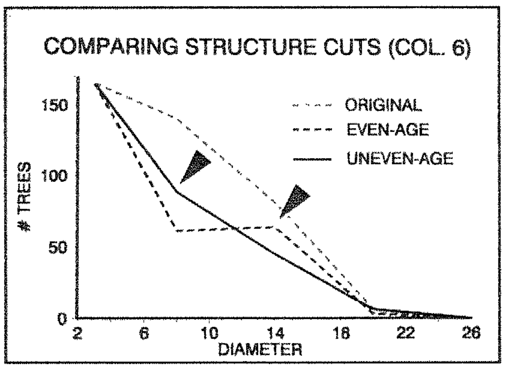
86. Now we shift back to the sample stand, which had no adjustments, and copy the desired residual from column 3 to column 5.

Original Stand 1	Goal % 2	Initial Goal 3	Adjust 4	Residual Goal 5	Cut Goal 6
		49.9			
13.0		13.0		13.0	[illegible]
32.7	41	20.4		20.4	[illegible]
38.8	37	18.4		18.4	[illegible]
12.1	22	11.0		11.0	1.1
0.1					0.1
96.7		62.8		62.9	33.8
From Tally Sheet	% from Table 6	All or Even-aged ?	Record shortages BALANCE	EA: N/A AA: 3+4	EA: 1-4 AA: 1-5

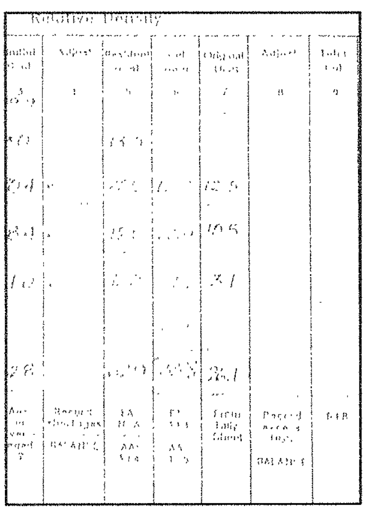
87. The cut goal, in column 6, is the present stand minus the desired residual, or column 1 minus column 5.



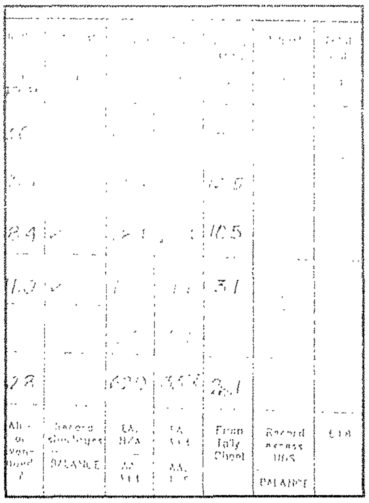
88. The cuts in column 6 reflect our "pure" structural goals before we correct for the quality of the stand. Now compare this cut with the "pure" structural cut for an even-aged thinning prescription (described in the article "Distribution of Cut"). Note that the emphasis in planning a thinning is on distributing the cut relative density in a way that will move the stand along to a more bell-shaped structure. The emphasis in selection system cuts is on structuring the residual to the J-shaped curve we want. The big differences between the cuts are in the pole and small sawtimber size classes.



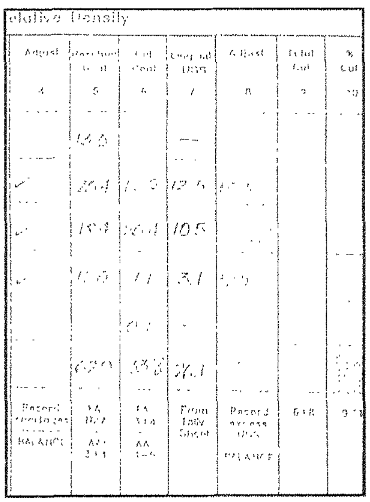
89. The principal value and volume in even-age management comes from the trees that are already largest, so we cut fewer of them. But in uneven-age management we want to bring the poles through to maturity. Even though these trees are not really younger in our transition stands, they are of species that can substitute for a younger age class until such an age class is developed over several cutting cycles.



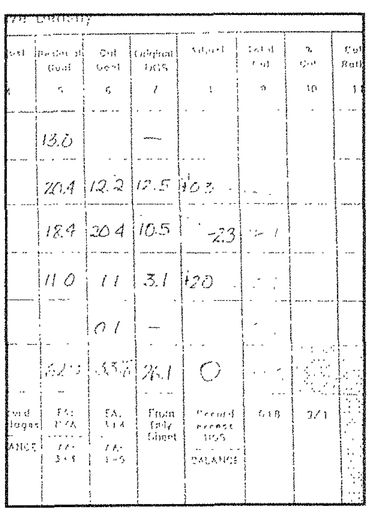
90. The calculations that remain are identical to those for an even-age cut. We adjust the cut for tree quality, by size class in the stand, then translate the cut to marking ratios and basal area. Be sure that you do not have more merchantable UGS than you can remove in the first cut, by comparing the total of column 7 to the total of column 6.



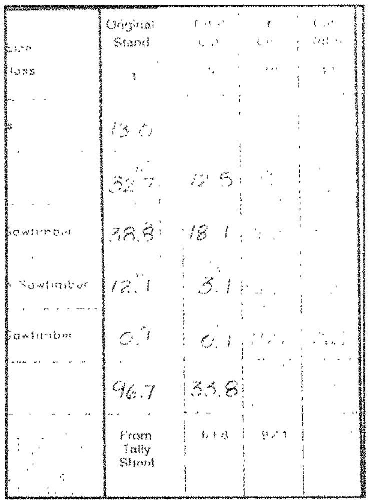
91. In this stand, the total merchantable UGS is less than our cut, so we can make an adjustment to remove all of it. We begin by subtracting column 7 from column 6 and recording negatives, or "UGS being left" in column 8.



92. We would like to increase the cut in UGS by enough to remove the excesses if we can, so we reverse the sign of these numbers. Then we reduce the cut in classes where the cut (column 6) exceeds the UGS (column 7). Be sure that any adjustment you do make is balanced; that is, that your final values in column 8 sum to zero.

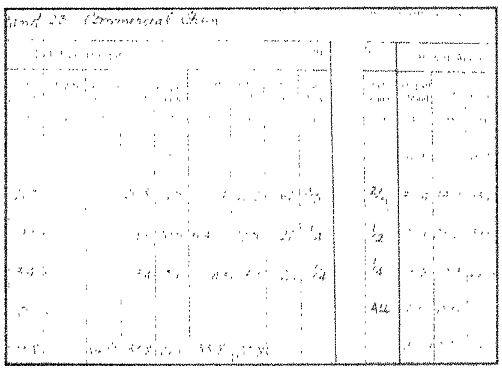


93. The final total cut, column 9, is column 6 plus column 8, or your structural cut plus any quality adjustments. Always check to be sure that this cut does sum to the relative density that you wanted to cut (total row, column 6) after the adjustments.



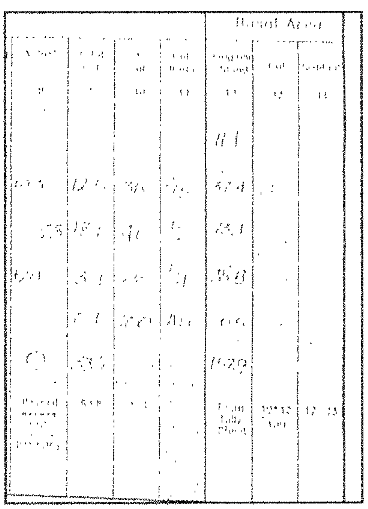
Original Stand	Cut
1	
13.0	
32.7	12.5
38.8	18.1
12.1	3.1
0.1	0.1
96.7	33.8
From Tally Sheet	

94. Column 10, the percentage cut, is equal to column 9 divided by column 1 times 100, and column 11, the Cut Ratio, is just this percentage translated to an easy-to-remember ratio.



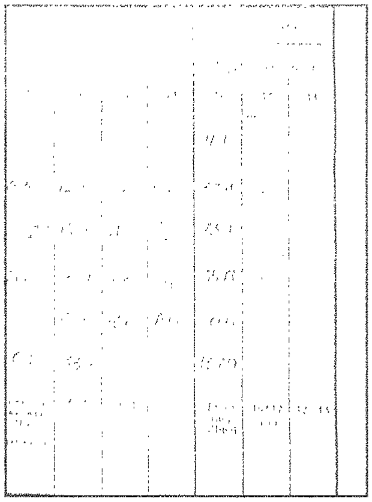
½
¼
All

95. This is another opportunity to compare the even- to the uneven-age prescription. You can see that for the sample stand, the comparison still stands after the quality adjustment: the even-age cut takes 3/5 poles, while the uneven-age cut takes 2/5. In the small sawtimber, the even-age takes 1/4, while the uneven-age takes 1/2.

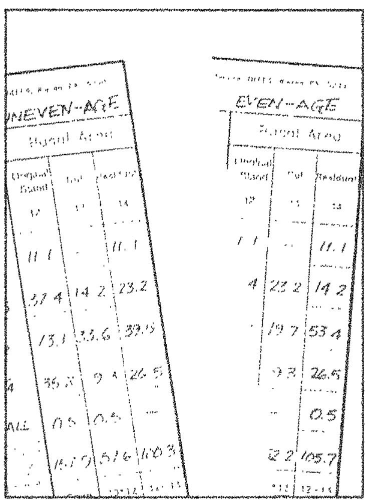


Basal Area
Original Stand
38.8
11.20
From Tally Sheet
Cut

96. The percentage cut, column 10, times the original basal area, column 12, gives the cut basal area, column 13.



97. The original basal area (column 12) minus the cut (column 13) gives the residual basal area (column 14). These residual basal area goals by broad size classes may help markers inexperienced with the selection system make quick prism checks of their progress through the stand.

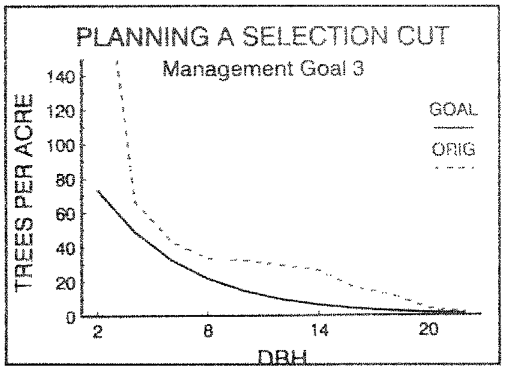


98. They also provide a final opportunity to compare the even- and uneven-age cuts. The results here are the same as they were at earlier comparisons, with the principal difference in the residuals in the pole and small sawtimber classes.

UNEVEN-AGE MARKING GUIDE

Poles	CUT 2/5, ALL UGS
SSaw	CUT 1/2, 1/2 UGS
MSaw	CUT 1/4, ALL UGS
LSaw	CUT ALL

99. If your quality adjustments have been done in such a way that you know the quality of the cut in each class, this information can be combined with the cut ratios to provide a marking guide.



100. Marking according to these ratios, whether calculated by hand or by computer, will help you achieve your objectives for the stand. Your residual stand will be at optimal relative density, will be of better overall quality, and, with each successive cut, will more closely approach the basic structure you have chosen for your management objectives.

The interval between cuts

101. A final decision to be made in implementing uneven-age management for a stand or forest is to choose the cutting cycle for each stand, that is, the interval between cuts. In general, cutting cycles should be shorter on better sites or for stands with low 'q's (a high proportion of the basal area in sawtimber). Stands with long cutting cycles should be cut back to lower residual densities to ensure that individual tree growth conditions remain suitable for most of the cutting cycle.

CUT WHEN

RELATIVE DENSITY

IS BETWEEN

80% and 90%

102. These general rules arise because timing of cuttings should be based on the projected growth rate and the time it takes to return to average maximum density. Cutting is usually economically feasible after the stand returns to 80 percent relative density, and should generally not be delayed beyond 90 percent relative density.

CUTTING CYCLE IN

MIXED HARDWOODS

USUALLY

15-20 YEARS

103. In cherry-maple stands that have been cut back to 60 percent relative density, it requires about 15 years to return to 80 percent relative density, 20 years to return to a relative density of 85 or 90 percent. So, cutting cycles of 15 to 20 years will be appropriate for most Allegheny hardwood stands. This timing is also appropriate for most oak and oak transition stands.

HELP WITH NEW PRESCRIPTIONS

104. Few of us--and few of the markers who actually implement our prescriptions--have much experience with the selection system. But as described in "Marking Ratios and the SILVAH System", marking ratios can help implement prescriptions that are unfamiliar.

TO HELP MARKERS:

- Broad size classes
- Quality data
- Prism self-checks
- Training plots

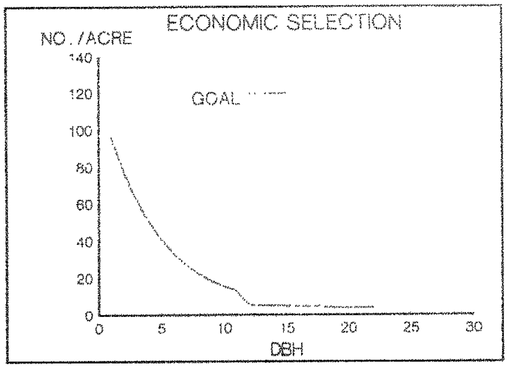
105. On the White Mountain National Forest, researchers developed aids for markers that they found worked well. Their prescriptions were presented in terms of large size classes, as ours are. They showed the approximate proportion of poor-quality stems in each cutting class. They asked the markers to check the structure of the leave stands fairly regularly with a prism during marking to ensure that the structure goals were being met, and they established some training plots for markers to practice the different prescriptions.

IN GROUPS, MARK TREES DOWN TO 1"

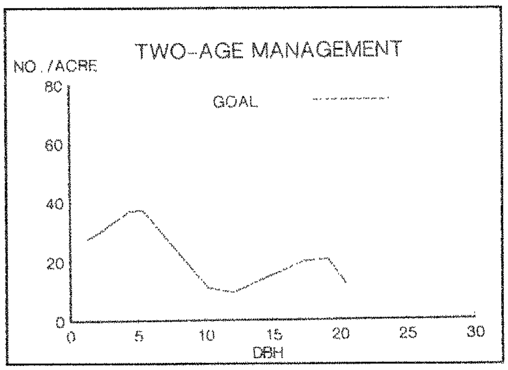
106. A few special considerations apply when individual tree selection is being combined with the removal of groups of trees, as in Management Goal 3. In between groups, the marking procedure and guidelines are the same as those for a strict individual-tree selection cut. But experience and judgment are required for the recognition of potential groups: if two or more larger trees that would normally qualify for removal are rather close together, and if ample seed source or advance regeneration of the desired intermediate and intolerant species exists in the nearby residual, then a group removal may be considered. All trees down to 1 inch should be marked by whatever convention is appropriate to the organization.

NEW TECHNIQUES ARE NEEDED

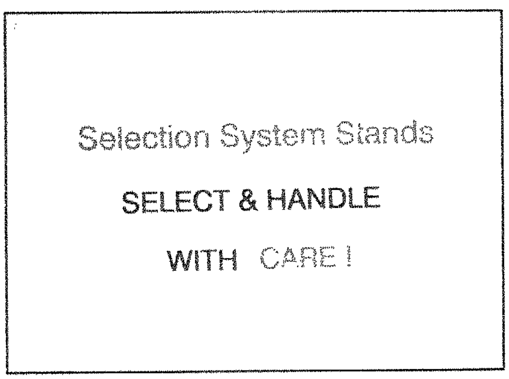
107. We have already alluded to the increased attention being paid to uneven-age management, and maintenance of continuous forest cover, by foresters who work in areas of heavy public use and with private nonindustrial landowners. New techniques are needed to manage forest lands to meet all the objectives of their various constituencies. So, I will briefly mention two modifications of traditional uneven-age management that we are studying. We have installed each of these treatments in three different forest stands, a total of six plots as of 1993, and we are following the growth and regeneration in these trials carefully.



108. The treatment we call economic selection differs from single tree and group selection only in that there is no cutting below 12 inches d.b.h. That is, pulpwood cutting is not required. A structural goal based on 'q' is established and used to control cuts, and density is reduced to about 60 percent after each treatment. This may be more realistic for private landowners, or areas where there is no pulp market. We will have to watch the stands that have been treated in this way for several years before we know how growth and yield of such stands compare with stands that are managed down through the pole class.



109. The treatment that we call two-age management is another alternative that may prove important in types with shade-intolerant species. The concept is to maintain two age classes on a particular site, with their ages one-half rotation apart. For example, in Allegheny hardwoods, with an 80 year rotation, we would initiate this treatment by harvesting the oldest and biggest trees, leaving a relative density of perhaps 35 to 40 percent. A new age class would grow up in the openings created by this radical cutting. Twenty years later, we would thin both age classes. At 40 years, we would harvest the remnant of the residual stand and thin the new age class, leaving, again, 35 to 40 percent density and initiating a new age class. Only time will tell if this fosters the development of shade intolerant species without ever completely removing high forest cover.



110. The increasing multiple-use demands on the forest resource are requiring us to develop greater flexibility and diversity in our "toolkits". Selection-system silviculture can be a valuable tool for certain stands. Those close to high-use corridors or recreation sites may benefit from this system. Those with an existing pool of tolerant species whose site limitations might put productivity at risk in the harsh conditions following even-aged removal may also thrive under a variant of this system. But the most precise overstory prescriptions will not get tolerant regeneration through the pressure of a heavy deer herd, nor will such prescriptions make fern, grasses, or other interfering understory plants disappear. So we recommend that selection system be used with care in its application, and with special care in the selection of stands that will truly prosper under this system.

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SILVAH - Manual Overstory Summary

Stand ID

AGS Size class		BC-WA-YP BA	BC-WA-YP RD	BC-WA-YP BdFt	RM-NRO-EH-Oth BA	RM-NRO-EH-Oth RD	RM-NRO-EH-Oth BdFt	SM-AB-StM-OO BA	SM-AB-StM-OO RD	SM-AB-StM-OO BdFt	All Species AGS BA	All Species AGS RD	All Species AGS BdFt
Saplings	value				1.0	1.2		3.2	3.7		4.2	4.9	
	f		1.44			1.21			1.17				
Poles	value	3.1	1.9		9.0	6.8		11.6	11.5		23.7	20.2	
	f		0.60			0.76			0.99				
Small Saws	value	30.0	11.7	2520	19.5	11.1	1248	5.8	5.5	371	55.3	28.3	4139
	f		0.39	84		0.57	64		0.94	64			
Medium Saws	value	25.8	8.0	3302	2.1	1.0	223				27.9	9.0	3525
	f		0.31	128		0.49	106		0.92	106			
Large Saws	value	.5	0.1	74							0.5	0.1	74
	f		0.27	148		0.44	120		0.91	120			
All Sizes AGS	value	59.4	21.7	5896	31.6	20.1	1471	20.6	20.7	371	111.6	62.5	7738

UGS Size class		BC-WA-YP BA	BC-WA-YP RD	BC-WA-YP BdFt	RM-NRO-EH-Oth BA	RM-NRO-EH-Oth RD	RM-NRO-EH-Oth BdFt	SM-AB-StM-OO BA	SM-AB-StM-OO RD	SM-AB-StM-OO BdFt	All Species UGS BA	All Species UGS RD	All Species UGS BdFt
Saplings	value				1.1	1.3		5.8	6.8		6.9	8.1	
	f		1.44			1.21			1.17				
Poles	value	.5	0.3		3.7	2.8		9.5	9.4		13.7	12.5	
	f		0.60			0.76			0.99				
Small Saws	value	6.8	2.7	286	6.8	3.9	218	4.2	3.9	134	17.8	10.5	638
	f		0.39	42		0.57	32		0.94	32			
Medium Saws	value	4.7	1.5	301	3.2	1.6	170				7.9	3.1	471
	f		0.31	64		0.49	53		0.92	53			
Large Saws	value												
	f		0.27	74		0.44	60		0.91	60			
All Sizes UGS	value	12.0	4.5	587	14.8	9.6	388	19.5	20.1	134	46.3	34.2	1109

Multiply factor (f) by basal area (BA)

AGS + UGS Size class		All Species MDM	MD	BA*f	BA*f	Cords	BA	RD	BdFt
Saplings	value				33.3		11.1	13.0	
	f				3.0				
Poles	value			317.9	317.9	6.7	37.4	32.7	
	f			8.5	3.5	0.18			
Small Saws	value			1060.0	1060.0	16.1	73.1	38.8	4777
	f			14.5	14.5	0.22			
Medium Saws	value			733.9	733.9	8.6	35.8	12.1	3996
	f			20.5	20.5	0.24			
Large Saws	value			13.3	13.3	0.1	0.5	0.1	74
	f			26.5	26.5	0.28			
All Sizes	value	1/(3-4) 14.5	2/3 13.7	2125.1	2158.4	31.5	157.9	96.7	8847

SILVAH - Distribution of Cut Worksheet

Stand ID

USDA, Forest Service, NEFES, Warren, PA 1/91

Size Class	Relative Density: Original Stand (1)	Goal % (2)	Initial Goal (3) 49.9	Adjust (4)	Residual Goal (5)	Cut Goal (6)	Original UGS (7)	Adjust (8)	Total Cut (9)	% Cut (10)	Cut Ratio (11)	Basal Area: Original Stand (12)	Cut (13)	Residual (14)
Saplings	13.0		13.0		13.0		N/A					11.1		11.1
Poles	32.7	41	20.5	✓	20.5	12.2	12.5	+ 0.3	12.5	38	2/5	37.4	14.2	23.2
Small Sawtimber	38.8	37	18.5	✓	18.5	20.3	10.5	-2.3	18.0	46	1/2	73.1	33.6	39.5
Medium Sawtimber	12.1	22	11.0	✓	11.0	1.1	3.1	+2.0	3.1	26	1/4	35.8	9.3	26.5
Large Sawtimber	0.1			✓	0.0	0.1			0.1	100	ALL	0.5	0.5	–
Total	96.7		6.3		62.9	33.8	26.1		33.7			157.9	57.6	100.3
	From Tally Sheet	% from Table 6	All- or Even-aged ?	Record shortages / BALANCE	EA: N/A / AA: 3+4	EA: 3+4 / AA: 1–5	From Tally Sheet	Record excess UGS / BALANCE	6+8	9/1		From Tally Sheet	10*12 / 100	12–13

APPENDIX B.--Cut relative density to come from and relative density to be retained in various size classes, in percent.

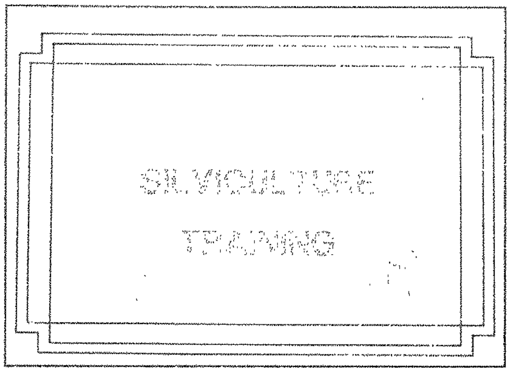
DIAMETER	SAPS	POLES	SSAW	MSAW	LSAW[1]
	EVEN-AGE SILVICULTURE CUT RELATIVE DENSITY TO COME FROM VARIOUS SIZE CLASSES				
MDM	Commercial Thinning and Shelterwood Cutting[2]				
8	--	100	0	0	0
9	--	96	4	0	0
10	--	88	12	0	0
11	--	81	19	0	0
12	--	74	24	2	0
13	--	68	26	6	0
14	--	63	27	10	0
15	--	58	28	13	1
16	--	54	28	14	4
17	--	51	27	15	7
MD	Combined TSI - Commercial Thinning				
4	91	9	0	0	0
5	82	18	0	0	0
6	74	26	0	0	0
7	67	29	4	0	0
8	61	30	9	0	0
9	55	31	14	0	0
10	51	31	15	3	0
	Precommercial Thinning				
--	100	0	0	0	0
	Thin-Harvest				
--	--	50	5	15	30[3]
	ALL-AGE SILVICULTURE RELATIVE DENSITY TO BE RETAINED IN VARIOUS SIZE CLASSES				
	Standard Selection Cutting (Mgmt Goal 3)				
	--[4]	41	37	22	0
	Single-tree Selection Cutting with Maximum Large Trees (Mgmt Goal 4)				
	--[4]	22	30	27	21

[1] For commercial thinning only, take up 50% of original density in large saws and adjust other sizes proportionally.
[2] Note that shelterwood cuts being made in stands that contain 5 or more square feet of basal area per acre in noncommercial (UGS) saplings and poles should include removal of all noncommercial stems (usually by injection with an herbicide) even though no other cutting will occur in the sapling class.
[3] For thin-harvest only, take up 75% of original density in large saws and adjust other sizes proportionally.
[4] In all-age cuts, all existing sapling density is retained.

Source: Marquis, David, A.; Ernst, Richard L.; Stout, Susan L. 1992. Prescribing silvicultural treatments in hardwood stands of the Alleghenies (revised). Gen. Tech. Rep. NE-96. Radnor, PA: U. S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 101 p.

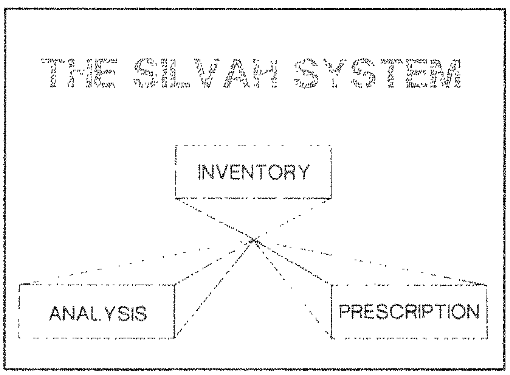
Summary

David A. Marquis

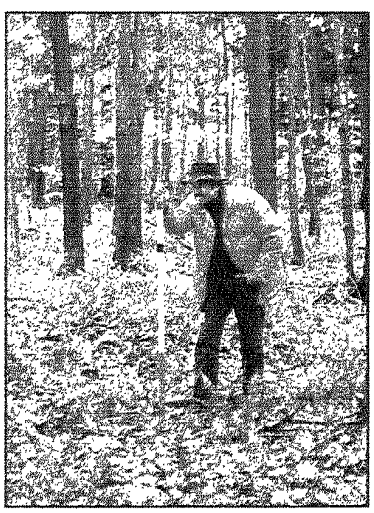


1. This series of articles on "Quantitative Silviculture for Hardwood Forests of the Alleghenies" has summarized both the scientific background and the practical guidelines that constitute the SILVAH stand analysis and prescription system. These papers are based on lectures given during periodic training sessions at the Kane Experimental Forest, Northeastern Forest Experiment Station, near Kane, PA.

   In the training sessions and articles, we have tried to provide a systematic and objective procedure that forest land managers can use to make silvicultural decisions in hardwood forests of the Allegheny region.



2. The SILVAH system involves a three-step process: stand inventory, analysis, and prescription. We have discussed the processes in detail. In the actual training session, we illustrate this approach using several sample stands.



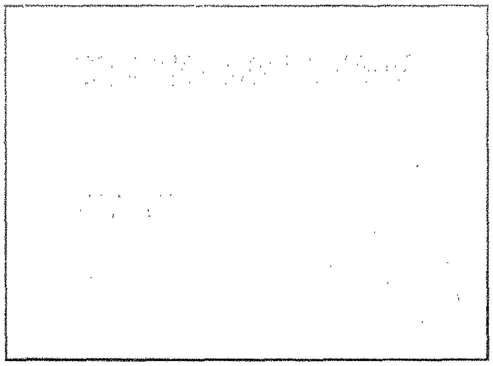
3. The <u>first</u> step is an inventory--a stand examination--during which we collect data on the overstory using a wedge prism to obtain basal area by species, diameter class, quality, and other attributes.

4. We also collect data on the understory, to estimate the amount and nature of advance reproduction,

5. the density of undesirable plants such as fern and grass,

6. or woody undesirables such as striped maple, beech, sassafras, and dogwood

7. or site limiting soil conditions.



8. In the second step, the data collected are used to analyze the stand, to determine the present stand condition, the need for thinning or regeneration, and the potential response to each of these possible treatments.

OVERSTORY ANALYSIS

Stand Diameter

Species Composition

Relative Stand Density

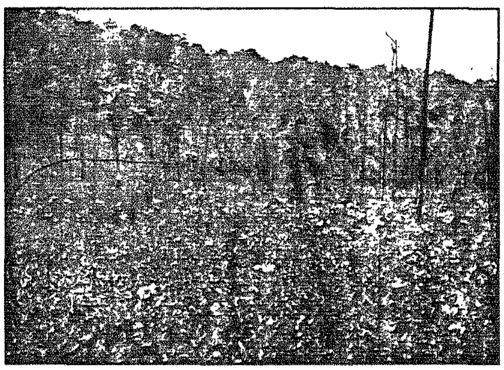
Stand Structure

9. Specifically, the overstory data are used to determine the stand diameter, species composition, relative stand density, and stand structure. These parameters provide insight into how the stand originated and developed, how close it is to maturity, whether it needs thinning to speed it along toward maturity, and whether any cutting would provide volumes and sizes of products that would make an economically feasible cut.

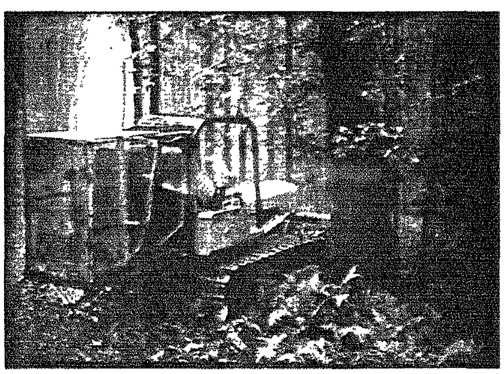
10. The understory data provide information on the potential of the stand to regenerate should a decision be made to harvest the overstory.

11. It provides information that helps predict whether clearcutting will result in good reproduction,

12. whether we can increase the numbers of advance seedlings in stands where they are lacking through shelterwood cutting without running into interference from undesirable plants,

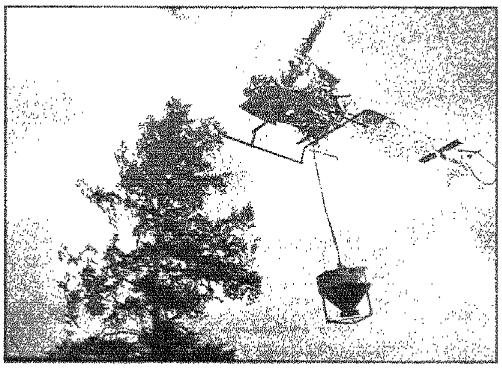


13. and whether reproduction is likely to fail under either method unless we are willing to invest in such treatments as

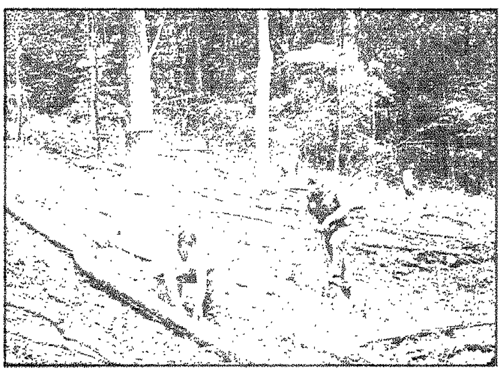


14. herbicide control of undesirables,

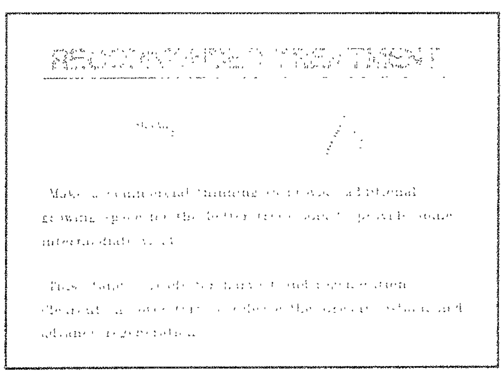
15. fencing to exclude deer,



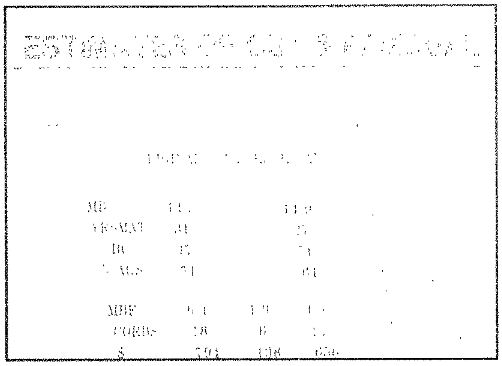
16. fertilization to speed growth of seedlings and get them above the reach of deer quickly, or



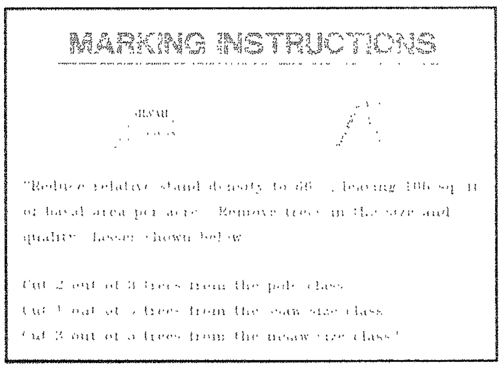
17. planting to augment natural reproduction.



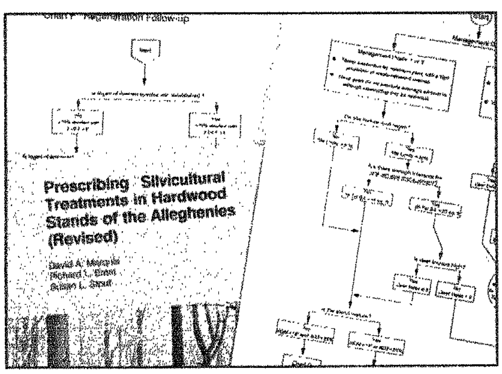
18. In the third step, the information gained from the analysis is used to decide on a course of action. A prescription outlining the work to be done in the stand is written.



19. If a cutting is prescribed, the prescription includes estimates of the cut and residual stands that will result,

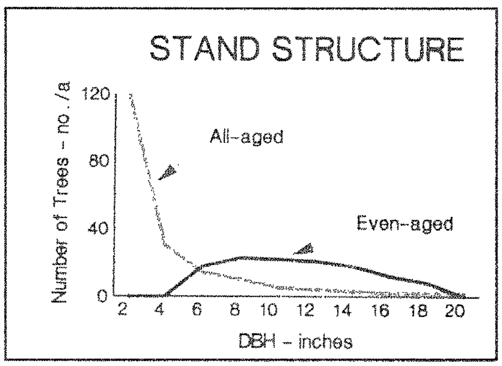


20. and a plan for distribution of that cut among species groups, quality classes, and size classes. This provides the stand marker with the information needed to ensure that the residual density and structure will actually accomplish the goals specified by the prescription.

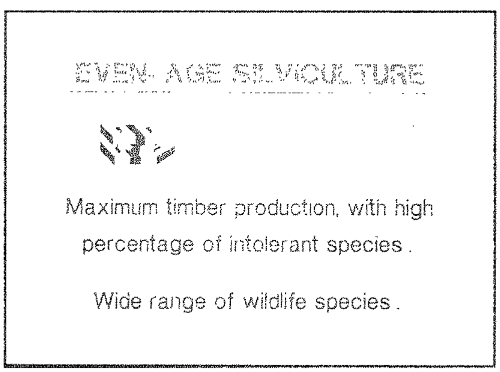


21. The system of stand inventory, analysis, and prescription that we have presented relies heavily on numerical guides to help decide the when, where, how, and how much. These guides must not be used in blind faith, since they represent only our best judgment at the present time; they will undoubtedly be improved and modified as research data accumulate. Furthermore, no guide can ever be perfect and complete for all of the many possible circumstances that you are likely to encounter.

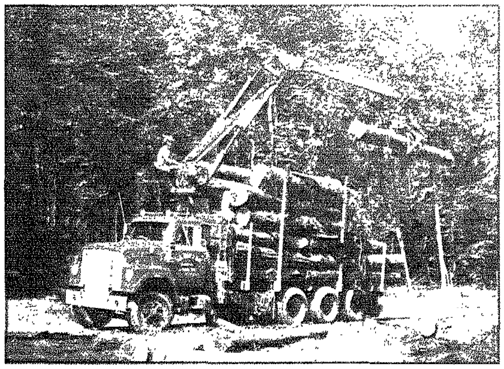
22. So our guides must always be used in combination with a full measure of professional judgment. Nevertheless, we feel that these guides <u>do</u> provide a more objective technique for prescribing stand treatments than has previously been available. We hope that these guides will reduce the amount of subjective judgment required and produce results that are silviculturally sound and consistent--not only from stand to stand but also from person to person, as well.



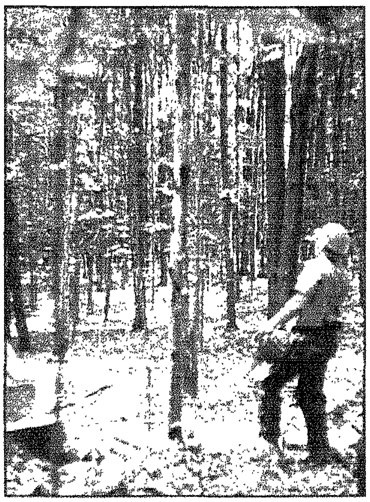
23. We also hope that we have refreshed your memory on the theory behind both all-age and even-age silviculture and their application in Allegheny hardwood, northern hardwood, and oak types.



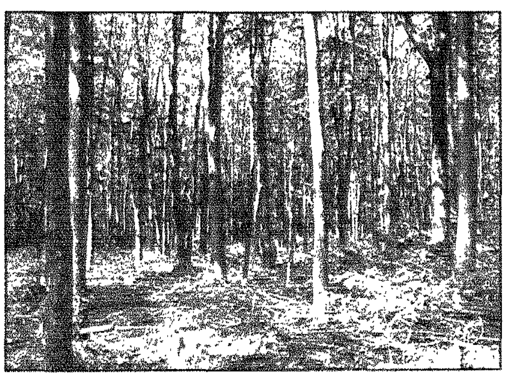
24. Even-age silviculture is used where the landowners' goals call for maximum timber production, because even-age silviculture favors the fast-growing, high-value, shade-intolerant species.



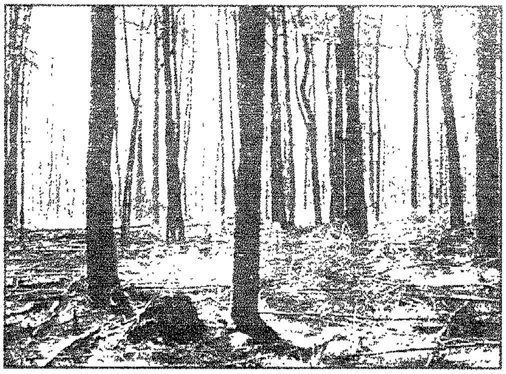
25. The goal under even-aged silviculture is to maximize growth and value,



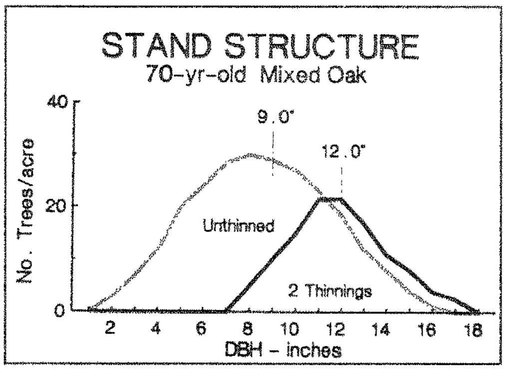
26. by thinning in such a way as to provide for rapid growth of the best trees without reducing total stand growth, and without subjecting trees to loss in quality due to taper, slower pruning, or forking.



27. Normally this means cutting stands back to about 60 percent of average maximum density.

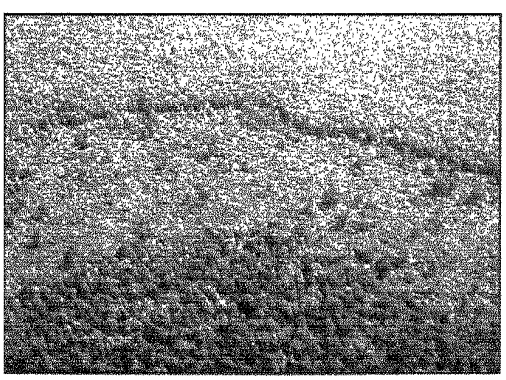


28. Such thinnings should generally occur from below.

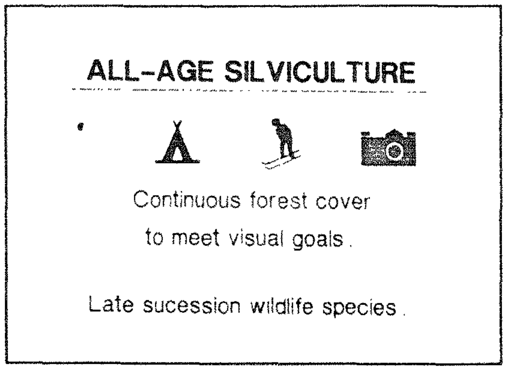


29. so that the stand is moved along toward maturity as rapidly as possible. Although intermediate cuts may not be possible unless they provide a reasonable profit, we must remember that this is not the primary purpose of such thinnings, and that any cut made in such a way as to delay rotations, reduce final values, or increase regeneration difficulties is actually working in opposition to our long- term goals under even-age management.

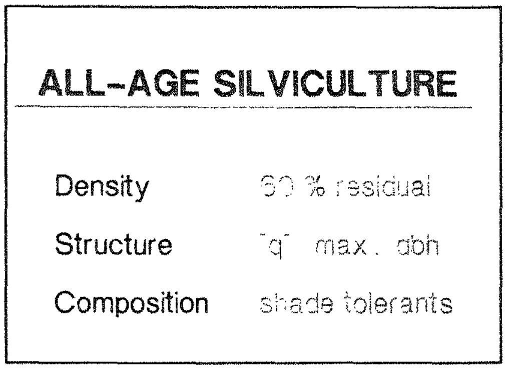
30. Although circumstances may sometimes force you to modify treatments from this theoretical ideal, you should be fully aware of the consequences of that modification on future stand condition and ultimate yield. In many instances, a no cut prescription is better than one that reduces stand diameter and composition of desired species.



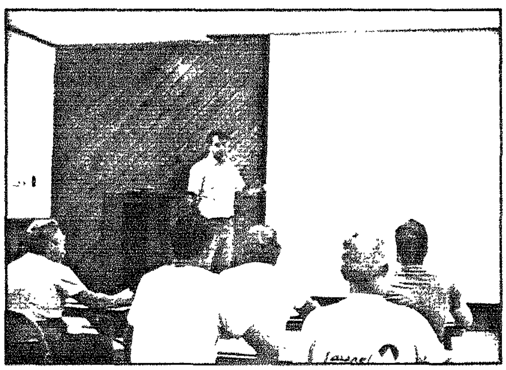
31. And, of course, when the stand finally reaches maturity, our goal is to harvest it and reproduce a new one by means that will provide full stocking of desirable mixed species composition.



32. All-age silviculture is an alternative in stands that contain shade tolerant species, and where management goals make a continuous high forest cover desirable for visual reasons, or to favor particular wildlife species.



33. With all-age silviculture, we regulate stand density, species composition, and stand structure, much as we did with even-age silviculture. The major difference is simply in the type of structure used.



34. We hope the information presented in this series will be useful to forest land managers in the Allegheny forest region, and that the SILVAH system will serve as an example of a quantifiable approach to silvicultural decisionmaking that could be adapted for use in many other forest regions. We are anxious to improve and extend this system, and we welcome any comments or suggestions.