INTENT TO CUT NOTIFICATION

Silvicultural References

Prepared By: Vermont Department of Forests Parks and Recreation
July 1, 1997

INTRODUCTION

This compendium of writings represents several decades of silvicultural research. When each document was published, it contained the best information available on proper management of northern and northeastern forest types. It was designed to provide a guide to foresters and others as to how to best manage for a sustainable future.

The recently enacted heavy cutting legislation and the emergency rules reference these guides. This publication is provided to assist landowners and loggers in preparing harvesting plans in meeting the requirements of the law and the rules.

Brian Stone
Chief of Forest Management
July 2, 1997

AGENCY OF NATURAL RESOURCES
DEPARTMENT OF FORESTS, PARKS AND RECREATION

Silvicultural References

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(1.)

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

by

David A. Marquis[1/]

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

In the discussions that follow, I have plagiarized freely from the ideas of many, but particularly those of Dick Trimble, Bill Leak, and Ben Roach in the eastern United States, and Bob Alexander and Bud Twombly in the West.

Regulation and Control

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

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

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

Most of you are probably familiar with the type of stocking guide developed originally by Sam Gingrich for the oak type in the eastern United States (Gingrich 1967) which shows the normal, full, or A level stocking for stands for varying basal area, numbers of trees, and average diameter (figure 1). These guides are by far the most useful means available to evaluate stocking. The data required for their use are easily collected and the evaluation can be readily made in the field. The A level on these stocking charts represents the normal stocking level of fully stocked stands. The B level is the minimum stocking at which the residual trees fully occupy the site. Total stand growth is about equal anywhere between the A and B levels, but individual tree growth is best at the B level. Stands are normally thinned or selectively cut to leave a residual stand at the B level. In stands below B level, trees are too widely spaced to utilize all the growing space, so the stand is understocked. Stands at the C level will normally grow to B level in 10 years. Thus, the C level is used as an indicator of stands that are so far understocked that they will not be considered for replacement. Similar stocking guides have since been developed for northern hardwoods in New England (Leak et al, 1969a), paper birch in the Northeast (Marquis et al, 1969), spruce--fir in the Northeast (Frank and Bjorkbom 1973), Allegheny hardwood (Roach 1975), and some western types.

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

In mixed hardwood stands of the East, Ben Roach (1975) has found that the various species present have markedly different growing space requirements, so that species composition must be considered in the evaluation of stocking. For ease in field use, he was able to place the various species into one of two species groups based on their growing space requirements (figure 3). Black cherry, white ash, and yellow-poplar require much less growing space than sugar maple, beech and other associated species. Thus, full stocking

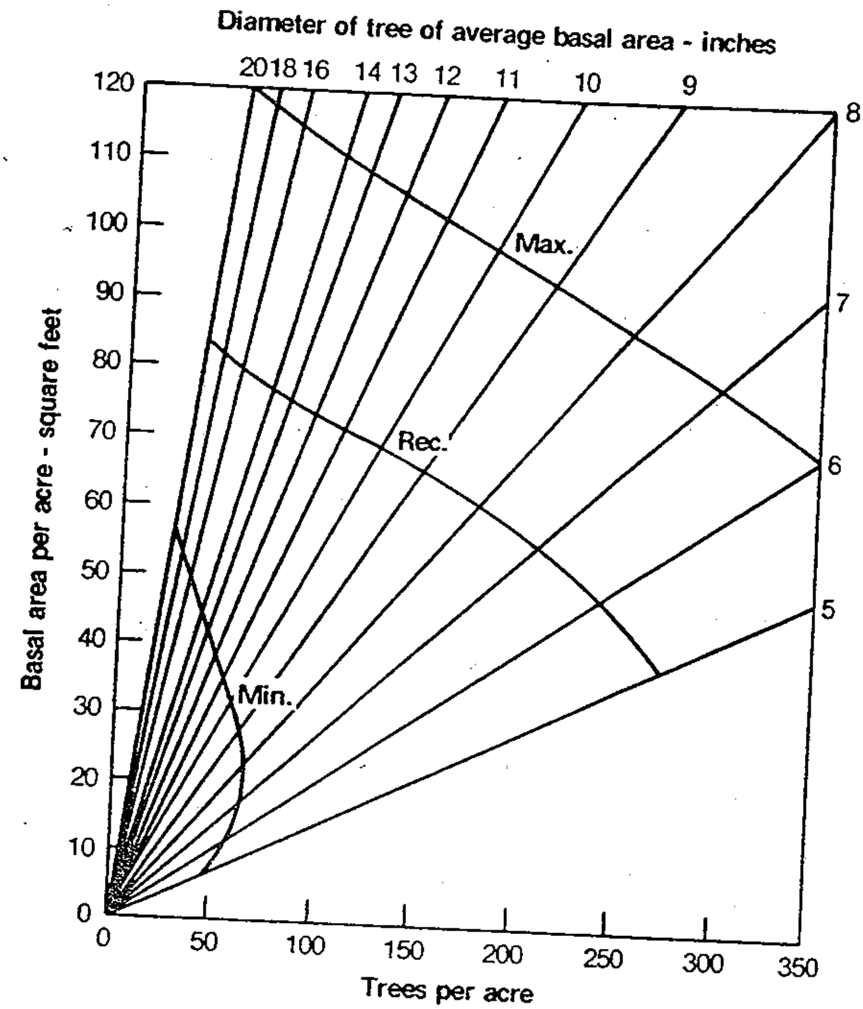

Figure 2.—Ponderosa pine high and medium site

levels are much higher for stands that contain high proportions of cherry, ash, or poplar. For example, a 10-inch diameter stand with no cherry, ash, and poplar could be cut back to 73 square feet of basal area, but a similar stand containing 80 percent black cherry, ash, and poplar should not be reduced below 109 square feet--a difference of 36 square feet. Obviously, the use of a simple basal area recommendation could result in severe over or under cutting in situations such as this.

Ben's stocking charts are the first I know about that have recognized species composition as a factor affecting stocking. But I suggest that the same concept will eventually be extended to other types, especially those containing a mixture of species with widely different tolerance levels and growth rates. Some of the western mixed conifers are likely candidates for this treatment; and in Appalachian hardwoods, it is already recognized that site affects stocking (Trimble et al, 1974)--a large part of this may be due to differences in species composition between sites.

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

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

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

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

Control of Diameter Distribution

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

The most widely accepted procedure for doing this is to utilize the quotient (called "q") between numbers of trees in successive diameter classes as a means of calculating a desired diameter distribution. There is recent evidence that distributions other than q may be advantageous under certain circumstances, but these distributions have not been fully evaluated as yet. So, I shall limit my discussion to the quotient q.

Meyer and others have shown that q tends to be a constant in many undisturbed, uneven-aged stands (Meyer et al, 1952). Thus, if you were to adopt a "q" of 1.3 this means that each diameter class would have 1.3 times as many trees as the next larger diameter class (table 2).

When the number of trees is plotted over diameter class, the distribution calculated using "q" graphs as a curve with a typical inverse-J shape (figure 4). Or, if plotted on semi-log paper, the distribution follows a straight line (figure 5). The distribution can be expressed mathematically by fitting a logarithmic regression to it. When this is done, the slope of the regression equation is equal to "q"; this provides a useful method of calculating the "q" of an actual stand (Leak 1963). Note that this provides the quotient for 1-inch diameter classes. For some strange reason, foresters usually calculate "q" by 2-inch classes. To get "q" for 2-inch classes, square the value for 1-inch classes.

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

Setting Maximum Tree Size Goals

Secondly, you must decide the maximum size tree to be left after each cut. The largest tree to be left may be as low as 18 to 20 inches d.b.h., or as high as 32 or more inches, depending upon site quality, the species involved, the importance of forest uses other than timber production, and the owner's economic objectives for the tract. The best guidelines available for making this decision are probably obtained from financial maturity data. Rate of return information of this sort is available for many eastern hardwoods--

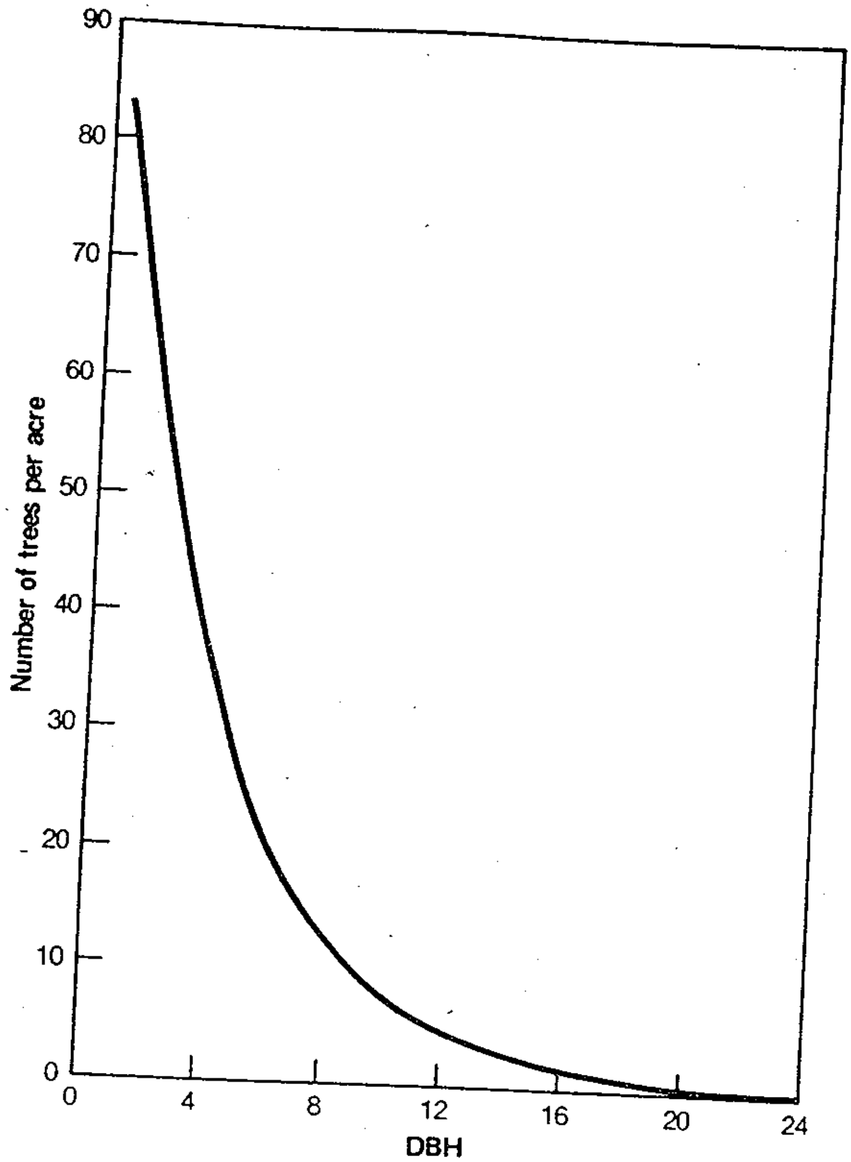

Figure 4.—Diameter distribution for a "q" of 1.3 (1.69), maximum tree size of 24 inches, and residual stocking level of 62 sq. ft. per acre.

northern red oak, white oak, chestnut oak (Trimble and Mendel 1969), black cherry, red maple, white ash (Grisez and Mendel 1972), sugar maple (Mendel et al, 1973), and yellow birch (Leak et al, 1969b). In my limited search, I could not find similar data for western species, but it may well be available. If not, it might be approximated from data on volume growth as a function of d.b.h., plus data on value.

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

Setting "q" Goals

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

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

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

There is no reason to establish an unchanging "q" factor for a particular stand. It is quite reasonable to establish a somewhat high "q" factor

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

	Quotient		
	1.14 (1.3)	1.26 (1.6)	1.41 (2.0)
	Average stand diameter		
D.b.h. group	9.0	6.2	4.4
	- no. trees per acre -		
1-5	81	215	406
6-10	42	66	111
11-16	25	22	21
17-24	13	6	3
All	161	309	541
	- Square feet of basal area per acre -		
1-5	4.2	9.7	12.1
6-10	14.2	21.2	25.4
11-16	23.6	20.4	15.5
17-24	29.1	12.7	5.0
All	71.1	64.0	58.0

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

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

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

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

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

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

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

The data thus collected is summarized, and average diameter and stand stocking determined by calculation or by reading them from stocking charts. The distribution of trees (basal area) by broad diameter classes is also obtained (figure 6).

Stand Prescription and Marking

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

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

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

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

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

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

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

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

The marking instructions thus prepared will pretty well guide the marking team in selecting how many of what size trees to take out. Within these limitations, there will still be some choices to make among trees in a class. The usual sorts of silvicultural or economic guidelines can be superimposed to provide the marker with information he needs for these choices. He would first remove culls, trees with significant defect, trees of low vigor, short-lived species, trees that lack potential to produce high quality logs, etc. He would retain high vigor trees, trees of the more valuable species, trees with potential for an increase in grade, trees with greater merchantable heights, etc.

Keeping the Markers on Target

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

To overcome this problem, it is desirable to have the tallyman of the marking crew periodically stop to take a prism estimate of the residual stand after marking, using a special cumulative tally form. Periodically, dividing the total for each size class by the number of prism points sampled up to that time provides data that can be compared to the goal. Adjustments in marking procedure are made on the basis of this information, and the marking continues through a process of successive approximation (figure 8).

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

Allowable Cut Projections

Allowable cut projections under uneven-aged management are fairly simple in concept. To project the amount that can be removed at the next cut, start with the number of trees and basal area present by diameter class after the current cut. The marking tally, or a special post-logging tally, will provide these data. Apply figures on expected growth by diameter classes to obtain the projected stand at the time of the next cut. The difference between the projected stand and the structural goal is the allowable cut.

The only difficult part about projecting yields by this procedure is the lack of data on growth. Ideally, this would be obtained from semi-permanent growth plots in the stand itself or by stand growth simulation techniques. However, where data to permit this are not available, average figures of growth by size class can often be used to make rough projections.

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

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

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

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

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

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

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

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

1/ Conversions used:

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

Cutting Cycles

The cutting cycle, or interval between cuts, will vary under selection management depending upon growth rate, residual stocking levels selected, site quality, and amount of merchantable volume available for cutting. Cuttings should be timed by the rate of return to full stocking. Cutting should be considered when the stand reaches 80 percent of full stocking, and should generally not be delayed beyond about 90 percent of full stocking. As a general rule, cutting cycles of 15 to 25 years will be appropriate for many forest types.

Cutting Method Options

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

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

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

Because the openings created by cutting of scattered individual trees are usually quite small, reproduction is generally limited to the shade-tolerant species. If single-tree selection cutting is applied in stands that contain intolerants, the species composition of the stand will gradually change as the intolerants are removed and replaced by more tolerant species (U.S. Forest Service, 1973, Trimble 1970, Trimble 1965). Complete conversion may take 50 to several hundred years, but true single-tree selection cutting will eventually produce stands dominated by the most tolerant species that are capable of growing on the site.

The species best adapted to single-tree selection include sugar maple, beech, hemlock, red spruce and balsam fir in the eastern United States, and western hemlock, western redcedar, Pacific silver fir, grand fir, red fir, white fir, subalpine fir, incense cedar, and Engelmann spruce in the western United States. In some types, and under certain stand conditions less tolerant species such as Rocky Mountain Douglas-fir and redwood may also respond to

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

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

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

Group selection cutting in some variation is silviculturally suitable for use in most forest types. Although it may be considerably less efficient for timber production than even-aged management, it would at least permit perpetuation of the present types where some form of uneven-aged management is required to meet aesthetic or recreation objectives. In a recent analysis for the National Forests, it was estimated that over 95 percent of western forests would receive group selection if a choice had to be made between single-tree and group selection (U.S. Forest Service, 1975).

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

only feasible alternatives in such situations. General overmaturity and decadence of many old-growth stands may also dictate even-aged methods (Alexander 1954, 1973, Hatch 1967, Issac 1956).

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

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

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

Owner Objectives Affect Choice of Cutting Method

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

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

Diameter-limit cutting of the type described here should serve about the same purposes as group selection with larger openings. It may be easier

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

Protection of Residual Trees from Logging Damage

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

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

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

The choice of skidding equipment (crawler versus rubber-tired skidders) and the skidding of logs versus tree lengths apparently has less effect on damage to residual trees than commonly supposed. Skidding damage is more frequent along a given length of skid road when rubber-tired skidders are used, but fewer skid roads are required so the total damage balances out.

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

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

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(2.)

A Silvicultural Guide for SPRUCE-FIR in the Northeast

by Robert M. Frank
and John C. Bjorkbom

USDA FOREST SERVICE GENERAL TECHNICAL REPORT NE-6
1973

FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
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CONTENTS

INTRODUCTION

THIS PUBLICATION was developed to answer the need for a silvicultural guide to the management of spruce-fir types in the spruce-fir region of northern New England and New York. Such types occupy 13.4 million acres of land, of which all but 5 percent are privately owned. This guide was designed not only to supplement professional knowledge, but also for the benefit of the many laymen who will find it informative.

The silviculture prescribed is based on achieving maximum production of timber of the desired species and size. This can be done by maintaining stands that fully use the growing capacity of the site, by regular timber-stand-improvement operations, by periodic harvests to achieve rapid growth, and by regeneration methods that will secure adequate reproduction quickly (fig. 1). The guide applies to sites that are reasonably capable of developing naturally into stands containing at least 50 percent of their basal area in spruce-fir. It is not designed for plantations, and caution is advised when applying this guide to pure upland red spruce stands or to pure stands of black spruce.

Silvicultural methods that are compatible with the many land uses other than timber production may require adjustment of the prescriptions in this guide. No general rules are possible because of the variety of circumstances that may be encountered. Each case must be considered individually.

The information contained in the guide is based on a review of literature, current research, consultation with forest managers, and observation. It is not the last word in silvicultural practice; the results of research now

Figure 1.—Spruce and balsam fir reproduction in a small opening in the stand, a common occurrence in the spruce-fir forest.

Soil surface temperatures between 115°F. and 130°F. result in the mortality of most young conifer seedlings even when they are exposed for very short periods of time (*Baker 1929*). Damage caused by late frost to leaders and new lateral growth is seldom severe.

Although seedlings of spruce and fir are similar in many respects, spruce is weaker and more fragile, and grows slower during the establishment period.

Seedlings that have obtained a height of about 6 inches can be considered as being established. Once a seedling becomes established, early growth is determined largely by the amount and character of overhead competition. Dense growth of bracken fern, raspberry, and hardwood sprouts are the chief competitors of seedlings on heavily cutover lands; but both balsam fir and the spruces will survive many years of suppression and still respond to release.

Site Classification

The shade tolerance of spruce and fir and the multiple-aged condition of the stands in which they normally occur make determination of site index difficult. In addition, spruce and fir do not have as wide a range in site index as do many other tree species that grow well on a wide variety of sites. For these reasons, site index as a method of site classification is not used in this guide. However, Meyer's (*1929*) site-index values for various stand types are illustrated below. The figures are based on the average height of dominant and codominant trees at 50 years:

Stand type	*Site-index range*
Primary softwood site:	
Spruce swamp	24 to 35
Spruce flat	27 to 39
Upper spruce slope	up to 35
Old farmland	31 to 44 or more
Secondary softwood site:	
Lower spruce slope	27 to 47
Old farmland	less than 39 to 50

Despite the wide variety of these sites, they can be placed in one of two general classes—primary softwood sites or secondary softwood sites (*Westveld 1941*). These classes are meaningful in terms of potential stand composition, growth, and reproduction.

Primary softwood sites occur under conditions of poor or impeded drainage in the so-called spruce-fir swamps, flats, and other lower topographic positions. Spruce-fir—particularly red spruce—also is common on the thin soils of upper slopes. Characteristic shallow rooting on these soils makes open stands susceptible to windthrow. These sites are composed mostly of softwood species. Hardwoods comprise less than 25 percent of the stand and are mostly paper birch, yellow birch, aspen, red maple, and an occasional beech or sugar maple. Feather mosses, ferns, and numerous herbs make up the low ground vegetation characteristic of these sites.

Secondary softwood sites occur on the better-drained sites of higher topographic positions and on medium-elevation ridge lands. Hardwoods may comprise from 25 percent to as much as 70 percent of stands on these sites, often competing harshly with spruce-fir. However, the tolerant red spruce and balsam fir may become established in the understory, responding to release if the overstory is removed. On such sites, the hardwoods usually are beech, sugar maple, and yellow birch. Herbaceous vegetation is less common than shrubs such as witch hobble (*Viburnum alnifolium* Marsh.), striped maple (*Acer pensylvanicum* L.), and mountain maple (*Acer spicatum* Lam).

Principal Damaging Agents

Many insects and diseases damage spruce and fir. However, spruce is relatively free from these destructive agents until it matures. Fir, at all ages, is more subject to insect and disease attack. Only the more important insects and diseases are mentioned here.

One of the most serious insects is the spruce budworm (*Choristoneura fumiferana* Clemens), a defoliator that attacks both spruce and fir, but prefers fir. Vast outbreaks of this insect in the past have killed millions of cords of pulpwood, primarily in stands containing mature and overmature fir.

The balsam woolly aphid (*Adelges piceae* Ratzeburg), which attacks fir, is an introcies present or adapted to the site. This objective is similar to objective 2, except that where markets are available for associated species of high value, management will be aimed at maximum returns from all species. However, in this guide, management of mixed species is limited to stands in which at least 50 percent of the basal area is spruce-fir. For many stands with less spruce-fir, the silvicultural guides for northern hardwoods or paper birch should be used.

The first three objectives are applicable when timber is the primary product. The fourth objective is necessary because other forest uses—recreation, water, wildlife, esthetics—may be considered primary products rather than byproducts of timber management. Although timber management is normally compatible, these uses of forest lands readily visible from tourist routes and scenic highways, in places adjacent to recreation areas, in roadside and waterside strips, and in watersheds, may well be considered the primary objective.

Objective 4.—Maximum production of the desired product other than timber, including recreation, water, wildlife, and esthetics by silvicultural methods that are compatible with some degree of timber production. To achieve objective 4, considerable adjustment of the prescriptions in this guide will usually be required, especially for even-aged silviculture. State service foresters or consulting foresters can be consulted for additional advice as specific cases are encountered.

SPECIES COMPOSITION GOALS

In stands where balsam fir is susceptible to insect and disease attack, the goal should be to decrease the proportion of fir in spruce-fir stands. This may be hard to do because fir tends to increase in proportion to spruce in second-growth stands. But foresters have been aware for years that the best way to achieve a better balance between spruce and fir is to reduce the amount of fir by harvesting it for pulpwood before it deteriorates. In general, spruce can be held in at least equal ratio to the less desirable fir only if a continuous forest cover and sources of spruce seed are maintained. If the site is producing fast-growing, high-quality fir, then the decision to favor spruce is less absolute. Product objective now enters into the decision-making. And for some uses, fir may even be encouraged.

In spruce-fir stands where hemlock is a significant component, it may be desirable to favor hemlock over fir. Hemlock is less susceptible to insects and diseases and is longer-lived.

Unfavorable site conditions retard the growth of hardwoods more than they retard the growth of spruce and fir. Therefore, on primary softwood sites, spruce and fir should be favored over the hardwoods. On secondary softwood sites, the difference in growth is not so great. On these sites, the greater value of the hardwoods for veneer or sawlogs becomes an important factor; and it may be desirable to favor hardwoods over spruce and fir.

In the final analysis, the forester should work toward creating and maintaining the species composition that best meets the owner's objective within biological and economical limitations.

SILVICULTURAL SYSTEMS

Silvicultural systems for spruce-fir stands lead to either uneven-aged stands or to even-aged stands.

Uneven-aged stands are those in which the trees are of at least three distinct age classes irregularly mixed in the same area (*Society of American Foresters 1950*). Except for very old stands, uneven-aged stands are distinctly irregular in height; and there is great variation in tree size (fig. 2). These stands are developed or maintained by relatively frequent harvests made throughout the rotation. The distribution of diameters in a balanced uneven-aged stand will plot into a characteristically inversed J-shaped curve.

Even-aged stands are those in which the difference between the oldest and the youngest trees does not exceed 10 to 20 years or 25 percent of the length of the rotation. Trees in these stands tend to be rather uniform in height, but they frequently cover a wide range harvest; but in all cases, the eventual goal is a sustained yield of products. Trees should be marked before harvesting. In the initial applications of silvicultural treatments to previously unmanaged stands, the marked trees are usually the undesirable trees that do not meet the quality standards for veneer logs or sawlogs now or prospectively.

The percentage of these undesirable trees diminishes with succeeding harvests. Generally, this is the marking priority: (1) poor-risk trees or those assumed to be doomed before next harvest; (2) poor-quality trees; (3) slow-growing trees; (4) trees of less desirable species; (5) trees whose removal will improve spacing in the reserve stand; and (6) mature trees of good quality, good risk, desirable species, and fast growth. And to make optimum use of growing space, the marking should leave a reasonably even distribution of acceptable trees. These trees are classed as crop trees or potential crop trees and meet product requirements now or are expected to in the future.

Table 3 (appendix) is a suggested tree classification for red spruce and balsam fir that may be used to select trees to be harvested or to be retained. It takes into consideration crown class, vigor, and live-crown ratio and shows the average 10-year diameter growth for trees in each class. Vigor-class definitions are also given in the appendix.

Each periodic operation is a combined harvest, intermediate thinning, and timber-stand improvement because trees in all size classes are included. Therefore there are usually no separate non-commercial thinning operations as in even-aged management, although initial harvest may be unprofitable if a large percentage of defective trees are cut.

When properly employed, the selection method perpetuates a well-stocked stand of the more vigorous, fast-growing, and well-formed trees distributed among all size classes (fig. 4).

Operating Interval

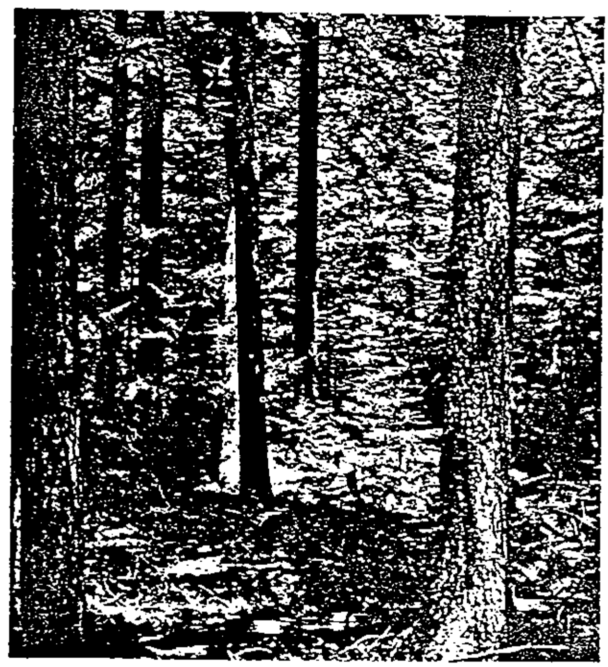
On the better sites and on accessible areas, the operating interval should not exceed 10 to 15 years, especially if the stand runs heavy to balsam fir. On the poorer sites and on less accessible areas, economic considerations may cause the operating interval to be as long as 20 to 25 years, although losses to mortality and defect may be relatively high.

Stocking and Stand Structure

Little research information is available for determining the best stocking and stand-structure goals to work toward in any specific forest situation. Selection of these goals is largely a matter of judgment. Probably there is little difference in growth of stands ranging from less than 75 square feet of basal area to as much as 150 square feet of basal area per acre in trees over 0.5 inches d.b.h. Dense stands heavily thinned to about 50 percent of initial basal area often continue to grow at a rate approximating former growth. Residual trees in these stands usually respond to release and can double and even triple former performance.

Balanced uneven-aged stand structures are presented as tentative goals in table 4 (appendix).

Figure 4.—A well-stocked stand of well-formed trees being perpetuated by the selection method of silviculture.



considered a variant of the shelterwood method.

Clearcutting for regeneration requires that all trees down to 1 or 2 inches in diameter are felled. Because of the large volume of wood removed, this method entails the lowest cost for temporary logging improvements per unit of volume. When properly distributed, clearcutting increases the capacity of the forest property to support wildlife by increasing available browse.

However, clearcut land may be left with limited means for regeneration unless advance reproduction is present, a seed source is available, or immediate planting is carried out. A harsh micro-environment can develop, making regeneration difficult. Slash may smother advance reproduction or hinder the establishment of new seedlings. Slash can also increase the fire hazard. However, slash problems on mechanized operations having a high degree of utilization are minimized because the slash is more evenly distributed and piles containing large materials are not accumulated. Esthetically, a clearcut area may present an unattractive appearance to some people until it greens up with a ground cover of herbs, shrubs, and trees. This process usually takes 2 or 3 years but begins the same year as the harvest.

Some of these disadvantages can be minimized by clearcutting in either alternate or progressive strips or in patches. Openings wider than one tree height are suggested for areas where environmental conditions within the openings will not become too severe for successful regeneration. In these areas, the distance that the seeds are disseminated often regulates the width of the opening. For balsam fir and black spruce, openings should be no more than 2.5 to 3.0 chains wide; and for red spruce and white spruce, they should be no more than 6.0 chains wide.

On hot dry sites and on areas subjected to excessive wind damage, narrow strips or small patches of a width not exceeding half the height of the trees being harvested are necessary to obtain maximum shelter from the residual stand. This procedure should improve seedling survival by providing more moderate surface temperatures and higher soil moisture.

After the initial openings in the stand are regenerated, adjacent areas can be cleared. The second operation will normally take place 3 to 10 years after the first operation. Uncut residual strips or patches should be at least 1 chain wide and preferably wider to help insure windfirmness in the residual trees.

Another desirable procedure for obtaining natural regeneration is the shelterwood system. In this method, at least two harvests are made. The first harvest, made to establish reproduction, should be made in a good seed year. About one-third to one-half of the basal area of the stand should be removed at this time, and the cut should be uniformly distributed. Harvests greater than this might leave the stand susceptible to wind damage. This harvest should remove the least desirable trees, leaving the larger and more vigorous trees of desirable species to provide seed. Factors to consider in tree selection are: susceptibility to wind damage; reduction of seed sources of less desirable species; and the spacing, vigor, and quality of the reserve stand. When the regeneration is well established, the remainder of the original stand can be harvested in one or more operations (fig. 6).

Figure 6.—Shelterwood system being employed in a spruce-fir stand. When the area has regenerated, the residual trees will be harvested.

better drained soils—hardwoods are more aggressive. Much effort is required to bring the spruce and fir through this competition. A management decision must be made about whether to fight these hardwoods or to include them in the next timber crop. The landowner's objective, the relative value of the species involved, and the cost of cleaning operations are factors that enter into this decision. A single cleaning about 8 years after final harvest or when average height is 10 to 12 feet is usually enough to insure softwood dominance and improve individual tree growth, but occasionally follow-up treatments will be needed. Crop-tree spacing should be between 5 and 7 feet. Use the growing-stock guide for sapling stands to estimate the number of crop trees to release.

Current height growth of the spruce-fir is a good indicator of the need for cleaning. As long as terminal growth is greater than 6 inches annually, cleaning is not urgently needed (*Westveld 1953*).

Where spruce and fir are desired and hardwoods are not, spraying with an approved selective silvicide is suggested. This should be done after current spruce-fir growth has hardened off and winter buds have developed, but when the leaves on the hardwoods are still functioning.

Where both softwoods and hardwoods are desired, broadcast spraying of silvicides cannot be used. Treatment of individual stems, either by cutting or by application of approved chemicals, will be necessary to accomplish the cleaning job. Cleaning operations may take from 2 to 8 man-hours per acre, depending on the age of the stand, its composition, and its density.

Stand improvement with the use of mechanized equipment has been tried in other timber types with some success (*Dosen et al. 1958, Lotan 1967, Tackle and Shearer 1959*). The limited experience to date suggests that such an operation is best done in stands with trees between 10 and 20 feet tall. If the minimum width of strips cleared in this way is at least equal to the tree height, then a satisfactory growth response may follow in spruce-fir stands. However, because the techniques are not yet fully developed, specific recommendations cannot be made.

THINNINGS AND INTERMEDIATE HARVESTS

Thinning shortens the time it takes to bring trees to rotation size and also salvages a portion of trees that otherwise would be lost through mortality. Thinning begins with the selection of crop trees or potential crop trees to be carried through to maturity. These trees should be of the most desirable species and of the highest quality. They should be evenly distributed through the stand.

With even-aged management, stands will probably need an initial thinning at 25 to 35 years of age, followed by periodic thinnings or intermediate harvests at 10- to 20-year intervals. When planning these operations, use the B-level in the growing-stock guide (fig. 7)—depending on mean stand diameter—to determine the minimum reserved stocking.

Stands with a high proportion of fir should be thinned first. Those having a high proportion of spruce can be delayed unless competition is severe. The first thinning may be a pre-commercial one, but succeeding thinnings should yield commercial harvests (at least 5 cords per acre). Remove fir and retain spruce if the quality of fir is below that of the spruce or if spruce is being favored over fir. In stands containing hemlock, favor hemlock over fir if the quality of the fir is poor.

Timber removals for thinnings or for intermediate harvests on primary softwood sites should not exceed 10 to 40 percent of the total basal area. For secondary softwood sites, 30 to 50 percent may be removed at any one time. Removals in excess of these amounts may result in substantial wind damage. Amounts to remove vary with conditions of the site. These percentages should take precedent over removals specified by the B-level in the growing-stock guide.

Growth responses to thinning in white spruce trees approaching maturity are significant when trees are released on at least three sides to a distance equal to crown diameter of the tree being released (*Frank 1973*). Similar thinning regimes are recommended at this time for other spruce and for fir.

red spruce in the Northeast are given in table 1 (*Meyer 1929*). Because the yield relationship between sites and for stands within sites is not distinct, there is an overlapping of various sites and stand types for specific yield values. The yield values in table 1 are given for four combinations of sites and stand types. These yields are from so-called normal unmanaged stands. Yields from stands under a management scheme including periodic harvests or thinnings would be substantially higher over a rotation.

In general, stands fully stocked to spruce-fir on secondary softwood sites will yield greater volumes of wood than will similar stands on primary softwood sites.

SILVICULTURAL PRESCRIPTIONS

Stand Diagnosis

Before silvicultural prescriptions can be written for a stand, the management objective must be decided upon, and the stand must be described.

The limits of the stand to be considered and treated as separate entities must be delineated. The area included should be small enough to have reasonably similar stand and site conditions throughout, yet large enough to permit efficient harvesting.

Once the boundaries are known, then the stand diagnosis can be made.

Reproduction Stands

These stands are made up of stems at least 6 inches tall, but the mean stand diameter is less than 0.5 inches. Stems may be of seedling or sprout origin.

Percentage of stocking is needed for diagnosis. To determine the percentage of stocking in stands 10 acres and larger, locate randomly or systematically at least one milacre plot (3.72 feet in radius or 6.6 feet square) per acre. In stands smaller than 10 acres, locate a minimum of 10 milacre plots.

Tally each of these sample plots in one or more of the following stocking classes:

Stocking class 1.—Stocked with at least two spruce or fir trees.

Stocking class 2.—Stocked with at least one spruce or one fir and one other commercial species or stocked with at least two other commercial species.

Stocking class 3.—Not stocked.

In a reproduction stand, a stocked plot is one in which there is a minimum of two stems. For a plot to be tallied in stocking class 1, both stems must be spruce-fir, otherwise the tally will be in stocking class 2. A plot will be tallied as stocking class 3 if the above requirements are not met.

To determine the percentage of stocking, divide the number of plots in each stocking class by the total number of milacre plots and multiply by 100. A tally sheet for recording this information is given as figure 8 (appendix).

Table 1.—Cubic-foot yield per acre of fully stocked, even-aged stands of second-growth red spruce[a] in the Northeast by stand age, site, and stand type

Age (years)	Secondary softwood site (lower slopes, old farmland)	Primary softwood site (flats, old farmland); and secondary softwood site (lower slopes, old farmland)	Primary softwood site (swamps, flats, upper slopes, old farmland); and secondary softwood site (lower slopes)	Primary softwood site (swamps, upper slopes)
	Cu. ft.	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*
40	1,650	1,110	600	138
50	3,770	2,760	1,670	480
60	5,550	4,200	2,750	940
70	6,620	5,150	3,470	1,400
80	7,280	5,700	3,920	1,670
90	7,650	6,000	4,160	1,800
100	7,870	6,190	4,310	1,900

[a] Based on the merchantable cubic-foot volume in trees in the 4-inch and larger diameter classes from a 1-foot stump to a top of 3 inches inside bark.

appropriate local volume table to the number of trees per acre by species and diameter class as shown on the tally sheet.

Next, complete the stand-diagnosis form (fig. 10, appendix). Then refer to the key to find the suggested prescription.

UNEVEN-AGED MANAGEMENT

Tally all trees in the 1-inch and larger diameter classes. If uneven-aged stands are being converted to even-aged strands, an estimate of reproduction and sapling stems is also required. Use the tally form (fig. 9) for recording these data.

Next, transfer the number of trees per acre by diameter classes from the tally sheet (fig. 9) to the stand-diagnosis form (fig. 11, appendix). Determine basal area per acre by diameter class and enter in the stand-diagnosis form. Also enter the data from the proper columns in table 4 for the operating interval desired. Be sure to use the data for the appropriate management objective.

Finally, use the following key to find the suggested prescription. For prescriptions 7, 8, 9, and 10, the differences by d.b.h. class that are excess may be harvested or removed in a timber-stand-improvement operation. But the total amount removed should not exceed the total differences between the stand estimate of basal area and the goal. Nor should the amount removed result in a stand susceptible to excessive wind damage.

THE KEY

I. Reproduction and Sapling Stands

Mean Stand Diameter Less Than 4.5 Inches

Stand Condition	*Prescription*
A. Mean stand diameter less than 0.5 inches	
B. Primary softwood site	
C. 50 percent or more of milacre sample plots are stocked with spruce-fir reproduction	1
CC. Fewer than 50 percent of milacre sample plots are stocked with spruce-fir reproduction	2
BB. Secondary softwood site	
D. 50 percent or more of milacre sample plots are stocked with spruce-fir reproduction	3
DD. Fewer than 50 percent of milacre sample plots are stocked with spruce-fir reproduction but total stocking is 50 percent or more	4
DDD. Total stocking of reproduction is less than 50 percent	2
AA. Mean stand diameter between 0.5 and 4.5 inches	
E. Primary softwood site	
F. 50 percent or more of milacre sample plots are stocked with spruce-fir saplings	5
FF. Fewer than 50 percent of milacre sample plots are stocked with spruce-fir saplings	2
EE. Secondary softwood site	

Stand Condition	*Prescription*
I. 50 percent or more of milacre sample plots are stocked with spruce-fir reproduction	11
II. Fewer than 50 percent of milacre sample plots are stocked with spruce-fir reproduction	12
HH. Secondary softwood site	
J. 50 percent or more of milacre sample plots are stocked with spruce-fir reproduction	11
JJ. Fewer than 50 percent of milacre sample plots are stocked with spruce-fir reproduction but total stocking is 50 percent or more	13
JJJ. Total stocking of reproduction is less than 50 percent	12
AA. Even-aged stand	
K. For maintaining even-aged stand condition	
L. Primary softwood site	
M. Mature stand	
N. 50 percent or more of milacre sample plots are stocked with spruce-fir reproduction	11
NN. Fewer than 50 percent of milacre sample plots are stocked with spruce-fir reproduction	
O. Growing stock above the B-level	12
OO. Growing stock below the B-level	14
MM. Immature stand	
P. Growing stock above the B-level	15
PP. Growing stock below the B-level	16
LL. Secondary softwood site	
Q. Mature stand	
R. 50 percent or more of milacre sample plots are stocked with spruce-fir reproduction	11
RR. Fewer than 50 percent of milacre sample plots are stocked with spruce-fir reproduction but total stocking may be 50 percent or more	
S. Growing stock above the B-level	13
SS. Growing stock below the B-level	17

commercial harvest should be conducted in a good spruce or fir seed year. The seed crop can take advantage of the opening of the stand and of any seedbed scarification that has occurred. Depending on site, the harvest should not remove more than 10 to 50 percent of the total basal area per acre; and at least 80 to 120 square feet of basal area per acre should be retained. If this minimum amount of residual growing stock is not possible because of poor quality, consider converting to even-aged silviculture. Examine again at the end of the operating interval.

8. Consider timber-stand improvement to favor crop trees of desired species. Examine in about 10 years.

9. If the management decision is to favor spruce-fir and the spruce-fir growing-stock component is adequate for management, use the stand-diagnosis form (fig. 11, appendix) to determine what diameter classes are overstocked. Mark heavier in these classes and keep spacing in mind, using the marking guides and table 3, appendix. Examine in about 10 years. If the spruce-fir growing stock component is not considered adequate, convert to even-aged silviculture. If the decision is to manage for all species, see the Silvicultural Guide for Northern Hardwoods in the Northeast or for Paper Birch in the Northeast.

10. If the management decision is to favor spruce-fir, begin a timber-stand-improvement operation to favor crop trees of desired species and to remove undesirable trees. Examine in about 10 years. If the spruce-fir component is not considered adequate, convert to even-aged silviculture. If the decision is to manage for all species, see the Silvicultural Guide for Northern Hardwoods in the Northeast or for Paper Birch in the Northeast.

11. Harvest all merchantable trees and fell all other trees 1 to 2 inches and larger in diameter. The size and shape of the clearings selected should provide environmental conditions suitable for natural regeneration. Examine in about 5 years.

12. To obtain spruce-fir regeneration, apply the first harvest of a shelterwood cutting or clearcut narrow strips. If artificial regeneration is necessary, clearcut and prepare the site; and direct-seed or plant spruce or fir on those areas not stocked with spruce-fir. In either case, examine in about 5 years.

13. If the management decision is to regenerate spruce-fir, remove a portion of the trees by applying the first harvest of a shelterwood cutting or clearcut narrow strips. Consider preparing the site, and direct-seed or plant spruce or fir on areas not stocked with spruce-fir reproduction. Hardwood sprouts may have to be controlled. Examine in about 5 years. If the decision is to manage for all species, harvest all merchantable trees and fell all other trees 1 to 2 inches and larger in diameter. The size and shape of the clearings selected should provide environmental conditions suitable for natural regeneration. Examine in about 5 years. If hardwoods account for 50 percent or more of the stocking in reproduction, see the Silvicultural Guide for Northern Hardwoods in the Northeast or for Paper Birch in the Northeast.

14. To obtain spruce-fir regeneration in a reasonable period of time, artificial methods are probably necessary. Clearcut, then prepare the site and direct-seed or plant spruce or fir on areas not stocked with spruce-fir. Examine in about 5 years.

15. Begin a periodic harvest program if a commercial harvest is feasible. Otherwise consider a timber-stand-improvement operation. Examine in about 10 years or at the next operating interval.

16. Consider a timber-stand-improvement operation. Otherwise do nothing now. Examine in about 10 years. If growing stock is below the C-level, consider preparing the site; and direct-seed or plant spruce or fir on areas not stocked with spruce-fir. Examine in about 5 years.

17. If the management decision is to regenerate spruce-fir, harvest all merchantable trees and fell all other trees 1 to 2 inches and larger in diameter. Then prepare the

Vigor Class Definitions*

Vigor I

Crown well developed, usually symmetrical; no dead branches in live crown. *Branches* long and slender, up-turned at least 15 degrees from horizontal except near bottom of crown; recent terminal and lateral growth good (at least 8 inches and averaging 10-12 inches except in heavy seed year). *Needles* long and lustrous, bluish-green for fir and slightly yellowish-green for spruce, growing densely on twigs; and on fir up-turned instead of flat on twigs. *Bark* on fir light gray, tight, smooth, and shiny, with many pitch blisters; on spruce, reddish and shredded on young trees, in large, thin, loose plates on mature trees.

Vigor II

Crown of poorer form than in Vigor I but giving the general impression of being healthy without making rapid growth; if large, crown may be fairly open, but if small, should be fairly dense; dead branches in crown limited to a few small ones. *Branches* may be shorter and less slender than in Vigor I but not stubby and heavy; horizontal or slightly drooping except may be slightly up-turned near top; terminal and lateral twig growth last few years usually fair to good (3 to 8 inches, except somewhat less during heavy seed years) although slow growth is admissible if crown form is otherwise good. *Needles* flattened on fir twigs and a deeper green with less bluish cast and not so dense on twigs as in Vigor I; spruce needles shorter, less lustrous and not so closely spaced on twigs. *Bark* on fir usually smooth, dirty gray, not shiny, pitch blisters less conspicuous; on spruce, rougher and more brownish on young trees, darker brown and with plates smaller and tighter than on Vigor I trees.

Vigor III

Crown of poor form (open, one-sided or thin), but not dying; may have dead branches in live crown. Branches may be short and stout, or if slender, foliage very sparse, horizontal or more commonly drooping, especially at tips; terminal and lateral growth very poor (less than 3 inches), except may occasionally be fair on trees with otherwise poorly developed crowns. *Needles* flat on fir twigs, widely spaced, often dull, unhealthy color; on spruce, short, not lustrous, and frequently yellowish, very slender and brittle, and appearing sparse or scattered on twigs. *Bark* on fir dark gray or almost brown, thick, rough and often broken into small scales on old trees, dirty dull gray on young trees, never smooth and shiny, pitch blisters inconspicuous or lacking; on spruce, dark brown to almost black, with scales smaller and heavier on young trees, thick, ridged, and fissured, and often reddish brown on old trees.

* McLintock, T. F. 1958. A tree classification for red spruce and balsam fir. U. S. Forest Service NE. Forest Exp. Sta. office report, 33 p.

Table 2.—Some silvical characteristics of balsam fir and the spruces

Species	Relative shade tolerance	Relative growth rate	Good cone crop frequency	Effective seed dispersal
			Years	*Feet*
Balsam fir	Very tolerant	Fast	2-4	100
Black spruce	Tolerant	Slow-medium	4	100
White spruce	Tolerant	Fast	2-6	300
Red spruce	Tolerant to very tolerant	Medium	3-8	200

Table 4.—Stocking goals for uneven-aged stands at the start of 5-, 10-, and 20-year operating intervals, by management objective, number of trees per acre, and basal area per acre

D.b.h. class (inches)	Management objective 1: Pulpwood product; Operating interval						Management objectives 2, 3, and 4: Multiple product; Operating interval					
	5-year		10-year		20-year		5-year		10-year		20-year	
	Trees	Basal area	Trees	Basal area	Trees	Basal area	Trees	Basal area	Trees	Basal area	Trees	Basal area
	No.	*Sq. ft.*	*No.*	*Sq. ft.*	*No.*	*Sq. ft.*	*No.*	*Sq. ft.*	*No.*	*Sq. ft.*	*No.*	*Sq. ft.*
1	514	3	459	2	370	2	173	1	153	1	122	1
2	343	8	306	7	246	5	135	3	118	3	96	2
3	229	11	204	10	164	8	104	5	92	5	74	4
4	152	13	136	12	110	10	80	7	70	6	57	5
5	102	14	91	12	73	10	61	8	54	7	44	6
6	68	13	60	12	49	10	47	9	41	8	33	7
7	45	12	40	11	32	9	36	10	32	9	26	7
8	30	10	27	9	22	8	28	10	25	9	20	7
9	20	9	18	8	14	6	21	9	19	8	16	7
10	13	7	12	7	10	5	16	9	14	7	12	6
11	9	6	8	5	6	4	13	8	11	7	9	6
12	6	5	5	4	4	3	10	8	9	7	7	6
13	4	4	4	3	—	—	7	7	6	6	5	5
14	3	3	2	3	—	—	6	6	5	6	4	4
15	2	2	—	—	—	—	4	5	4	5	3	4
16	—	—	—	—	—	—	3	5	3	4	2	3
17	—	—	—	—	—	—	3	4	2	4	—	—
18	—	—	—	—	—	—	2	3	2	3	—	—
19	—	—	—	—	—	—	1	3	—	—	—	—
Total	1,540	120	1,372	105	1,100	80	750	120	660	105	530	80

Table 6.—Horizontal distances to borderline trees when using a 10-factor prism or angle gauge for trees 0.5 inches d.b.h. to 19.4 inches d.b.h.

D.b.h. (inches)	Distance (feet)	D.b.h. (inches)	Distance (feet)	D.b.h. (inches)	Distance (feet)	D.b.h. (inches)	Distance (feet)	D.b.h. (inches)	Distance (feet)
0.5	1.37	4.3	11.82	8.1	22.27	11.9	32.72	15.7	43.17
0.6	1.65	4.4	12.10	8.2	22.55	12.0	33.00	15.8	43.45
0.7	1.92	4.5	12.37	8.3	22.82	12.1	33.27	15.9	43.72
0.8	2.20	4.6	12.65	8.4	23.10	12.2	33.55	16.0	44.00
0.9	2.47	4.7	12.92	8.5	23.37	12.3	33.82	16.1	44.27
1.0	2.75	4.8	13.20	8.6	23.65	12.4	34.10	16.2	44.55
1.1	3.02	4.9	13.47	8.7	23.92	12.5	34.37	16.3	44.82
1.2	3.30	5.0	13.75	8.8	24.20	12.6	34.65	16.4	45.10
1.3	3.57	5.1	14.02	8.9	24.47	12.7	34.92	16.5	45.37
1.4	3.85	5.2	14.30	9.0	24.75	12.8	35.20	16.6	45.65
1.5	4.12	5.3	14.57	9.1	25.02	12.9	35.47	16.7	45.92
1.6	4.40	5.4	14.85	9.2	25.30	13.0	35.75	16.8	46.20
1.7	4.67	5.5	15.12	9.3	25.57	13.1	36.02	16.9	46.47
1.8	4.95	5.6	15.40	9.4	25.85	13.2	36.30	17.0	46.75
1.9	5.22	5.7	15.67	9.5	26.12	13.3	36.57	17.1	47.02
2.0	5.50	5.8	15.95	9.6	26.40	13.4	36.85	17.2	47.30
2.1	5.77	5.9	16.22	9.7	26.67	13.5	37.12	17.3	47.57
2.2	6.05	6.0	16.50	9.8	26.95	13.6	37.40	17.4	47.85
2.3	6.32	6.1	16.77	9.9	27.22	13.7	37.67	17.5	48.12
2.4	6.60	6.2	17.05	10.0	27.50	13.8	37.95	17.6	48.40
2.5	6.87	6.3	17.32	10.1	27.77	13.9	38.22	17.7	48.67
2.6	7.15	6.4	17.60	10.2	28.05	14.0	38.50	17.8	48.95
2.7	7.42	6.5	17.87	10.3	28.32	14.1	38.77	17.9	49.22
2.8	7.70	6.6	18.15	10.4	28.60	14.2	39.05	18.0	49.50
2.9	7.97	6.7	18.42	10.5	28.87	14.3	39.32	18.1	49.77
3.0	8.25	6.8	18.70	10.6	29.15	14.4	39.60	18.2	50.05
3.1	8.52	6.9	18.97	10.7	29.42	14.5	39.87	18.3	50.32
3.2	8.80	7.0	19.25	10.8	29.70	14.6	40.15	18.4	50.60
3.3	9.07	7.1	19.52	10.9	29.97	14.7	40.42	18.5	50.87
3.4	9.35	7.2	19.80	11.0	30.25	14.8	40.70	18.6	51.15
3.5	9.62	7.3	20.07	11.1	30.52	14.9	40.97	18.7	51.42
3.6	9.90	7.4	20.35	11.2	30.80	15.0	41.25	18.8	51.70
3.7	10.17	7.5	20.62	11.3	31.07	15.1	41.52	18.9	51.97
3.8	10.45	7.6	20.90	11.4	31.35	15.2	41.80	19.0	52.25
3.9	10.72	7.7	21.17	11.5	31.62	15.3	42.07	19.1	52.52
4.0	11.00	7.8	21.45	11.6	31.90	15.4	42.34	19.2	52.80
4.1	11.27	7.9	21.72	11.7	32.17	15.5	42.62	19.3	53.07
4.2	11.55	8.0	22.00	11.8	32.45	15.6	42.90	19.4	53.35

Note: Borderline distances for trees larger than 19.4 inches d.b.h. can be calculated by multiplying d.b.h. by 2.75.

TALLY SHEET FOR

POLETIMBER AND SAWTIMBER STANDS

Stand Condition:

☐ Even-aged

☐ Mature

☐ Immature

☐ Uneven-aged

Type of Management:

☐ Even-aged management

☐ Uneven-aged management

Softwood site:

☐ Primary

☐ Secondary

D.b.h. class	Fir	Spruce	Other softwood	Paper birch	Other hardwood	Tree count	Conversion factor	Number Trees per acre
1							1,833	
2							458	
3							204	
4							115	
5							73	
6							51	
7							37.4	
8							28.6	
9							22.6	
10							18.3	
11							15.2	
12							12.7	
13							10.8	
14							9.4	
15							8.2	
16							7.2	
17							6.3	
18							5.7	
19							5.1	
20							4.6	
21							4.2	
22							3.8	
23							3.5	
TOTAL								

No. of sample points: ______

Milacres stocked:*	No.	%
Spruce-fir	____	____
Other species	____	____
Total stocked	____	____
Milacres not stocked	____	____
Total milacres	____	____

*Milacres stocked should be tallied when: (a) uneven-aged stands are to be placed under even-aged management; (b) even-aged management is to be maintained in mature even-aged stands.

Figure 9.—A tally sheet for poletimber and sawtimber stands.

STAND-DIAGNOSIS FORM FOR UNEVEN-AGED MANAGEMENT

Management objective: ______________________________

D.b.h. class (inches)	Number of trees per acre				Sq. ft. of basal area per acre			
	Tally sheet	Table 4 goal	Difference +	-	Tally sheet	Table 4 goal	Difference +	-
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
21								
22								
23								
TOTAL								

Computed amount of growing stock to be removed: __________ sq. ft. per acre

Prescription: ______________________________

Figure 11.—A stand-diagnosis form for uneven-aged management.

#3

UNEVEN-AGED MANAGEMENT OF NORTHERN HARDWOODS IN NEW ENGLAND

by William B. Leak and Stanley M. Filip

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UNEVEN-AGED MANAGEMENT OF NORTHERN HARDWOODS IN NEW ENGLAND

CONTENTS

UNEVEN-AGED MANAGEMENT implemented by the selection system of cutting, has been recommended for handling certain northern hardwood forests in New England. During the past 17 years, the Northeastern Forest Experiment Station has issued three summary papers that deal with aspects of the management of uneven-aged northern hardwoods *(Gilbert and Jensen 1958, Leak and others 1969, Filip 1973)*. However, most of this earlier work dealt with silvicultural aspects rather than the entire managerial job of growing the timber, controlling the yields, and removing the products through an uneven-aged system. Furthermore, the traditional approach to uneven-aged management — single-tree selection coupled with biologically based structural goals—can be broadened to better meet current needs.

Three main issues must be examined by a forest manager in deciding whether or how to adopt uneven-aged management. First, he must decide upon a harvest-cutting method based primarily upon regeneration objectives and cost considerations. Second, he must decide how to control the yields, which involves setting residual stand objectives, marking stands, and predicting future yields. Third, he must decide how the timber will be removed; and then he must develop a transportation plan suited to the harvesting equipment.

These three questions will be examined in depth in this paper, providing a basis for setting up an uneven-aged management program for northern hardwoods. Because each forest property is unique, methodology will be stressed. However, applicable data and examples will be given where possible. Material that is readily available in other summary bulletins or as common professional knowledge will not be presented.

CHOICE OF CUTTING METHOD

The choice of an appropriate cutting method depends upon an understanding of the underlying differences between even-aged and uneven-aged management. The basis of even-aged management is this: the forest is (or will be) composed of reasonably even-aged stands of sufficient acreage so that they can be surveyed (mapped) and relocated. Under even-aged management, the appropriate harvest cutting methods—clearcutting, shelterwood, and seed-tree—are those that create new even-aged stands of sufficient acreage. The minimum acreage to qualify as *sufficient* is unique to each property and is difficult to define. On large properties in the northern hardwood region of New England, the minimum size of a stand seems to lie between 10 and 40 acres.

In contrast, forests under uneven-aged management are split into recognizable and relocatable stands on some basis other than age class. The basis for stand differentiation can be forest type, site, logging conditions, or some combination of these factors; but we do not keep track of acreages by stand age class because it is infeasible to do so. The appropriate harvest cutting methods are those that attain growth, quality, and species objectives without produc-

Table 1.—Species composition[1] based on the tallest commercial stem per milacre plot[2]

Cutting method	Tolerants	Inter-mediates	Intol-erants
	Percent		
Single-tree selection	81-92	7-18	1
Selection openings .01 acre +	68-80	18-31	1-2
Small patches .1 to .6 acre	62-77	7-34	4-16

[1] Tolerants are beech, sugar maple, eastern hemlock, and red spruce; intermediates yellow birch, white ash, and red maple; intolerant paper birch.
[2] Leak and Wilson 1958, Leak 1959, and Marquis 1965.

of some young regeneration together with the establishment of some new stems right after cutting—partly because of increased scarification from logging disturbance. Indications are that a conscious effort toward group selection—even using small groups containing only a few trees—will produce a marked increase in the proportion of intermediates as compared to standard single-tree selection. Maintenance of this initial advantage in species composition will require repeated release, especially of the smaller groups, during successive cutting cycles.

Although degree of cutting and size of opening have an important influence on the proportions of tolerant, intermediate, and intolerant species, it is important to realize that site factors will influence the regeneration of individual species within tolerance groups. Efforts are now under way to correlate soils and species in New England forest stands, and some general relationships already are emerging *(Lanier 1974)*. Loose to firm soils derived from glacial till commonly support typical northern hardwoods. Glacial-till soils underlain at about 3 feet or less with a hardpan support a fairly rich species mixture of both softwoods and hardwoods—possibly because such areas exhibit such a wide range in drainage. Outwash soils—sands and gravels—often contain high proportions of red spruce and white pine where the drainage is good, and higher amounts of balsam-fir where the drainage is poorer.

Much more information is needed about species/soils relationships. Until such information is available, however, the successional tendencies of a stand can sometimes be determined by careful field examination, with particular emphasis on understory development following past disturbance from cutting or natural causes. It is important to realize that the effects of cutting method on regeneration may be limited by soil and site conditions.

Harvest Costs Related to Cutting Method

A complete cost-and-return analysis of the various uneven-aged management options will

Table 2.—Species composition by cutting method and canopy opening, based on tallest commercial stem per milacre plot. Regeneration 3 feet tall to 1.5 inches dbh 7½ years after cutting (Leak 1959).

Cutting method and residual basal area	Canopy opening, size	Beech	Sugar maple	Eastern hemlock	Red spruce	Yellow birch	White ash	Red maple	Paper birch
					Percent				
Liquidation: 38 square feet	All	26	17	9	3	16	16	7	6
Diameter-limit: 64 square feet	.01 acre +	32	13	19	6	19	1	3	7
	Less than .01 acre	40	6	38	12	2	1	1	—
Moderate selection: 83 square feet	.01 acre +	38	20	8	1	16	11	4	2
	Less than .01 acre	63	15	15	4	2	1	—	—
Light selection: 95 square feet	.01 acre +	39	11	26	4	11	7	—	2
	Less than .01 acre	50	11	26	8	1	4	—	—

ence between current structure and residual structure is the current yield of the stand. And, finally, growth must be projected several years (the cutting cycle) into the future to determine future structure. The difference between future structure and residual structure is the projected allowable harvest for that stand. Summation of allowable harvest by projected harvest dates for all stands or compartments in the forest produces an allowable harvest schedule for the forest.

Stand Structure Guides

The establishment of an appropriate residual structure for a stand is perhaps the most critical step in the regulation process because it has a very important bearing on the efficiency and productivity of uneven-aged management.

To allow for continuous yields, numbers of trees over dbh class must follow something approaching a reverse-J-shaped form. However, the exact form of the diameter distribution will vary depending upon regeneration, mortality, and cutting rates. A well-known theory of population dynamics indicates that any population subject to a consistent schedule of birth and death rates (including removals) will develop a stable (constant-shaped) age distribution curve.

When that population reaches a point where regeneration equals losses, the age distribution becomes stationary or constant *(Keyfitz 1968)*. Simulation work with northern hardwood stands *(Adams and Ek 1974)* illustrates how this principle may apply in practice to uneven-aged stands: constant or sustainable size (rather than age) distributions were derived for a range of residual basal areas and harvest options, some based on cutting through only the upper (sawlog) end of the diameter distribution. Apparently, sustained production from uneven-aged stands can be obtained by cutting through all or only part of the diameter distribution, provided that adequate regeneration is obtained to sustain the distribution. The decision on cutting policy would depend upon a careful analysis of the economics and markets involved. The appropriate residual stand structure would vary for each harvesting option.

In developing structural guidelines, we should not plan to keep in the residual stand trees that are well beyond their financial maturity. Growing hardwoods to very large sizes is not economical in stands devoted primarily to timber production.

Developing guidelines for the lower end of the structure is problematical. On the one hand, it might seem reasonable to maintain small numbers of 6- and 8-inch trees so that only a minimum volume of residual growing stock is in unmerchantable trees. However, northern hardwood stands have high regenerative potential. In cut stands, there is a tendency for the numbers of smaller stems to increase rapidly. So, the maintenance of small numbers of unmerchantable stems requires a commitment to cultural or marginal work in the smaller sizes.

Cultural work in understory trees generally is less beneficial to the residual stand than cultural work in the overstory. In typical uneven-aged stands maintained by single-tree selection, the 6- to 8-inch and smaller trees tend to be in the understory. However, where group or patch selection is practiced, there are better possibilities for cultural work in the areas of essentially even-aged young growth. So the feasibility of maintaining smaller-than-natural numbers of marginal or unmerchantable stems depends upon a commitment to cultural work which, in turn, is made more feasible by the maintenance of a group- or patch-wise distribution of size classes.

The concept of q *(Meyer 1952)*—the quotient between numbers of trees in successive 2-inch dbh classes—has traditionally been used to define stand structure for uneven-aged management. As discussed earlier, population theory and simulated results *(Adams and Ek 1974)* indicate that optimum residual structure may not follow the q distribution very well. However, when used with flexibility, q still remains as the best general method for defining residual structural goals.

Past recommendations indicate that northern hardwoods become financially mature at not larger than 20 to 22 inches dbh—often smaller—and that optimum residual stocking lies somewhere between 70 and 80 square feet

Table 5.—Examples of the basal areas and volumes removed per acre for two residual stocking alternatives

Dbh class (inches)	Initial stand		q = 2.0				q = 1.6			
			Residual		Cut		Residual		Cut	
	Trees	Basal area	Trees	Basal area	Basal area	Volume	Trees	Basal area	Basal area	Volume
	No.	*Sq. ft.*	*No.*	*Sq. ft.*	*Sq. ft.*	*Bd. ft.*	*No.*	*Sq. ft.*	*Sq. ft.*	*Bd. ft.*
6	94.7	18.56	92.0	18.04	0.52	—	73.2	14.34	4.22	—
8	53.9	18.81	46.0	16.06	2.75	—	40.6	14.18	4.63	—
10	27.0	14.72	23.0	12.54	2.18	—	27.6	12.31	2.41	—
12	27.2	21.35	11.5	9.03	12.32	1,539	12.5	9.84	11.51	1,441
14	16.1	17.21	5.8	6.15	11.06	1,638	7.0	7.45	9.76	1,447
16	7.2	10.05	2.9	4.01	6.04	968	3.9	5.41	4.64	742
18	4.9	8.66	1.4	2.54	6.12	1,054	2.2	3.80	4.86	813
20	1.6	3.49	.7	1.57	1.92	339	1.2	2.61	.88	151
22	.5	1.43	.4	.95	.48	47	.7	1.76	—	—
All	233.1	114.3	183.7	70.9	43.4	5,585	163.9	71.7	42.9	4,594

of basal area per acre *(Leak and others 1969)*. Table 4 gives minimum residual structural goals for a range in q. As q increases, the number and proportion of small trees increase. The acceptance of a 20-inch upper limit provides for 70 square feet of residual basal area while a 22-inch upper limit provides for a little more. These suggested structures should be used flexibly. In some cases, one q might be applied to the sawtimber sizes, and another q might be used to guide the marking in the poletimber sizes. Some of the possibilities are best illustrated by example.

In table 5, figures are given for an initial stand that averages 114.3 square feet of basal area and therefore can support a harvest cutting. This is an actual 40-acre stand on the Bartlett Experiment Forest, about 100 years old. Although the stand structure follows a fairly typical reverse-J form, the trees actually occur in a patch-like arrangement due to patch cuttings several years earlier.

One option in marking this stand would be to assume that little or no work will be done in the 8-inch class and smaller. Although 6- and 8-inch trees contain some merchantable material, the harvesting of these sizes would be a marginal operation, more like a cultural treatment than a harvesting operation. Under this option, the appropriate residual structure is one that will concentrate the cutting in the larger sizes, 10 inches and over. The appropriate choice is q = 2.0. Notice that a residual q of 1.9 (table 4) or less would require more and more cultural work in the 6- and 8-inch classes. By subtracting the residual goal for q = 2.0 from the initial stand and using local volume tables, and basal area and volume to be removed in each dbh class is easily determined. Note that the goal can be met by removing very little from the 6- and 8-inch classes (table 5).

Under more intensive management, some marginal or cultural work in the 6- and 8-inch classes and smaller might be contemplated. The decision to invest in such work would be based upon site and quality considerations, and also upon an evaluation of whether these smaller sizes did in fact occur in group- or patch-wise arrangements. Under this option, a residual structure of q = 1.8 would work well; q = 1.9 could also be considered. However, low q values of 1.4 or 1.5 could not be considered for an immediate goal. Such low q distributions would not only require heavy treatment in the small sizes—which might or might not be justified: they simply could not be met in the larger sizes because of a lack of trees.

cultural needs of the stand. Periodically, the tallyman will take a 10-factor prism estimate of the *residual stand after marking*. Trees will be recorded by 2-inch dbh classes on a standard cumulative tally sheet. Very little time is required to take these plots, so it seems quite feasible to take two or three plots per hour on a fixed time schedule. It is very important to take the plots systematically regardless of stand conditions, presence of patches or groups, etc.

Periodically, the prism tally is converted to trees per acre, and the average prism estimate is compared to the structural goal:

D.b.h. (inches)	*Goal (No. trees)*	*Residual stand (prism) (No. trees)*
6	44	28
8	30	25
10	20	22
12	13	17
14	9	6
16	6	6
18	4	4
20	3	3
22	2	—

In this hypothetical case, the obvious trend has been to mark too many 6-, 8-, and 14-inch trees; marking trees 16 inches dbh and larger is all right except for some apparent overmarking in the 22-inch class. The tallyman should discuss these trends with the markers so that an attempt will be made to bend the actual residual back toward the goal. The next check on marking practice will indicate whether progress is being made or whether additional changes are needed.

By this process of successive checks and revision, the average per-acre residual should come fairly close to the goal. Although this approach results in some degree of unevenness in marking procedure, remember that the primary purpose of structural control is to regulate yields from the stand rather than to ensure uniform silvicultural treatment. In reasonably homogeneous stands, successive prism estimates of the residual stand after marking converge fairly rapidly to a constant structure. Notice in table 6 that the average prism tally had settled down to a fairly constant structure by the time nine plots had been taken.

Table 6.—Successive prism estimates of the residual stand per acre after marking a 37-acre northern hardwood stand

Dbh class (inches)	Number of prism plots			
	5	9	15	21
	No. trees	*No. trees*	*No. trees*	*No. trees*
6	41	28	24	29
8	11	25	25	25
10	22	22	24	24
12	25	17	18	16
14	9	6	8	7
16	3	6	7	8
18	5	4	4	5
20	4	3	2	2
22	—	—	—	—
24	—	—	.2	.1

Some markers prefer to combine 2-inch diameter classes into 4-inch classes for purposes of marking control. Reducing the number of classes simplifies the marking procedure.

Cultural needs in groups or patches of young growth, and cull removal, probably should be marked during the regular marking operation. Trees smaller than 6 inches can be marked, although it does not seem feasible under current conditions to keep records on numbers of residual stems smaller than 6 inches, especially by prism methods. A complete tally of marked unmerchantable stems should be taken as a basis for estimating cultural costs. The actual cultural operation might be performed during the logging job or later as a separate operation.

Allowable Harvest Projection

Under uneven-aged management of northern hardwoods, the projection of allowable harvest is simple in concept. Begin with the residual structure after a marking or cutting operation. The prism tally used for the marking operation can meet this need, or a more detailed post-logging inventory that accounts for marked-but-not-cut, cut-but-not-marked, and damaged trees. Increases in basal area and numbers of trees are projected by dbh classes over the next cutting cycle—recommended as 12 to 20 by northern hardwoods of 120 to 130 square feet of basal area; at these high densities, natural mortality is high.

In general, northern hardwood stands that have been cut to residual basal areas of 70 to 80 square feet should produce 2.0 to 2.3 square feet of basal area per acre annually over the next 10- to 20-year period, unless complications arise from insect-disease attack.

The next important consideration in projecting growth is how to distribute anticipated basal-area production between poletimber and sawtimber. The distribution of growth depends upon stand density and stand structure. In table 8, notice that stands having more than 100 square feet basal area produce 80 to 100 percent of their growth in sawtimber trees, 10.5 or 11.0 inches dbh or larger, regardless of structural differences in percentage of sawtimber.

In stands of 60 to 100 square feet of basal area and 25 to 50 percent of sawtimber (q = 1.7+), roughly 50 to 70 percent of the growth is in sawtimber trees (table 8). These stands with high q and low percentage of sawtimber are typical of second-growth even-aged stands 80 to 100 years old. Under 50 to 70 percent sawtimber, represented by a q of 1.4 to 1.6, the percentage of basal area growth in sawtimber trees ranges from about 60 to 80 percent. Note that the percentage of growth in sawtimber trees appears to increase only moderately as the percentage of sawtimber increases to 70 to 90 percent. Apparently a q of 1.4 to 1.6 will result in only a little less sawtimber production than a q of 1.3 or less.

Table 8.—Approximate percentage of basal growth in sawtimber trees (10.5 or 11.0 inches dbh and larger) by basal area per acre and percentage of sawtimber[1]

Percent sawtimber	Basal area in square feet per acre	
	60 to 100	100+
	Percent	*Percent*
25-50 (q = 1.7+)	50-70	100
50-70 (q = 1.4-1.6)	60-80	95-100
70-90 (q = 1.3 and less)	70-85	80+

[1] Based on summarization and rounding-off of data reported by Blum *(1960)*, Filip and others *(1960)*, Filip *(1972)*, Leak *(1961)*, and unpublished data.

An example of a projection of allowable harvest based on reported growth figures is given in table 9 for the same stand tabulated in table 7. An annual basal area growth of 2.0 square feet per acre is assumed. Since the initial stand contains 57 percent sawtimber, we assumed that the percentage of growth in sawtimber trees would lie between 60 to 80 percent, or about 70 percent (table 8). The growth was then distributed among dbh classes within sawtimber and poletimber in proportion to the initial basal area per class. Then the calculations follow those in table 7. In this particular case, the estimated allowable harvest based on reported growth figures (table 9) came out roughly the same as allowable harvest based on actual compartment growth (table 7).

TRANSPORTATION

One of the most important obstacles to economical uneven-aged management is the cost of developing and maintaining an adequate transportation system. In terms of cost, the truck-road system is the most important consideration and will be discussed first. Following that, some suggestions will be given on the skidding and harvesting phases.

Truck Roads

Under even-aged management, based on clearcutting, the cost of building truck roads to the landing or landings can be spread over the entire merchantable volume found on the cutting area. After the clearcutting, no truck road access may be needed until the first commercial thinnings are made perhaps 60 years later.

Uneven-aged management in northern hardwoods requires truck-road access every 12 to 20 years (the cutting cycle) to landings located within skidding distance of all sections of the stand or compartment. Because of frequent use, the only feasible approach in uneven-aged management is to set up permanent truck roads to service all areas of the stand or compartment. These roads need not be maintained annually, but they will need to be opened up and repaired as necessary for each cut.

The number and location of truck roads depends upon the maximum feasible skidding distance, which in turn depends upon current and future equipment. Past experience on the Bartlett Experiment Forest with tractor-arch combinations indicates that skidding distances up to 1,500 feet are reasonable *(Filip 1967)*. With recent and expected advances in equipment, perhaps this figure could be increased somewhat. But using 1,500 feet as an example, we think that the truck roads could be located so that each serves a strip about 3,000 feet wide. On this basis, a mile of truck road could service about 350 to 400 acres of the stand. On the first entry into the stand, the primary financial consideration is to determine to what extent stumpage returns from 350 to 400 acres will cover the costs of building 1 mile of a certain standard of road. On reentries into the stand, the same question would be applied to the costs of reopening and repairing the permanent road.

For example: the 5.5 Mbf of sawtimber to be harvested per acre from the stand represented in table 5 might bring a stumpage value of $40 per M, or $220 per acre. This amounts to $88,000 to balance against the cost of building or reopening 1 mile of road.

Skidroads

Two types of skidroads must be considered. The main skidroads are constructed by bulldozing. Most of the timber from a given section of the sale comes down the main skidroad. The secondary skidroads commonly consist of natural paths or corridors in the woods through which tree lengths are skidded and winched to the main skidroad.

The main skidroads should be laid out, following the usual precautions, in advance of the logging operation. These roads should provide ready access to the marked timber, especially to concentrations of timber marked in groups or patches. Grades should be gradual —less than 20 percent in most cases—to reduce erosion hazards. Uphill skidding should be avoided, although some uphill winching is feasible. Since the skidding operation may seriously damage up to 5 percent of the residual stand *(Nyland and Gabriel 1972)*, special precautions should be taken to minimize such damage. The skidroads should be as straight as possible, because much of the serious damage occurs on sharp turns. Where a turn or switchback is required, it should be located where the margins of the turn are bordered by mature trees that will be removed during the sale or left indefinitely. Furthermore, the roads should be reasonably wide—depending upon equipment and size of timber to be removed—to help eliminate damage to border trees.

The number and spacing of main skidroads depends heavily upon terrain and equipment. Some past experience indicates that skidding-winching distances of 300 to 400 feet from the main skidroad are reasonable *(Trimble and Barr 1960)*. Since uphill skidding is not very feasible, this means that main skidroads should not be spaced more than about 500 feet apart.

In most cases, the main skidroads will be used again and again for successive cuttings. However, for each cutting, some rerouting will be necessary to avoid patches of good regeneration and to provide good access to concentrations of marked timber.

The secondary skidroads, which generally require no bulldozing, are located as needed by the skidder operators. These skidroads are used to move small amounts of timber to the main skidroads, and are not subject to heavy traffic.

Harvesting

Felling operations cause more damage to the residual stand—up to 12 percent—than any other operation *(Nyland and Gabriel 1972)*. Special efforts should be made to prevent this kind of injury.

The use of group and patch selection should help to prevent damage to the residual stand because trees can be felled toward the center of the opening rather than into the residual stand. There is some precedence for this point of view, although comparative data are not yet available *(Smith 1962)*. In fact, one of the criteria in selecting and marking groups should be the control of logging damage. For example, if a mature tree cannot be felled without damaging several adjacent trees, the entire group probably should be taken.

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FOREST SERVICE, U.S. DEPT. OF AGRICULTURE, 6816 MARKET STREET, UPPER DARBY, PA. 19082

A STOCKING GUIDE FOR EASTERN WHITE PINE

Abstract. — A stocking chart for eastern white pine is presented and described. The chart shows basal areas and numbers of trees by mean stand diameter, representing the upper limit in stocking for practical management (A curve) and minimum stocking for full site utilization (B curve).

Eastern white pine (*Pinus strobus* L.) is one of the most important timber species in New England—it accounts for about one-fifth of the board-foot volume. Although some studies on thinning have been made, foresters lack a practical guide for thinning white pine. The stocking guide for white pine presented in this paper is similar to those for hardwoods described by Gingrich (*1964*) and Leak, Solomon, and Filip (*1969*). Detailed techniques in developing the white pine guide were given by Philbrook (*1971*).

Description of Guide

The stocking guide (fig. 1) applies to nearly pure even-aged white pine stands. The guide shows an A curve, a B curve, basal area per acre, number of trees per acre, and mean d.b.h. for trees in the main crown canopy. The A curve represents 80 percent of full stocking, based on Frothingham's (*1914*) yield data. Because most natural stands contain openings and, therefore, trees are not as well spaced as in yield study data, the A curve was considered the upper limit in stocking for practical management. The B curve represents minimum stocking for full site utilization. Stands above the A curve are overstocked, stands between the A and B curves are adequately stocked, and stands below the B curve are understocked.

Under most conditions, stands are considered for thinning when stocking is more than halfway between the A and B curves. Stocking after thinning should be near the B curve. If the stand was originally near (or above) the A curve, it would be best to bring the stand down near the B curve in several successive thinnings. After thinning, the stand should consist of well-spaced, good quality trees with crowns large enough for vigorous tree growth.

An Example

Assume that we have a stand containing 110 square feet of basal area per acre and having a mean stand diameter of 8 inches. We plot a point for this stand in figure 2. Because the point is near the B curve, we allow the stand to grow toward the A curve. The stand grows until it reaches 165 square feet of basal area and a mean diameter of 10.0 inches (indicated by the solid line in figure 2). Then we decide to thin, and we cut the stand back to a basal area of 116 square feet and a mean diameter of 9.2 inches (dotted line).

The mean stand diameter was reduced from 10.0 to 9.2 inches presumably because some large, poor quality trees were cut. The stand grows to 200 square feet of basal area per acre and a mean diameter of 13.4 inches (solid line). We thin a second time. After thinning, the stand contains 140 square feet of basal area per acre and has a mean diameter of 13.9 inches (dotted line). Then the stand grows to 222 square feet of basal area per acre and a mean stand diameter of 18.0 inches. At this time, we might consider a harvest cut.

Of course, the example given is hypothetical. A forester would have considerable flexibility in using the guide.

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A SILVICULTURAL GUIDE FOR WHITE PINE IN THE NORTHEAST

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INTRODUCTION

SINCE COLONIAL TIMES, eastern white pine has made significant contributions to the economy of the Northeast. For many years, this species was the primary building material in that region.

Although its economic importance has diminished in recent years because of limited volumes and quality, white pine is still in strong demand for use in construction lumber, furniture, doors, window sashes, and other products. Because it is relatively strong, light, stable, and easily worked, white pine will always have a prominent spot in the marketplace.

It is believed by some that white pine cannot succeed itself. This is partially true, for white pine usually does not replace white pine without the application of management practices. White pine seedlings grow very slowly; few exceed a height of 1 foot in 5 years. By contrast, hardwood seedlings and seedling sprouts grow rapidly; this gives the broadleaf species an immediate advantage that results in complete dominance on most sites—especially on the better ones—after a harvest.

It is well known that after the initial period of slow growth, white pine grows faster, sustains rapid growth over a longer period, and yields more volume per acre than stands of other species. But we are not capitalizing on this potential. Too many of our pine stands are harvested with little regard for the particular needs of white pine reproduction. As a result, the very existence of white pine as an important component of our forests is threatened.

This guide points out special measures required to regenerate and to grow white pine, and encourages a wider application of these rarely used management practices.

GROWTH AND DEVELOPMENT OF WHITE PINE

Seed production

White pine begins to bear cones before it is 20 years old. Its optimum seed-bearing age is between 50 and 150 years. Abundant cone crops may occur only once every 3 to 5 years; white pine cones require 2 years to mature. By the fall of the first year, the cones are 1 to 2 inches long. The cones reach their full length—5 to 11 inches—early in the summer of the second year, if there is no infestation by the white pine cone beetle, which can cause extensive damage to the second-year cone crop. By knowing a year in advance that there will be a seed crop, the land manager gains valuable lead time in scheduling harvest cuts.

Seedling development

Good seed germination and seedling growth do not require full sunlight. Although seedlings grow rapidly under full light, many may die because of high surface-soil temperatures. Seedlings under a full canopy of pine, the shade of hardwood seedlings, or tall vegetation such as goldenrod or fire weed, also have a high mortality rate because of insufficient light and an inability to compete for available moisture.

A light intensity greater than 20 percent of full light—but less than full sunlight—will prevent seedling losses due to high surface-soil temperatures, yet support vigorous seedling growth.

A seed bed of exposed mineral soil is the best medium for the germination, growth, and survival of seedlings because of the capacity of mineral soil for holding moisture. Seedlings that develop in a seed bed of mineral soil that is protected from full sunlight rarely die because of high temperatures or insufficient moisture.

Site consideration

White pine can be grown on nearly every soil within its range; the heavy clayey soils are exceptions. Because competition from hardwoods is an important factor in establishing pine, the choice to manage for pine must be made with this consideration in mind. Hardwoods offer the least competition on excessively drained and well-drained sandy soils, and on droughty, loamy sands. On stony loams, silty loams, and glacial tills with good or impeded drainage, hardwoods are more aggressive and usually will predominate unless special measures are taken.

There are no hard and fast rules for selecting a forested site for hardwood or white pine management. Over a rotation, white pine will outgrow the hardwoods on the poor and the good sites. But, because of unfavorable economics of trying to grow pine on good hardwood sites, the wisest decision might be to manage for pine on the poorer or lighter soils (strong pine land) and for hardwoods on the heavier soils (strong hardwood land). This practice not only will provide good representation of hardwood and white pine, but also will ease the task of developing a greater proportion of white pine (Lutz et al. 1947).

The literature suggests that the breaking point between strong pine land and strong hardwood land-falls close to a site index of 60 for hardwoods. This value is not fixed or exact because there are indications that pine lands in some areas of the Northeast have a site-index value close to 65. There also are areas with a lower value.

The important point is that, for sound management, a breaking point should be established, and that it is safe to expect that this point will fall within site indexes 55 to 65 for hardwoods. The two broad site classes established here serve as a guide in deciding to manage for white pine or hardwoods; they should be adjusted for local conditions. The site indexes for hardwoods include northern hardwoods and oaks.

Site class 60+ (site index 60 or greater)

On the best sites—site index 70 or greater—stands should be allowed to revert to hardwoods, and cultural measures that favor the development of quality hardwood sawtimber should be used. The medium sites, site index 60 to 69, are best suited for growing mixtures of pine and hardwoods. Without management, medium sites will revert to hardwoods regardless of the amount of pine in the existing stand. To develop a new mixed stand, a shelterwood cut applied at the time of the final harvest should ensure that some pine is established. What usually happens is that white pine becomes established in groups mostly on those areas that are less suited for hardwoods (Lutz et al. 1947).

The group arrangement of white pine and hardwoods provides a preferred method of management whereby treatments are directed toward releasing the entire group rather than individual stems. This approach will ensure good representation of pine in the new stand as long as the white pine groups are freed of overtopping hardwoods periodically during the first 25 years

Site class 59 or less (site index 59 or less)

These poorer sites are best suited for growing white pine rather than hardwoods. Because hardwoods are less aggressive and easier to control on these sites, managing for pure stands of white pine is economically feasible.

Many of these sites have reverted to hardwoods (usually oak) because of an absence of management. The use of cultural measures that ensure the development of white pine rather than hardwoods on poorer sites is a paying proposition that should rate top priority.

Site-index comparisons

Although a comparison of site indexes for white pine and hardwoods would be useful in making good decisions in the field, there has been little work in this area. Foster's (1959) comparison of site indexes for red maple and white pine indicated little difference between the species (Fig. 1). As an example, his comparison curves show a white pine site index of 59 at age 50 (number of rings at breast height) compared to a red maple site index of 57. The curves cross at a site index value of about 62.

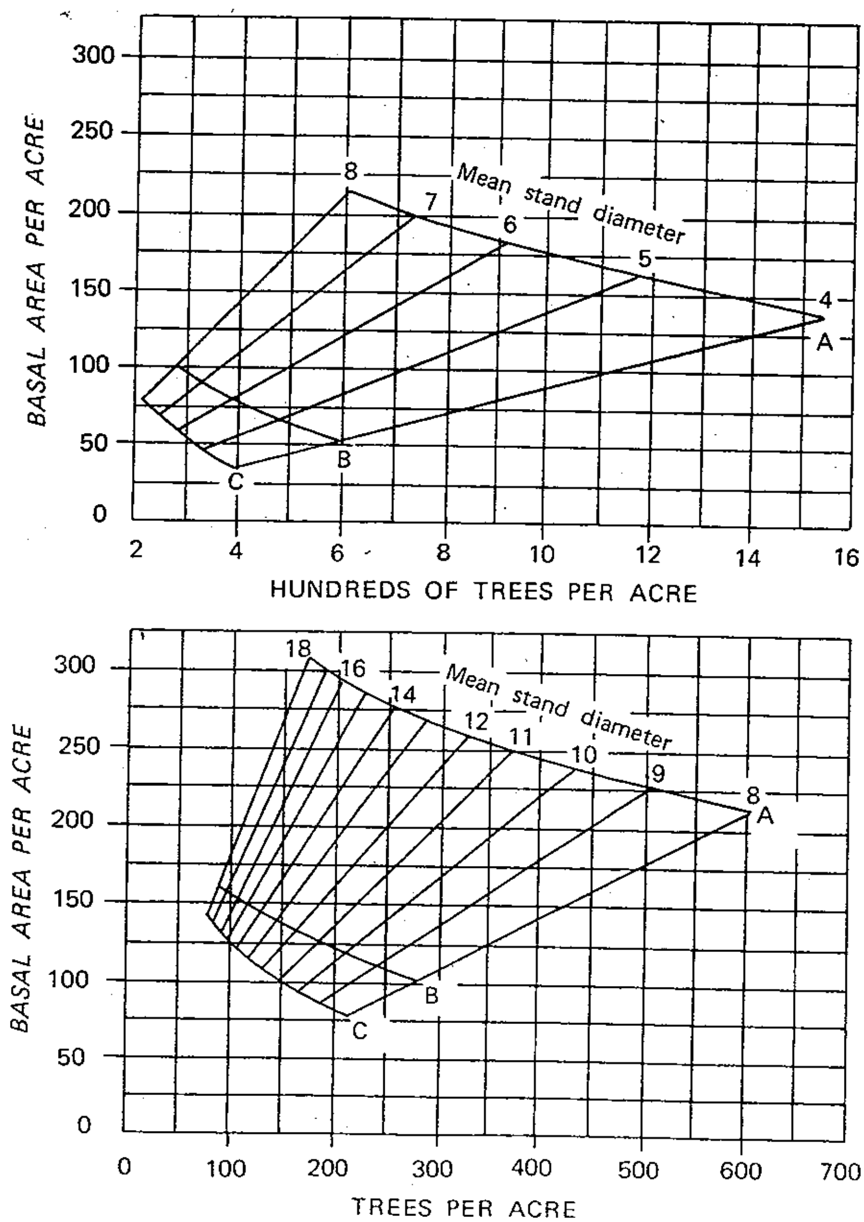
Doolittle (1958) found a difference in site index of 9 to 12 between oaks (including northern red oak) and white pine in the southern Appalachians. His study also showed a broad site-index range for white pine—from 66 to 98.

Barrett et al. (1973) noted that white pine stands in New Hampshire have a narrow site-index range—from 64 to 71. These data plus Foster's (1959) work indicate much smaller differences in site-index values between white pine and the hardwoods than those that Doolittle found. In the Northeast, a difference in site index of about 5 in favor of pine probably would be more applicable domly or systematically located points within the stand, tally by diameter class the overstory trees that fall within the range of the prism. To calculate the basal area and number of trees per acre, follow the instructions on the tally sheet.

Average basal area and trees per acre, as found by averaging the results for each point, are used to enter the stocking chart. The position of the stand on the stocking chart gives the mean stand diameter. As a shortcut, basal area per acre can be measured with an angle gage, mean stand diameter can be estimated visually, and numbers of trees can be determined by the stand location on the chart.

As an example, suppose the average basal area is 120 ft^2 and the total number of trees is 450. The mean stand diameter would be about 7.0 inches. Or suppose the average basal area is 140 ft^2 and the mean diameter is estimated about 8 inches. The total number of trees would be estimated from the chart at about 400 (Fig. 2).

Figure 2.—Stocking chart for nearly pure even-aged white pine stands (Philbrook et al. 1973).



index classes. The site-index curves are corrected to a breast-height age of 50.

Volumes by stand age and site index are given in Table 1 for pure white pine stands near A-level stocking (Leak et al. 1970). The yields—in board feet (fbm) and cubic feet (ft^3) per acre—increase markedly with age and site index, and will be higher or lower depending on whether the stand is above or below A line. Also, yields in white pine will drop as the proportion of hardwood increases.

Growth rates in white pine stands may vary greatly with site condition and stocking density. The average white pine stand will grow from 300 to 800 fbm per acre per year. Study plots on exceptionally good sites have shown yearly growth rates as high as 1,200 fbm per acre for site index 60, and as high as 1,600 fbm for site index 80. However these growth rates represent optimum conditions in small, well-stocked stands.

PLANTATION CULTURE

Growth and yield

Volume yields from plantation-grown white pine may not be the same as those from natural white pine stands. Because plantations are established quickly and uniformly, and contain few if any weed species, yields tend to be higher. However planted stock may suffer initial setbacks in growth and additional damage from pests such as the white pine weevil, and may exhibit stagnation (mutual suppression of growth among trees of nearly the same size and age). One of the most important factors that influences merchantable volume production is the initial spacing at planting.

Table 2 shows yields (in cords per acre) for plantations in Pennsylvania, where white pine was planted close together—4x4-foot spacing. To convert cords to cubic feet, multiply by about 100 ft^3 per cord. In comparing some of these figures with those in Table 1, notice that plantation yields seem to be slightly lower than those from natural stands. Where the original spacing was wider than 4 x 4 feet, which is usually the case, current volumes in cords or in cubic feet should be only slightly lower than those shown in Table 2. However board-foot volumes 30 to 50 years or more after planting generally are much higher with wider spacing, because the trees are larger. Conversions from cubic feet to board feet vary greatly; from about 2 fbm/ft^3 in 40-year-old stands on medium sites to 7 fbm or more per cubic foot in older, larger stands.

Table 2.—Yields, in cords per acre, (to a 4.0-inch top) for white pine planted at 4 x 4-foot spacing. (Delong 1955)

Stand age	Site index					
	40	50	60	70	80	90
15	—	—	—	0.2	0.9	1.9
20	—	0.2	1.4	3.6	6.2	8.5
25	0.5	2.6	5.9	10.4	15.1	19.5
30	2.6	6.3	12.1	19.5	26.5	33.5
35	5.6	10.4	19.8	30.0	40.3	50.6
40	9.4	16.2	27.9	40.1	52.5	64.1
45	13.8	22.2	35.0	48.6	62.3	74.5
50	17.1	27.6	41.4	56.0	70.4	83.4
55	19.3	32.5	47.0	62.7	78.2	91.3

SELECTING A STAND PRESCRIPTION

To prepare a prescription for a white pine stand, identify the condition of the stand; then follow the suggested treatment for that condition. The key to the prescription is the letter (A, B, C, etc.) to the right of each description of conditions. Details of the prescriptions are presented on pages 9 through 11.

WHITE PINE SEEDLINGS

(mean dbh up to 1.5 inches or average seedling height of 1 to 10 feet)

1. 50 percent or more of the plots (4.45-foot radius) stocked with white pine
   2. 50 percent or more of the plots stocked with white pine free to grow . . . . A
   2. 50 percent or more of the plots stocked with white pine not free to grow:

STAND PRESCRIPTIONS

The following prescriptions are directed toward increasing production of white pine sawlogs. Emphasis is placed on measures for increasing the proportion of white pine on the better sites, and on developing pure stands of white pine on the poorer hardwood sites.

A. Survival of white pine is not at stake, so weeding can be delayed. Reexamine in 5 years.

B. *On the better sites* (hardwood site index 60 or greater), strive to develop a mixed stand of hardwood and white pine rather than a pure stand of pine. Weed out the hardwoods in areas where white pine reproduction is most abundant. This will result in a mixed stand with a group arrangement of the hardwood and pine components. In areas where this group arrangement does not develop naturally, manage for hardwoods.

On the poorer sites (lighter soils—hardwood site index 59 or less), the goal is to grow pure stands of pine if possible. Remove the hardwoods that are interfering with the height growth of the pine, or those that are interfering directly with the amount of light that reaches the pine. Release should be on an individual-tree basis or by group where groups are present. Hardwoods that are not competing with the pines should be retained in the stand as protection against damage from snow or the white pine weevil. Reexamine the area in 5 years.

C. This situation usually develops after the previous stand of pine has been removed and the hardwoods have voluntarily taken over the site. There is usually a good pine seed source, either from an adjacent area or from old remnant "bull pines" left on the site. On the poorer, lighter soils it occurs frequently, especially where the overstory hardwoods have been subjected to partial cuts. On the better sites, where there is an abundant seed source, pockets or groups of white pine are found in drier areas—such as knolls and small ridges—that are less suited for hardwoods.

On the better sites, manage for hardwoods; favor the development of groups rather than individual stems of white pine when thinning the hardwoods.

On the poorer sites, encourage the development of white pine by maintaining light stocking of the hardwoods through frequent thinnings. Favor the development of areas that are heavily stocked with pine by thinning more heavily in these areas. If the hardwood overstory is sawtimber size, use a two-cut shelterwood system to remove it.

D. Manage for hardwoods.

E. This situation usually develops naturally on the poorer sites, but rarely on the best sites without previous management. As survival of white pine is not at stake because of competition, the thinning can be delayed until the white pine averages 20 feet in height. To improve the distribution of white pine where required, release the crowns of the tallest and best white pine trees. For the practice to be worthwhile, at least 60 well-distributed trees per acre should need the release; if fewer than 60 per acre require release, do nothing.

F. The hardwoods are more aggressive on these better sites, so they usually overtop most of the pine. The choice is to work for a mixed stand, concentrating on groups of pine rather than individuals. Where there are natural groups of pine, weed out the hardwoods in these groups to provide overhead release. If the groups are large, about 1/2 acre or larger, leave a few hardwoods spaced about 15 feet apart for protection against weevils. Small dense groups of pine less than 1/2 acre in size can be completely released. Manage for hardwoods if small groups of pine are not present.

G. The goal here is to grow pure stands of pine if possible. Remove a minimum of 50 percent of the hardwood overstory, concentrating on the release of individual crop trees or groups. Use the crop-tree selection method and release about 200 white pine trees per acre. Remove only those hardwoods that interfere with sunlight to the tops of the pine. For protection against weevils, retain the light-crowned species, if possible, rather than the coarse-crowned species such as oak. Reexamine in 5 years.

H. Manage for hardwoods; use the appropriate management guide. Favor the development of white pine in thinning the hardwoods.

I. Manage for white pine. Apply a commercial thinning to reduce the basal area to B-level, removing the hardwoods in favor of pine. If there are no markets for small wood products, for example, firewood, apply a noncommercial thinning.

operation. In stands with a higher initial stocking A level or above, reduce to B level in two operations

S. Manage for hardwoods, but favor white pine in the main crown during thinning.

T. Manage for hardwoods. Where pine makes up 30 percent or more of the basal area, strive to create site conditions that are favorable for regenerating pine. This can be done by thinning the hardwoods by groups and by patches.

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APPENDIX II

DIAGNOSTIC TALLY SHEET
FOR
EASTERN WHITE PINE

Cumulative Tally - Number of Trees Per Acre (B.A. Factor 10).

Number of Trees	Diameter Breast Height												
	2	4	6	8	10	12	14	16	18	20	22	24	26+
1	458	115	51	29	18	13	9	7	6	5	4	3	3
2	917	229	102	57	37	25	19	14	11	9	8	6	5
3	1375	344	153	86	55	38	28	21	17	14	11	10	8
4	1834	458	204	115	73	51	37	29	23	18	15	13	11
5	2292	573	255	143	92	64	47	36	28	23	19	16	14
6	2750	688	306	172	110	76	56	43	34	27	23	19	16
7	3209	802	357	201	128	89	65	50	40	32	27	22	19
8	3667	917	407	229	147	102	75	57	45	37	30	25	22
9	4125	1031	458	258	165	115	84	64	51	41	34	29	24
10	4584	1146	509	287	183	127	94	72	57	Tally Legend		Number Plots	
11	5042	1260	560	315	202	140	103	79	62	/			
12	5501	1375	611	344	220	153	112	86	68	0			
13	5959	1490	662	372	238	165	122	93	74	X			
14	6417	1604	713	401	257	178	131	100	79				
15	6875	1719	764	430	275	191	140	107	85				
Totals													
# Trees													
B.A.													

Total Number of Trees Per Acre - Add the last figure used in each block and divide by the number of point samples tallied.

B.A. Per Acre - Add the total number of entries by species or groups of species, multiply by 10, and divide by the number of point samples tallied.

BASAL AREA PER ACRE

Acceptable Species

White Pine ________ Sq Ft

Other Acceptable Species

________________ Softwood ________ Sq Ft

________________ Hardwood ________ Sq Ft

Total Acceptable Species ________ Sq Ft

Undesirable Species and Cull

________________ Softwood ________ Sq Ft

________________ Hardwood ________ Sq Ft

TOTAL BASAL AREA PER ACRE ________

Stand Prescription:

STAND DESCRIPTION
(Even-Age Management)

Number of Trees Per Acre ________

Mean Stand DBH ________

Total Basal Area Per Acre ________

Basal Area, B Level ________

Basal Area, C Level ________

Site Index:

Species: ________

Age			
Height			
Site Index			

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Silvicultural Guide for Northern Hardwood Types in the Northeast (revised)

William B. Leak
Dale S. Solomon
Paul S. DeBald

Purpose and Scope

This is the third silvicultural guide for northern hardwoods (beech-birch-maple) in the Northeast. The first, published in 1958 (Gilbert and Jensen 1958), provided general guidelines on initial cutting methods in uneven-aged old-growth stands and even-aged second-growth stands. The second, published in 1969 (Leak et al. 1969), provided quantitative information on stocking and yield as well as a key to specific stand presecriptions, particularly for even-age management. This revised guide includes new information on forest types, site, stocking, growth and yield, and regeneration methods, including shelterwood and group selection.

The information in this guide applies to about 20 million acres of northern hardwood and mixed hardwood-conifer types across New England and New York. Outside this area, the guide should be applied with caution. The guide is primarily concerned with timber production. A guide to the management of wildlife habitat in hardwood and conifer types in New England is in preparation.

Regional Conditions

Northern hardwoods and associated species are used for a variety of products, including veneer, sawlogs, boltwood, pulpwood, fuelwood, and miscellaneous products such as posts. In New England, sawlogs and veneer presently account for about one-quarter of the hardwood harvest, and pulpwood accounts for about one-half. In states such as New Hampshire, fuelwood currently accounts for a significant proportion of the hardwood cut. In many areas, markets for low-quality material provide opportunities for improving the northern hardwood forest without heavy investments in noncommercial silvicultural work. Also, substantial increases in land and timber prices over the last 10 to 15 years have strengthened timberland investments. Indications are that current trends will continue upward, though perhaps at a lower rate.

Many timberland owners in New England own land primarily for reasons other than growing timber. In New Hampshire and Vermont, only 6 percent of the owners, controlling 21 percent of the timberland, listed wood production as one of the important reasons for ownership (Kingsley and Birch 1977). Foresters must consider the other values of timberland—recreation, esthetics, buffers, wildlife, investment, etc.—and be prepared to use silvicultural approaches that will complement or enhance these values.

Species and Sites

Three cover types, or subtypes, are described in this guide: beech-birch-maple (typical northern hardwood), beech-red maple, and mixedwood (hardwoods and associated softwoods). The occurrence of these types usually is related to site conditions—soils, climate, and bedrock mineralogy; in parts of the Northeast, these forest types are known to occur on certain land types, forest habitats, or soil series. Those who manage stands primarily for paper birch, oak, white pine, spruce-fir, or cherry-maple should use the guides written specifically for those types.

The beech-birch-maple type contains sugar maple as the characteristic species in proportions ranging from 15 to 20 percent to nearly 100 percent of the basal area. This type is characteristic of well- to moderately well-drained, fine-textured or loamy till soils. Sugar maple and/or white ash are most abundant on the best soils—for example, those that are enriched with organic matter or derived from limestone. However, on average beech-birch-maple sites, beech may account for up to 50 percent of the basal area. The most common birch species are yellow and paper birches. However, in southern New England, sweet birch and northern red oak (often of good quality) may be common associated species. The successional tendency is toward the tolerant species—beech and sugar maple.

Beech-red maple stands usually occupy poorer sites than beech-birch-maple stands—soils that are more shallow, wetter, or drier than those with typical northern hardwoods. The central characteristic of these hardwood stands is that sugar maple is uncommon and/or slow growing. On dry sites, beech may be the predominant species. On wet sites or shallow soils, red maple often is the most common species. Yellow birch and paper birch (or sweet birch in southern New England) are common associates. Some of these stands originated from heavy cutting of softwood or mixedwood stands. Old stands sometimes show a successional trend toward tolerant softwood types—hemlock and/or red spruce. Or the successional tendency may be toward a predominance of beech. Some of the characteristic soils are productive for red oak; less so for sugar maple, yellow birch, or white ash.

Table 1.—Silvical characteristics of the important species of the three cover types

Species	Shade tolerance	Early relative height growth	Relative site requirements	Natural pruning	No. years between good seed crops	Sprouting vigor	Delayed germination
Sugar maple	Tolerant	Slow to moderate	High	Poor to medium	3–7	Moderate—small stumps	Negligible
American beech	Tolerant	Slow	Medium	Poor	2–5	Low—stump sprouts High—root suckers	None known
Yellow birch	Intermediate	Moderate	Medium to high	Medium	1–3	Low	Seldom
Paper birch	Intolerant	Fast	Medium	Good	2	Moderate—small stumps	None known
White ash	Intermediate (more tolerant as a seedling)	Moderate	High	Good	2–5	Moderate to high	Up to 75 percent
Red maple	Intermediate	Moderate	Low	Medium	1	High	Moderate percentage may germinate 2nd spring
Aspen	Intolerant	Very fast	Low	Good	4–5	High—root suckers	None
Northern red oak	Intermediate	Moderate	Medium	Medium	3–5	High	None
Red spruce	Tolerant	Very slow	Low	Poor	3–8	None	None known
Eastern hemlock	Tolerant	Very slow	Low	Poor	2–4	None	None known
Eastern white pine	Intermediate	Slow to moderate	Low	Poor	3–10	None	None known

Table 2.—Species of regeneration favored (not exclusively) by certain harvesting methods in three cover types

Type	Individual tree-selection	Group selection	Dense shelterwood[a]	Open shelterwood[b]	Clearcut
Beech-birch-maple	Sugar maple Beech	Birches	Sugar maple Beech	Yellow birch	Birches
Beech-red maple	Beech Red maple	Red maple Birches	Beech Red maple	Red maple Yellow birch	Birches
Mixedwood	Tolerant softwoods or hardwoods	Red maple Birches	Hemlock Spruce Tolerant hardwoods	Red maple Birches	Birches

[a]Residual crown cover of about 80 percent.
[b]Residual crown cover of 30 to 50 percent (occasionally up to 70 percent).

However, in assessing each stand, additional factors must be considered in reaching a decision on the immediate silvicultural techniques. Either an uneven-age or even-age approach can be used to grow most species groups or products: uneven-age management with group selection can ensure a good mix of intermediate and some intolerant species; even-age management with shelterwood cutting can be designed to encourage a high proportion of tolerants (Table 2). And rotation age, stocking, stand structure, and logging equipment can be varied to meet various product objectives.

One of the important additional factors to consider is current stand condition. For example: high-risk stands may need to be regenerated by clearcutting or shelterwood to prevent large volume losses; or clearcutting a stand with a wide range in tree diameter may remove a high proportion of financially or biologically immature trees.

Another factor is accessibility. With high costs for road construction, some form of heavy cutting may be the only economically feasible regeneration harvesting method on the first entry. Esthetic and wildlife objectives also should be considered in choosing a silvicultural system. And in special circumstances, the possibility of site and/or stand deterioration needs to be assessed. For example, clearcutting on very poorly drained soils without adequate advance regeneration or in potential frost pockets may result in an overabundance of herbaceous or shrubby vegetation.

Uneven-Age Management

Harvesting Methods

Uneven-age management is implemented by individual-tree selection and group selection. Individual-tree selection removes trees one by one to maintain a fairly uniform and continuous crown cover appropriate for regenerating tolerant species. Group selection is the removal of trees in groups roughly 1/20 to 2 acres in size. It is especially appropriate where: (1) the objective is to maintain up to one-half of the regeneration in intolerant or intermediate species, and (2) the overstory contains groups of poor-risk, defective, or overmature trees. Group selection generally is applied in combination with individual-tree marking between the groups.

Group selection may be applied in two ways: groups of overstory trees can be removed, leaving a desirable stand of seedlings, saplings, or small poles; or entire groups of trees down to 2-inches d.b.h can be removed. The latter approach is used to eliminate undesirable sapings and small poles, resulting in a maximum proportion of intolerant or intermediate regeneration.

Growth and Yield

Results from a study of residual basal area and structure in a second-growth, beech-red maple stand illustrate the typical responses of hardwood stands in New England to density and structure (Table 3). Basal-area and cubic-foot

We emphasize that the maximum tree size of 20 inches d.b.h. is a very flexible goal. Tree vigor and quality are more important than the specified maximum tree size in deciding which trees to take or leave. On poor sites, tree vigor and quality of some species may decline rapidly at 16 inches d.b.h. or larger; on these sites, low amounts of sawtimber (q = 1.7) are most appropriate. On good sites, trees may easily be grown to 24 inches or larger; on such sites, high proportions of sawtimber (q = 1.5 to 1.3) should be best.

On the basis of these combinations of q and residual basal area, residual structural goals in terms of basal area per acre by diameter class are outlined in Table 4 for both hardwood and mixedwood types. Only three diameter classes are used since this results in easier application and allows for some departure from the strict reverse J-shaped form. Recent information indicates that slightly S-shaped form of diameter distribution may be more natural, productive, and economical.

In choosing a structural goal, it often is reasonable to aim for a q that is about the same as or slightly lower than the existing q before cutting. The q before cutting can be judged quickly by using the tabulation for percent sawtimber. A more precise estimate of the appropriate residual structure can be developed by following the marking guide procedures described in the next section. The structures listed in Table 4 should be used as a guide, and can be attained by feasible and economical cutting practices.

The structural goal of q = 1.7 is appropriate for the first entry in many cutover stands, which often have a low proportion of sawtimber (Fig. 1). However, the initial cut in a previously unmanaged stand may produce an extremely variable diameter distribution. Total residual density, and the removal of poor growing stock, are more important than structure in these early cuts. During subsequent entries, it may be feasible to leave a higher proportion of sawtimber (a lower q). On mediocre sites (e.g. beech/red maple stands), the sawtimber will decline in vigor and growth rate as it becomes larger, so it may never be possible to grow large-size trees or to reduce the q below 1.5 or 1.7. On good sites (e.g., supporting sugar maple/ash) capable of sustaining high proportions of sawtimber (Fig. 2), q's of 1.3 are attainable.

On areas scheduled for maximum production of fiber or fuel, low proportions of sawtimber (a q of 1.7 or higher) should be best.

In poletimber stands with less than about 25 to 30 ft^2 of sawtimber, there is little reason to be concerned about structure. Such stands can be treated by commercial stand improvement measures that remove the poorer quality overstory stems and leave 70 to 80 ft^2 of basal area per acre. In subsequent treatments, as the sawtimber component develops, the use of structural goals will be more appropriate.

Table 4.—Minimum stand structure objectives for residual hardwood (beech-birch-maple and beech-red-maple) and mixedwood stands

D.b.h. class (inches)	q = 1.7		q = 1.5		q = 1.3	
	Hardwood	Mixedwood[a]	Hardwood	Mixedwood[a]	Hardwood	Mixedwood[a]
	Ft^2 of basal area/acre					
6–10	38	54	30	42	21	30
12–14	18	26	20	28	20	28
16+	14	20	20	30	29	42
All	70	100	70	100	70	100

[a]Softwood basal area 25 to 65 percent of total.

Figure 2.—Northern hardwood stand with a high proportion of fairly good-quality sugar maple. The residual goal in this stand would be about 50 ft^2 of sawtimber or a q of approximately 1.3.

2. Unacceptable Trees: Trees that will not produce sawlog or better material now or in the future *or* trees that are high risk—subject to mortality or rapid losses of merchantable volume or quality before the next harvest. Valuable high-risk trees are especially important to recognize.

3. Cull: Trees with more than 50 percent of their cubic volume in sound or rotten cull; or use a local or agency definition.

Certainly, additional tree condition classes could be developed to meet local timber or wildlife needs. Individual species or species groups often should be tallied to help refine silvicultural objectives and develop marking guides. Prism-plot basal areas, by d.b.h. and tree condition class can be summarized as in the following example:

D.b.h. class (inches)	*Mature*	*Immature*	*Defective*	*High risk*	*Cull*	*Total*
			ft^2 basal area/acre			
6–10	—	40	10	—	—	50
12–14	—	10	10	20	—	40
16+	5	5	5	10	—	25
All	5	55	25	30	—	115

Table 6. Summary of general marking guides

Type	Stand size class	Initial stand: Sawtimber basal area	Initial stand: Total basal area 5.0 inches +[a]	Cutting method	Regeneration favored	Residual stand: Sawtimber basal area	Residual stand: Total basal area 5.0 inches +[a]
		Ft²	Ft²			Ft²	Ft²
Beech-birch-maple	Poletimber	30	100 +	Stand Improvement	Sugar maple-beech		65
	Small sawtimber	30–50	100 +	Single-tree	Sugar maple-beech	30–40	70
				Group	Yellow birch-paper birch	30–40	70
	Large sawtimber	50–75	100 +	Single-tree	Sugar maple-beech	40–55	75
				Group	Yellow birch-paper birch	40–55	75
Beech-red-maple	Poletimber	30	100 +	Stand Improvement	Beech-red maple		65
	Small sawtimber	30–50	100 +	Single-tree	Beech-red maple	30–40	70
				Group	Yellow birch-paper birch	30–40	70
	Large sawtimber	50–75	100 +	Single-tree	Beech-red maple	40–55	75
				Group	Yellow birch-paper birch	40–55	75
Mixedwood	Poletimber	50	130 +	Stand Improvement	Tolerant softwoods or hardwoods		80
	Small sawtimber	50–70	130 +	Single-tree	Tolerant softwoods or hardwoods	45–55	100
				Group	Intermediate[c] and intolerant hardwoods	45–55	100
	Large sawtimber	70–90	130 +	Single-tree	Tolerant softwoods or hardwoods	55–75	100–120
				Group	Intermediate[c] and intolerant hardwoods	55–75	100–120

[a]Stands with less basal area than specified should be left to grow.

[b]Group selection normally includes individual-tree selection between groups.

[c]If tolerant or intermediate softwood regeneration is present, group selection can be used to favor these species by group removal of the overstory where the softwood regeneration is well developed.

Figure 3.—Portion of a group-selection opening in nearly mature northern hardwoods. Complete removal of the understory will result in maximum amounts of intolerant-intermediate regeneration.

managed stands, the percentage of milacres stocked with at least one stem between 3 feet tall and 1.5 inches d.b.h. usually exceeds 65 percent. Percent stocking of desirable species much lower than this—below 50 percent, for example—would indicate the need for special attention to regeneration, perhaps the use of small group-selection openings. The number of stems of commercial species (1.5 to 4.5 inches, or in the 2, 3, and 4-inch classes) commonly ranges from about 200 to 450. If adequate stocking in the seedling class is present, but 2- to 4-inch saplings seem deficient, a harvest cutting to the recommended residual basal area should solve the problem. There is no concensus at present on the need for mechanical or chemical treatments to improve the composition of the seedling-sapling component under single-tree selection. Work on the Bartlett Experimental Forest with single-stem timber stand improvement in understory beech produced little permanent change at high cost. However, the subject deserves further study.

Even-Age Management

Harvesting Methods

Two even-age harvest cutting methods commonly used in the Northeast are clearcutting and shelterwood. The seed-tree method also is recommended sometimes for large cutting areas where the available seed source of desired species is limited.

Clearcutting is the harvesting of all merchantable trees on an area generally followed by a chemical or mechanical removal of trees down to 2 inches d.b.h. (Fig. 4). Sometimes groups of trees larger than 2 inches d.b.h. are left if they are of desirable species. Isolated residual trees may develop large limbs and poor quality. However, pole-size or larger sugar maple with good crowns, clear boles, and no tendency to produce epicormic sprouts will experience little

Figure 5.—Shelterwood seed cut in northern hardwoods leaving approximately 70 percent crown cover (approximately 60 ft^2 of basal area per acre). Marking from below followed by brush saw removal of stems under 5.0 inches d.b.h. has created ideal conditions for regenerating tolerant and moderately tolerant species.

for hardwoods (60 to 70 ft^2) and softwoods (100 to 120 ft^2); for intermediately tolerant regeneration (chiefly yellow birch), the seed cut should leave a residual stand of about 30 to 50 percent crown cover (30 to 40 ft^2); perhaps a little higher on wet sites. Marking for seed cuts (and preparatory cuts) must be from below, removing smaller stems as first priority, and leaving a uniformly distributed stand. Tables 17–19 in the Appendix help relate crown cover to basal area by species group. These tables allow shelterwood prescriptions to be written in terms of crown cover or basal area, or both.

The final removal cut for any species should be made when the regeneration is 3 to 4 feet tall or more for most species (> 2 feet for birch; > 1 foot for spruce). Winter removal minimizes logging damage to the regeneration. However, summer removal is a possibility with hardwoods because of their sprouting ability. Other logging precautions to minimize damage to the regeneration include the careful layout of major skid trails, directional felling, log-length skidding, and the use of winching devices.

In previously cutover stands, where a good stocking of saplings and poles are present under an existing overstory, a natural shelterwood can be applied simply by removing the overstory. The main concerns are damage to, and adequate stocking in, the residual stand. Several planned modifications to the shelterwood system have been tried where the time between the seed cut and removal cut has been lengthened to maintain continual cover for esthetic purposes; these are known as delayed or extended shelterwoods. In the extreme, this approach becomes a two-age system where removal cuts are made at half-rotation intervals.

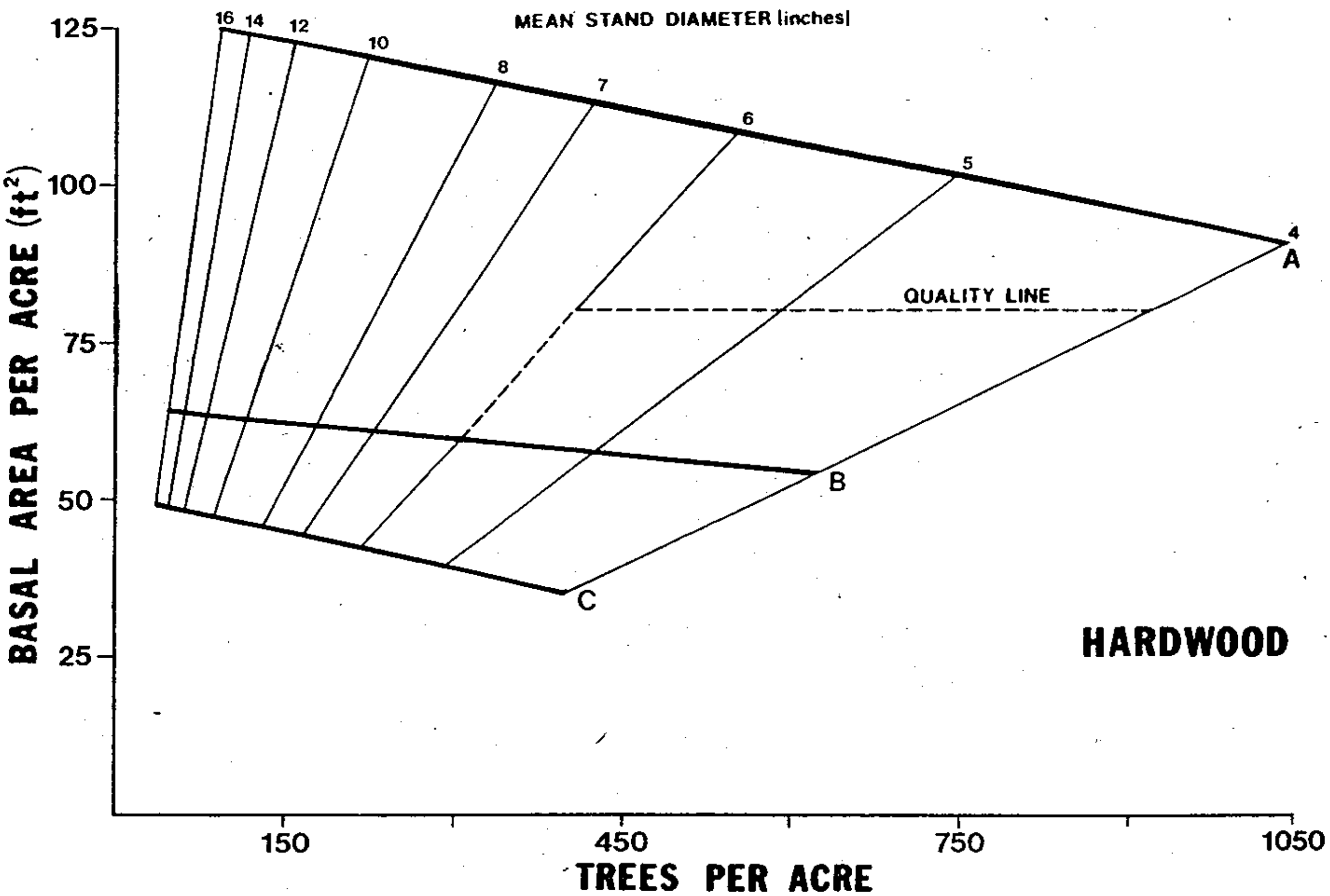


Figure 6.—Stocking guide for main crown canopy of even-aged hardwood stands (beech-red maple, beech-birch-maple) shows basal area and number of trees per acre and quadratic mean stand diameter. The A line is fully stocked, the B line is suggested residual stocking. The C-line is minimum stocking. The quality line is the density required to produce high quality stems of beech, sugar maple, yellow birch, and red maple.

Average density of mixedwood stands is higher than that of hardwood stands (Figs. 6–7). The mixedwood A line is from 20 to 55 ft^2 above the hardwood A line. Similarly, the B line is from 35 to 45 ft^2 above the hardwood B line when the percentage of softwood is from 25 to 65 percent of the basal area of trees in the main crown canopy.

A Quality line also is shown for hardwoods (Fig. 6). Limited research indicates that species such as beech, sugar maple, red maple, and yellow birch do not prune well naturally unless grown at 80 ft^2 of basal area per acre. Paper birch, aspen, and white ash appear to be the only common hardwoods in the Northeast that will develop acceptable quality in small poletimber stands maintained at or near the B line. At average stand diameters of about 6 inches, clear lengths of about 1 1/2 logs should be present on many trees. At this time or after additional clear bole development the stand can be thinned back to the B line (plus 5 to 10 ft^2 to allow for logging damage), perhaps in two operations if basal area is high and crowns are small. Up to stand diameters of roughly 6 inches, light improvement work to maintain species composition and select for stem quality is acceptable. The Quality line in Figure 6 is dotted because species compostion and local experience will influence the level of stocking required in young stands to ensure quality development. To grow limb-free or small limbed hemlock and spruce, density should be maintained

Table 8.—Volumes per acre in cubic feet (4.0-inch ib top) and board feet (8.0-inch ib top) for unmanaged hardwood stands, by site index, mean stand diameter, and age

Mean d.b.h. (inches)	Age	Site 50 Cubic feet	Site 50 Board feet	Age	Site 60 Cubic feet	Site 60 Board feet	Age	Site 70 Cubic feet	Site 70 Board feet
	Years			*Years*			*Years*		
4.0	35			30			25		
6.0	59	1289		49	1547		41	1821	
8.0	83	1606	2983	67	1924	3560	55	2254	4258
10.0	120	1934	5554	87	2311	6640	69	2675	7632
12.0	182	2272	8259	114	2700	9783	85	3144	11461
14.0				157	3102	13048	102	3579	15079
16.0				196	3154	13257	127	3654	15390

50 to 60 tend to be beech-red maple or mixedwood sites; soil productivity is limited somewhat by shallow, compacted layers, coarse textures, restricted aeration, or excessive stoniness. Sites below 50 usually are poorly drained or shallow to bedrock. Sites below about 50 to 55 are best suited to growing softwoods, or hardwoods on shorter rotations (e.g., paper birch and aspen).

Rotation age usually is based on (1) the culmination of mean annual increment, or (2) the time required to grow a certain-size tree or product. Tables 8 and 9 indicate that culmination of mean annual board-foot growth in both managed and unmanaged stands ranges from about 100 to 120 years. Mean diameters at the point of culmination vary with site—the range is 14 to 18 inches. Culmination of mean annual increment for cubic volume occurs at age 40 to 50 in unmanaged stands and 80 to 90 years in managed stands. In Table 9, some inconsistency is evident in the trend of mean annual increment because of the timing of intermediate cuts.

Intermediate Cuttings

Where there are good markets for pole-size material, noncommercial thinning/cleaning often is not needed; in many cases, silvicultural needs can be met through commercial operations in pole stands. However, if an analysis of the reproduction following clearcutting or shelterwood cutting indicates that desired species objectives will not be met (see section on even-age regeneration), a noncommercial operation may be warranted. The silvicultural objective should be to increase the proportion of plots dominated by acceptable species to about 40 percent (equivalent to C-line stocking). Where the objective is to increase the proportion of softwood species, cleaning can be done in seedling stands with selective herbicides. To change the species mix in hardwood stands, mechanical or chemical stem treatments should be done in stands between about 10 to 20 years of age. Examples where noncommercial work might be warranted are in: (1) mixedwood regeneration where the objective is to grow softwoods; (2) mixtures of valuable hardwoods (yellow birch, sugar maple, ash) in combination with fast-growing less valuable species such as red maple; (3) other situations where economic analysis indicated that costs are justified.

In most hardwood stands between 4 and about 6 inches mean d.b.h., the stocking guide (Fig. 6) recommends fairly high stocking for those species that are resistant to natural pruning. Improvement work during this period might be accomplished by light, commercially marginal operations that remove 15 to 25 ft^2 of basal area per acre. In stands of paper birch, ash, and aspen averaging 4 to 6 inches d.b.h., heavier cuttings down to the B line are permitted for fuelwood or pulp.

Pruning is not a common silvicultural treatment in northern hardwoods. But the high value differential between clear and knotty logs is reason enough to continue to exam the prospective costs and returns from this practice. Pruning probably is most feasible for valuable species that are moderate to poor self-pruners: sugar maple, yellow birch, and red oak. Prune trees that are about 4 to 6 inches during the late summer or dormant season; do not remove more than a third of the live crown. Do not flush cut. Place the saw just outside the branch bark ridge and cut downward and slightly outward.

Beyond 6 inches mean diameter, commercial thinnings generally will be feasible, lowering the basal area to about the B-line level (perhaps in two operations) plus an allowance of 5 to 10 ft^2 for logging damage. Then, when a stand reaches one-half to three-fourths of the distance from the B line to the A line, additional commercial thinnings can be made to reduce the basal area back to B-line level (plus damage allowance). Most commercial thinning will be in the main crown canopy, removing dominant, codominant, and intermediate trees. Keep in mind that certain types of marking (from above, from below) may change the residual mean diameter and also the appropriate B line. The objective is to provide adequate growing space for the stems with highest value potential by removing:

1. Risk trees: Valuable trees that will not last until the next thinning, or that will experience severe degrade.

2. Unacceptable stems: Trees that will not produce sawlog material now or in the future due to defect or cull.

3. Undesirable species.

4. Acceptable stems crowding high-value stems.

Stand Evaluation

Reproduction and Sapling Stands

In these young even-aged stands (mean stand diameter up to 4.0 inches) the primary need is for a method of judging the adequacy of stocking and species, and predicting the need for early noncommercial treatment.

To determine stocking, sample about 2 plots per acre in each young stand up to a total of about 50; plot size should be 8.9 feet (1/700 acre) or 7.4 feet (1/1,000 acre) in diameter. Record:

1. The species that will dominate the plot if left untreated. This requires the application of all available knowledge on species growth rates, tolerance, longevity, etc.

2. The desirable species not free to grow (commercial or desirable species) that will dominate the plot if one or two undesirable overstory stems are removed.

If at least 40 to 60 percent of the plots are dominated by desirable free-to-grow stems, the stand should attain C-line or B-line stocking of acceptable species when it reaches the lower end of the stocking guide. If stocking of desirable free-to-grow stems is less than 40 percent, the stocking of desirable species not free to grow should be examined to determine whether a precommercial operation will raise the representation of desirable species to C-line or B-line levels.

Poletimber and Sawtimber Stands

These are even-aged or uneven-aged stands with mean diameters larger than 4.0 for trees in the main crown canopy. Take a minimum of 10 systematically located sample points in uniform stands, and up to 30 points in variable stands. On a cumulative tally (Table 10) (or a conventional tally and with the data in Table 11) record trees counted with a 10-factor prism by 2-inch diameter classes, and the following tree classes (denoted by the tally legend):

1. Species or species group (optional)

2. Acceptable growing stock

   a. Mature trees (optional if species are tallied)

   b. Immature trees (optional)

3. Unacceptable stems

   a. Defective (optional)

   b. High risk (optional)

   c. Cull (optional)

For uneven-age management, the tally should include all trees in the 6-inch class and larger. For even-age management, the tally should include all trees in or touching the main crown canopy (exclude the suppressed trees). Where the choice has not yet been made between even-age and uneven-age management, the tally legend should distinguish between suppressed trees and those in the main crown canopy. Acceptable growing stock will produce sawlog or better material now or in the future. Unacceptable stems will not. Maturity can be tallied in the field using the size guidelines in Table 5, and current tree condition can be noted. If the tally legend separates species or species groups, maturity can be scored later using the general guidelines at the bottom of Table 12. Also, in even-age stands, measure breast height age and total height for up to five dominant stems per stand to determine site index (Figs. 8–9). Determine whether the stand is beech-birch-maple, beech-red maple, or mixedwood. And judge on the ground whether a commercial cutting is now feasible; this judgment should be based on volume, quality, accessibility, and markets.

Table 11.—Basal area per tree and numbers of trees per acre conversion for a 10-factor prism

D.b.h.	Prism conversion	Basal area per tree	D.b.h.	Prism conversion	Basal area per tree	D.b.h.	Prism conversion	Basal area per tree
Inches	*No. trees/acre*	*Ft²*	*Inches*	*No. trees/acre*	*Ft²*	*Inches*	*No. trees/acre*	*Ft²*
1.0		0.0055	11.5		0.7213	22.0	3.8	2.6398
1.5		.0123	12.0	12.7	.7854	22.5		2.7612
2.0	458.4	.0218	12.5		.8522	23.0	3.5	2.8852
2.5		.0341	13.0	10.8	.9218	23.5		3.0121
3.0	203.7	.0491	13.5		.9940	24.0	3.2	3.1416
3.5		.0668	14.0	9.4	1.0690			
4.0	114.6	.0873	14.5		1.1467			
4.5		.1104	15.0	8.2	1.2272			
5.0	73.3	.1364	15.5		1.3104			
5.5		.1650	16.0	7.2	1.3693			
6.0	50.9	.1963	16.5		1.4849			
6.5		.2304	17.0	6.3	1.5763			
7.0	37.4	.2673	17.5		1.6703			
7.5		.3068	18.0	5.7	1.7671			
8.0	28.6	.3491	18.5		1.8667			
8.5		.3941	19.0	5.1	1.9689			
9.0	22.6	.4418	19.5		2.0739			
9.5		.4922	20.0	4.6	2.1817			
10.0	18.3	.5454	20.5		2.2921			
10.5		.6013	21.0	4.2	2.4053			
11.0	15.2	.6600	21.5		2.5212			

The essential information from the plots can be summarized (Table 12) to provide a basis for either the uneven-age or even-age stand options. For the uneven-age summary, the first six basal area columns provide a description of the initial stand; not all columns need be used, or more can be added to provide a species breakdown. From these data, the initial percentage of sawtimber can be determined, as can the initial approximate q from the tabulation in the section on uneven-age stocking. If the prescription key suggests a harvest cutting, the residual goal is determined by: (1) examining various approaches (marking rules) for removing the poorer quality material so as to leave a good-quality stand with the required total basal area; *or* (2) using a residual goal based on the initial q of the stand; *or* (3) using the general guidelines in Table 6. The marking goal is simply the difference between the initial total basal area and the residual goal; however, 5 to 10 ft² may be subtracted from the marking goal for logging damage.

For the even-age summary, basal area of the initial stand is listed by tree condition class. Number of trees per acre is taken from the cumulative tally. Total basal area per acre and number of trees are used to read mean stand diameter from the stocking chart (Figs. 6–7). Basal area at the A, B, C, and Quality lines also are taken from the stocking chart. If the prescription key calls for a treatment, the residual goal generally is determined by the B line or Quality line. However, residual goals higher than the B line may be prescribed to maintain maximum amounts of quality material, for esthetic purposes, etc. The marking goal is the difference between the initial and residual, minus any allowance for logging damage. Distributing the residual goal and marking goal among tree condition classes helps in the development of marking guides and helps ensure that the treatment will improve the quality of the stand.

Stand Prescription

Key

Use the following key to identify the stand condition and find the appropriate prescription (A, B, C, etc.). Details of the prescriptions follow the key. Also, consult the appropriate section describing the treatment within the text.

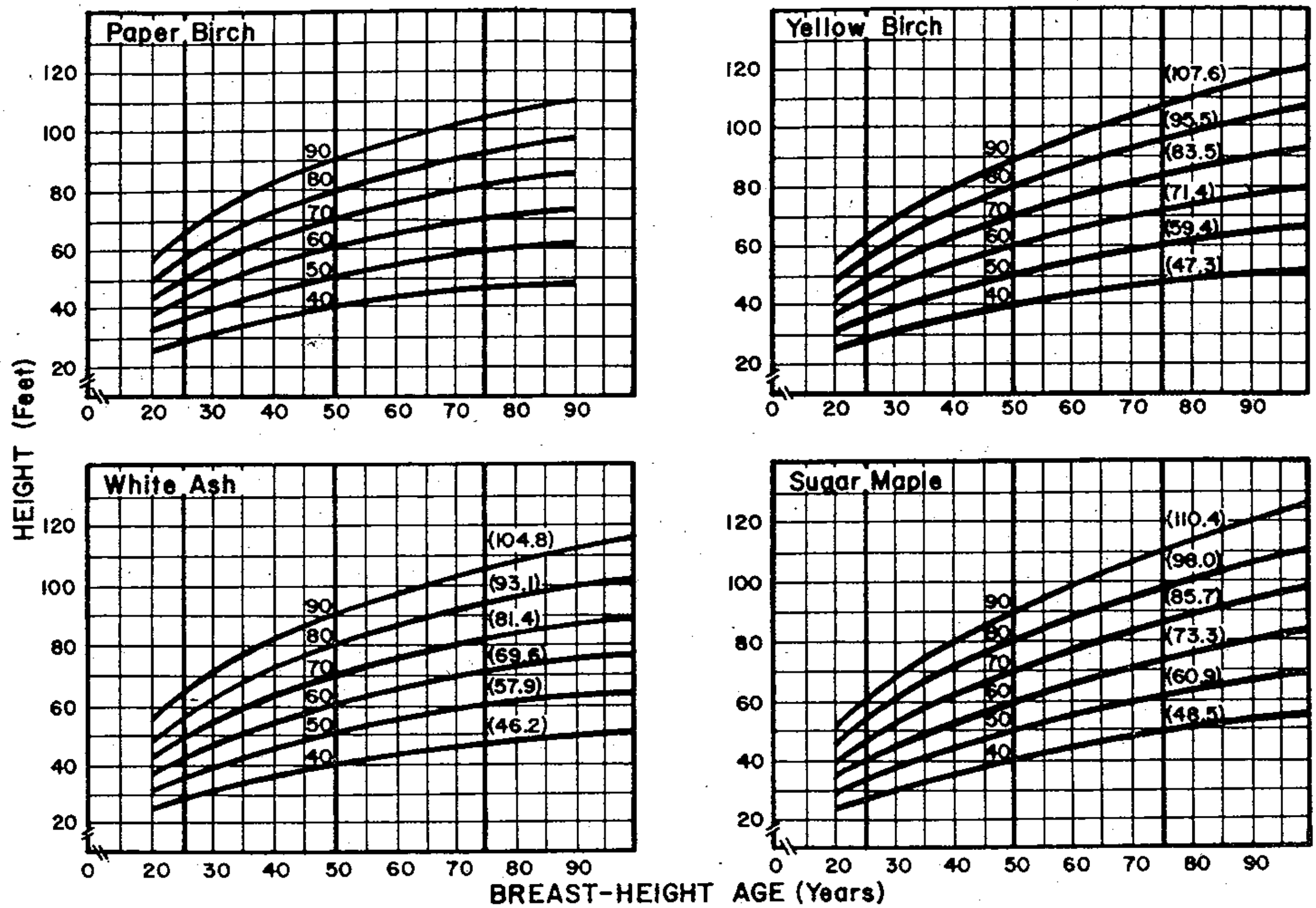


Figure 8.—Site-index curves (breast height age 50) for paper birch, white ash, yellow birch, and sugar maple in Vermont and New Hampshire. Values in parentheses are for site-index breast height age 75 (Curtis and Post 1962b).

Poletimber and Sawtimber Stands (mean d.b.h of overstory 4.0 inches or more)

1. Objective: uneven-age management
   2. Acceptable mature and immature growing stock more than:
      40 ft^2 (hardwood stand) or
      60 ft^2 (mixed-wood stand)
      3. Acceptable mature and immature growing stock 12 inches and larger more than:
         25 ft^2 (hardwood) or
         40 ft^2 (mixedwood)
         4. Total basal area more than:
            100 ft^2 (hardwood) or
            130 ft^2 (mixedwood) D
         4. Total basal area less than:
            100 or 130 ft^2 E
      3. Acceptable mature and immature growing stock 12 inches d.b.h and larger less than:
         25 ft^2 (hardwoods) or
         40 ft^2 (mixedwood)
         4. Total basal area more than:
            100 ft^2 (hardwood) or
            130 ft^2 (mixedwood) F
         4. Total basal area less than:
            100 or 130 ft^2 G
   2. Acceptable mature and immature growing stock less than:
      40 ft^2 (hardwood) or
      60 ft^2 (mixedwood) H
1. Objective: even-age management
   2. Stocking of acceptable growing stock less than C line for the appropriate type I

G. This stand has suitable quality for uneven-age management, but sawtimber stocking is low and stand density is not critically high. Reexamaine in 10 to 20 years.

H. This stand has too little quality growing stock for efficient uneven-age management. Reconsider the possibility of even-age management through clearcutting or shelterwood cutting. The other alternative is a long series of improvement cuts and selection/group selection to gradually improve the condition of the stand.

I. Acceptable growing stock is inadequate. Plan to regenerate the stand with clearcutting, strip cutting, or shelterwood cutting when commercially feasible.

J. Apply clearcutting to maximize the proportion of intolerant and intermediate species. Strip cutting should maximize intermediates such as yellow birch. In sensitive areas, a heavy two-cut shelterwood can be applied by leaving 30 to 50 percent residual crown cover (30 to 40 ft^2) following the seed cutting and removing the overstory in about 5 years.

K. Use a light two-cut shelterwood, leaving about 80 percent or more crown cover (60 to 70 ft^2 of basal area), during the initial seed cutting and removing the overstory when the tolerant advanced regeneration is more than 3 feet tall.

L. This immature stand has adequate young growing stock for even-age management, and sufficient stand density to support a commercial thinning. Stands should be thinned to not below the B line. However, only up to one third of the main canopy basal area should be removed at any one time. In stands within about 20 years of maturity, commercially thin only if there will be losses in volume or value if the stand is left untreated until final harvest.

M. This immature stand has adequate acceptable growing stock and density for even-age management, but commercial thinning is judged not feasible because of accessibility, current markets, etc. Leave untreated until commercial thinning prospects improve.

N. This immature stand has adequate acceptable growing stock for even-age management, but stand density is not critically high. Reexamine in 10 to 20 years.

O. This immature stand has sufficient potential quality and density for even-age management, but adequate clear length has not yet developed. Light thinning or improvement cutting to the Quality line, removing a small amount of poor quality or risky material, is permitted; this option is best suited to stands where quality, species, and site index are above average.

P. This immature stand has sufficient quality and density for even-age management, but adequate clear length has not yet developed. Light thinning is judged not feasible. Leave untreated, and reexamine in 10 years.

Q. This immature stand has sufficient potential quality for even-age management, but adequate clear merchantable length has not yet developed. For production of quality material, leave the stand untreated so that increasing stand density will encourage natural pruning. For fuelwood production, the stand may be thinned to B line.

Regulation

Regulation refers to the methods used to control the amount and periodicity of timber yields from a property. Commercial timberland owners, industrial owners, and certain large public ownerships may need regular, sustained or increasing yields. Owners of small tracts may have less need to control yields.

With uneven-age management, periodic yields from each stand or group of stands are achieved by setting a residual stand density, structure, and growing-stock condition (in terms of risk and quality potential) that will produce good volume or value growth over the cutting cycle (see Tables 3 and 4).

The first cut in a heavily stocked stand will produce fairly high gross yields, but may be low in net yield and value. Ensuring harvests in any stand are made at intervals equal in length to the cutting cycle. During these harvests, residual stand density is roughly consistent, though the proportion and quality of the residual sawtimber may be increasec gradually until it reaches a desirable level. This approach will result (after the first cut) in fairly constant cubic-foot yields roughly equal to annual growth times the cutting cycle, and gradually increasing sawtimber yields until an essentially constant level is reached.

On a large uneven-aged property, where annual yields are feasible and desired, the entire property can be divided intc a number of cutting units or groups of stands equal to the years in the cutting cycle. Then, each year, a different cutting unit is harvested to provide an annual yield. At the outset, units are entered in order of priority based on maturity, risk, stocking, etc.

Uneven-age regulation commonly is called volume, basal area, or growing-stock control. However, since the cutting units will have roughly equal acreages (or acreages inversely proportional to productivity), there is some element of area control involved as well.

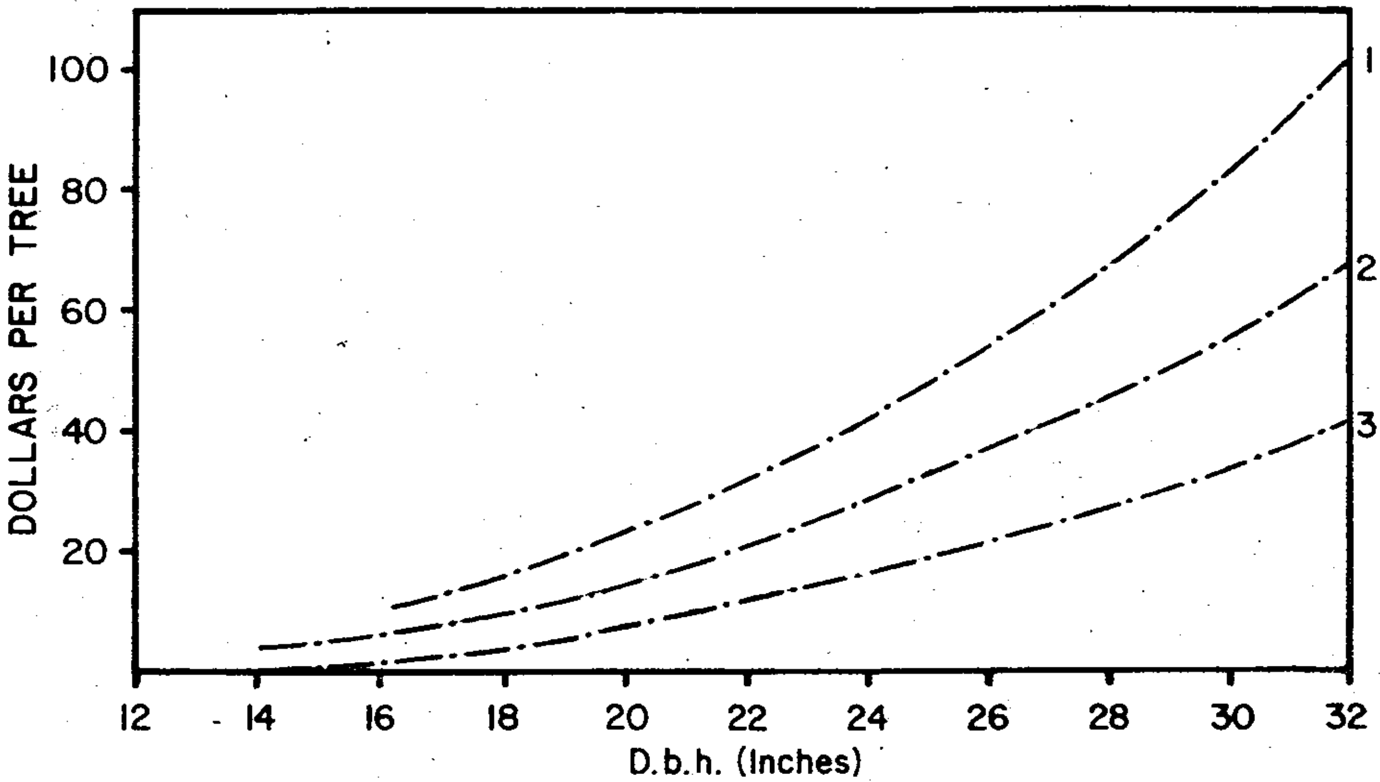


Figure 11.—Relative values of two-log hard maple trees, by butt-log grade.

Potential Timber Values

The biological recommendatons in this silvicultural guide capitalize on the diversities mentioned through the manipulation of species mix, tree size, timber quality, and product objectives. But are higher timber values worth waiting for? Are they worth working for? The short answer is: probably. The long answer depends on a number of factors.

One factor concerns the anticipated timber yields themselves. As shown earlier, we can expect timber yields sooner through silvicultural activities. We also can expect the overall volume yields to be greater. But in order to test the economic effectiveness of our silvicultural guidelines, we need to assess the possible dollar returns from those physical yields, along with their costs.

We must first consider the product potential of a stand with and without silvicultural treatment (Table 13). We would, for example, expect a low product potential in unmanaged stands and higher potentials in managed stands, depending on our efforts to develop those potentials. In Table 13, product distribution A represents a typical unmanaged northern hardwood stand (Filip and Williams 1968). Distributions B, C, and D represent a range of improved product mixes that might be expected through the application of silvicultural guidelines, and reflect an upgrading of timber quality through thinnings.

Table 13.—Assumed percentages of sawtimber volume

Product	Product distribution			
	A	B	C	D
Veneer	2	4	6	8
Sawlogs				
High quality	3	6	9	12
Medium quality	40	45	50	55
Low quality	15	15	15	15
Pallet stock	40	30	20	10

Table 15.—Estimates of net present value for northern hardwoods by thinning regime[a] and product distribution (based on projected real stumpage prices and 4-percent discount rate)

Mean d.b.h. (inches)	Stand age	Product distribution[b] A	B	C	D
	Years	*- - - - - - - - - Dollars - - - - - - - - -*			
		9-Inch Thinning			
8	67	5	12	19	25
10	83	20	33	46	58
12	98	35	54	74	93
14	110	42	66	89	113
16	125	35	58	81	104
18	142	32	55	78	101
		7-Inch Thinning			
8	64	14	23	32	41
10	76	36	52	68	85
12	90	50	73	95	118
14	101	66	96	125	155
16	114	60	89	118	147
18	128	57	86	116	145
		Quality-Line Thinning			
8	61	20	30	40	50
10	72	48	67	86	105
12	83	66	92	117	143
14	95	77	108	139	170
16	107	75	108	140	173
18	119	69	101	133	165
		Unmanaged			
8	67	5	—	—	—
10	87	11	—	—	—
12	114	6	—	—	—
14	157	−6	—	—	—
16	196	−15	—	—	—
18	230	−19	—	—	—

[a] Thinnings beginning at 9, 7, and approximately 5 (Quality line) inches mean stand diameter, and no thinning (unmanaged), and with yield schedules as shown in Tables 20–23.

[b] See Table 13 for product distributions.

Rate of Return

As an alternative to net present value, we might consider a rate of return analysis of timber management strategies. The internal rate of return (IRR), for example, is the compound rate of interest that equates the present value of expected future returns with the present value of expected future costs. It is the interest rate at which net present value is zero.

Using the same timber value and cost information that we used to estimate net present values, we estimated the internal rates of return for the same management strategies and product distributions. We found that we might expect managed northern hardwood stands to yield real rates of return that range from 5 to 8 percent (Table 16); and that unmanaged northern hardwoods might, at best, yield rates below 5 percent.

Note that the IRR cited are real rates. They do not include the effects of inflation. We can, though, approximate nominal or market rates by adding our inflation expectations to

Table 16.—Estimates of real rate of return for northern hardwoods by thinning regime[a] and product distribution (based on real stumpage prices)

Mean d.b.h. (inches)	Stand age	Product distribution B	C	D
	Years	*- - - - - - - - Percent - - - - - - - -*		
		9-Inch Thinning		
8	67	5.0	5.3	5.6
10	83	5.5	5.8	6.1
12	98	5.7	5.9	6.2
14	110	5.7	6.0	6.2
16	125	5.6	5.8	6.0
18	142	5.4	5.7	5.9
		7-Inch Thinning		
8	64	5.7	6.2	6.5
10	76	6.4	7.0	7.3
12	90	6.5	7.0	7.3
14	101	6.5	6.8	7.0
16	114	6.3	6.8	7.0
18	128	6.2	6.5	6.7
		Quality-line Thinning		
8	61	6.2	7.1	7.5
10	72	6.8	7.2	7.5
12	83	6.9	7.5	7.8
14	95	6.9	7.4	7.7
16	107	6.7	7.0	7.3
18	119	6.6	7.0	7.2

[a] Thinnings beginning at 9, 7, and approximately 5 (Quality line) inches mean stand diameter, and with yield schedules as shown in Tables 20–23.

Appendix

Table 17.—Cumulative percent crown cover for sugar and red maples, yellow and paper birches, 10-factor prism

D.b.h. (inches)	Tree count											
	1	2	3	4	5	6	7	8	9	10	11	12
2	59	119										
4	28	57	85	114								
6	21	41	62	82	103							
8	17	34	51	68	84	101						
10	15	30	44	59	74	89	103					
12	13	27	40	53	67	80	93	106				
14	12	24	37	49	61	73	86	98	110			
16	11	23	34	45	57	68	80	91	102			
18	11	21	32	43	54	64	75	86	96	107		
20	10	20	30	40	50	60	70	80	91	101		
22	10	19	29	38	48	57	67	76	86	96	105	
24	9	18	27	36	45	54	64	73	82	91	100	109
26	9	17	26	35	43	52	61	69	78	87	95	104

Table 18.—Cumulative percent crown cover for white ash, white pine, red spruce, balsam-fir, and hemlock, 10 factor prism

D.b.h. (inches)	Tree count																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
2	32	64	95	127														
4	15	30	45	60	74	89	104											
6	11	21	32	43	54	64	75	86	96	107								
8	9	18	27	36	44	53	62	71	80	89	98	107						
10	8	16	24	32	40	47	55	63	71	79	87	95	103					
12	8	15	22	30	38	45	52	60	68	75	82	90	98	105				
14	7	14	20	27	34	41	48	54	61	68	75	82	88	95	102			
16	6	13	20	26	32	39	46	52	58	65	72	78	84	91	98	104		
18	6	13	19	25	32	38	44	50	57	63	69	76	82	88	94	101	107	
20	6	12	18	24	30	37	43	49	55	61	67	73	79	85	92	98	104	110
22	6	12	18	24	30	35	41	47	53	59	65	71	77	83	88	94	100	106
24	6	12	17	23	29	35	41	46	52	58	64	70	75	81	87	93	100	104
26	6	11	17	23	28	34	40	46	51	57	63	68	74	80	86	91	97	103

Table 21.—Residual and cumulative thinned[a] volume per acre for Quality-line thinning and site index 60

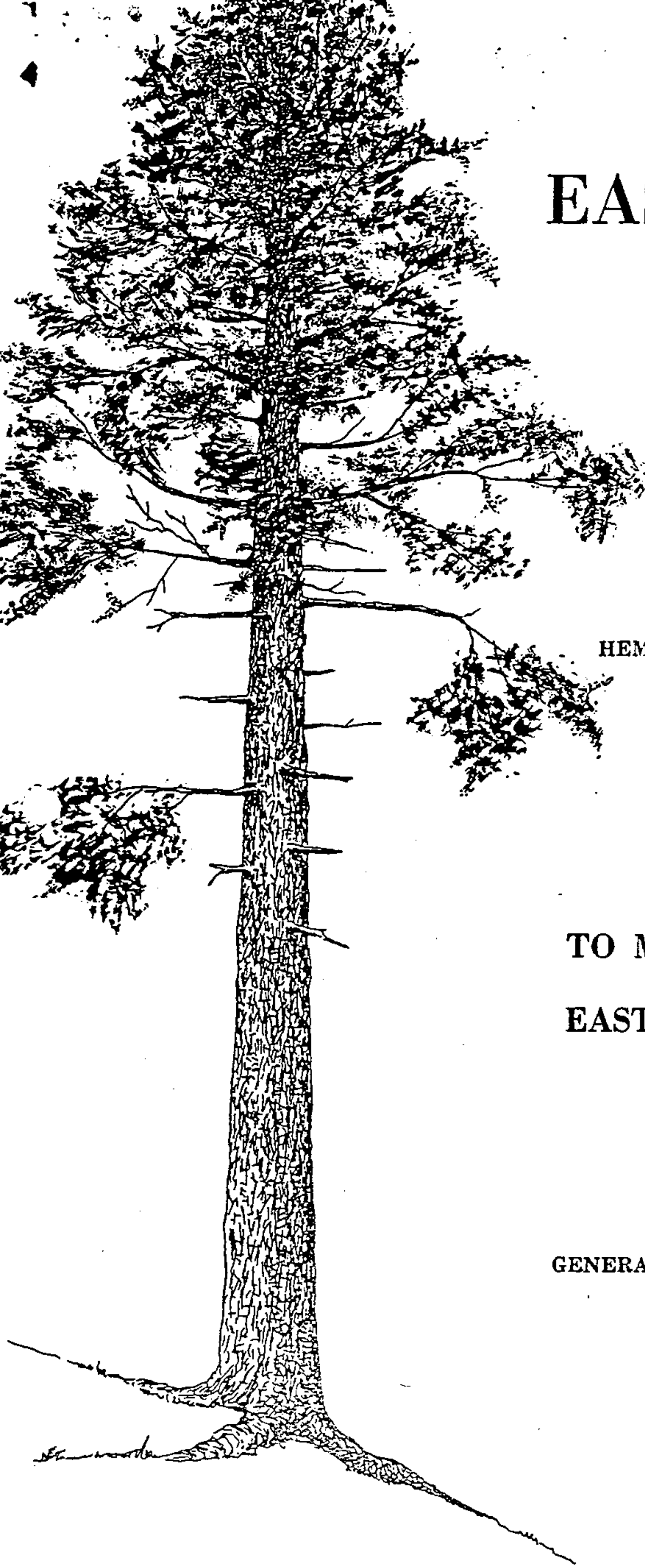
Mean d.b.h. (inches)	Age	Residual basal area	White ash Thin I	White ash Thin II	White ash Residual I	White ash Residual II	Sugar maple Thin I	Sugar maple Thin II	Sugar maple Residual I	Sugar maple Residual II	Yellow birch Thin I	Yellow birch Thin II	Yellow birch Residual I	Yellow birch Residual II	Paper birch Thin I	Paper birch Thin II	Paper birch Residual I	Paper birch Residual II	Other Thin I	Other Thin II	Other Residual I	Other Residual II	Combined Thin I	Combined Thin II	Combined Thin A	Combined Residual I	Combined Residual II	Combined Residual A
	Years	Ft²	Board feet/acre																									
4	30	91	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
6	48	93	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
8	61	66	23	—	58	—	305	—	756	—	319	—	783	—	119	—	293	—	129	—	321	—	895	—	895	2211	—	2211
10	72	91	23	—	153	—	305	—	1910	—	319	—	1840	—	119	—	728	—	129	—	840	—	895	—	895	5471	—	5471
12	83	85	73	—	213	—	927	—	2695	—	918	—	2454	—	357	—	802	—	405	—	1211	—	2680	—	2680	7375	—	7375
14	95	75	162	—	268	—	2060	—	3408	—	1950	—	3100	—	546	—	135	—	915	—	1538	—	5633	—	5633	8449	—	8449
16	107	91	162	—	332	—	2060	—	4217	—	1950	—	3836	—	546	—	—	—	915	—	1904	—	5633	—	5633	10289	—	10289
18	119	78	269	—	283	—	3424	—	3590	—	3191	—	3266	—	546	—	—	—	1530	—	1621	—	8960	—	8960	8760	—	8760

[a] Six thinnings at mean d.b.h. 5.2, 6.1, 7.8, 10.2, 13.1, and 16.5 inches.

Table 22.—Residual and cumulative thinned[a] volume per acre for 7-inch thinning and site index 60

Mean d.b.h. (inches)	Age	Residual basal area	White ash Thin I	White ash Thin II	White ash Residual I	White ash Residual II	Sugar maple Thin I	Sugar maple Thin II	Sugar maple Residual I	Sugar maple Residual II	Yellow birch Thin I	Yellow birch Thin II	Yellow birch Residual I	Yellow birch Residual II	Paper birch Thin I	Paper birch Thin II	Paper birch Residual I	Paper birch Residual II	Other Thin I	Other Thin II	Other Residual I	Other Residual II	Combined Thin I	Combined Thin II	Combined Thin A	Combined Residual I	Combined Residual II	Combined Residual A
	Years	Ft²	Board feet/acre																									
4	30	91	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
6	49	102	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
8	64	79	—	22	69	17	—	272	885	—	—	297	965	—	—	153	416	—	—	129	387	—	—	873	873	2722	17	2739
10	76	76	34	50	120	—	435	272	1550	—	459	297	1550	—	206	153	684	—	195	130	700	—	1329	902	2231	4604	—	4604
12	90	67	101	50	170	—	1305	272	2227	—	1318	297	2202	—	440	153	392	—	594	130	1020	—	3758	902	4660	6011	—	6011
14	101	88	101	50	302	—	1305	272	3949	—	1318	297	3884	—	440	153	—	—	594	130	1822	—	3758	902	4660	9957	—	9957
16	114	76	201	50	261	—	2612	272	3415	—	2605	297	3595	—	440	153	—	—	1197	129	1575	—	7055	901	7956	8610	—	8610
18	128	91	201	50	311	—	2612	272	4077	—	2605	297	4010	—	440	153	—	—	1197	129	1881	—	7055	901	7956	10279	—	10279

[a] Four thinnings at mean d.b.h. 7.1, 9.1, 11.7, and 14.9 inches.



EASTERN HEMLOCK

HEMLOCK UTILIZATION GUIDE No. 1

FORESTER'S GUIDE TO MARKING AND GRADING EASTERN HEMLOCK TIMBER

GENERAL FORESTRY ASSISTANCE PROJECT

1973

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FOREST MANAGEMENT CONSIDERATIONS

Many landowners may now choose to have hemlock encouraged as a major component of the forest stand or to have the existing stand improved. It is incumbent upon the forester to choose a silvicultural practice which will promote the existence of hemlock of seed-bearing size in the stand.

Any type of harvesting must be limited if hemlock is to be well represented in the reproduction. Even though a substantial amount of hemlock is present in the stand before logging, a clear-cut is not considered advisable.

Recommended silviculture to perpetuate hemlock.

Even aged stand — shelter wood cutting
Uneven aged stand — selection cutting

Hemlock reproduction is extremely tolerant and will exhibit excellent response after release. It is effected less by suppression than any of its associates. Openings in the canopy of about 20 to 30 feet in diameter will give best results and shouldn't exceed 35 feet to obtain optimum hemlock reproduction.[1]

Tree Marking Guide

To obtain the best log quality, hemlock should be thinned at pole size and harvested in the range of 16 to 18 inches D.B.H., especially on poorer sites. Stands of younger, good vigor trees are less apt to develop shake and compression wood than stands composed of older or poorer vigor trees. The GFA demonstration project revealed that twice as many poor vigor trees exhibited shake as did the good vigor trees.

Mark for removal all leaning trees, those with sweep or crook and those showing other signs of poor vigor. Note the characteristics of good vigor and low vigor in Table 1, "Tree Vigor Classes."

When marking, keep in mind the optimum and maximum size of canopy opening in accord with recommended silvicultural practices.

1 R. H. Westveld, "Applied Silviculture in the U.S.," 1935, Edwards Brothers Inc., Ann Arbor, Michigan

TABLE 1 — TREE VIGOR CLASSES

Note: Roots, trunks and crowns of all trees should be examined on all four sides.

GOOD VIGOR

Roots	Trunk	Crown
Firm No extensive rot. No serious mechanical injury.	No rot, frost cracks, or other mechanical injury permited in first 8′ of bole. No rot above 8′.	Natural pruning and occasional dead branch permitted. Intermediate or better. Medium in size and in density of foliage. Permits a few large dead limbs or a few branches that are dying back.

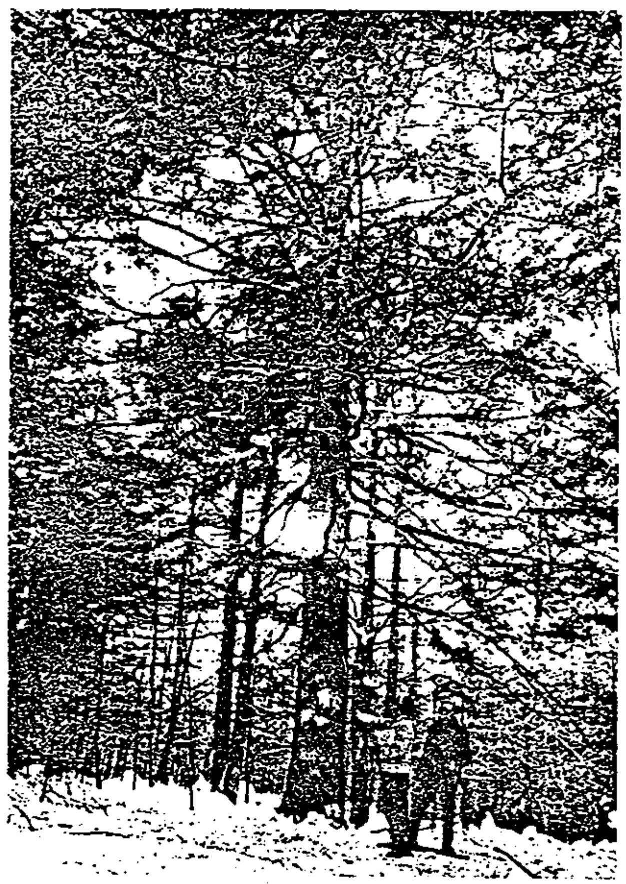
Trees not meeting above specifications are low vigor.

LOW VIGOR

Roots	Trunk	Crown
Sprung roots. Serious rot or mechanical damage.	Heavy rot in first 8′. Excessive crook in first 8′. Moderate rot above 8′. Large weak crotches. Many large broken limbs.	Small, suppressed or thin. Many large dead limbs. Many branches dying back.

Any tree exhibiting at least one of the above characteristics should be considered low in vigor.
Over-mature trees should be included in low vigor class.

Modified from: "Suggested Hardwood Tree Class Standards for Farm Foresters," U.S. Forest Service. 1945.



Mature open grown trees develop large branches causing degrade.

HEMLOCK TREE GRADING FOR THE TIMBER CRUISER

A tree grading system provides a working tool for timber appraisal and inventory purposes. The application of tree grades while cruising can provide a measuring stick to determine stand values or to evaluate changes in timber quality between inventories.

Tree Grading Procedure —

- Determine tree volume based on diameter and height measurements and make appropriate scaling deductions for visible defects.

  Making the volume estimate first will enable the cruiser to become quickly aware of the defects also involved in grading.

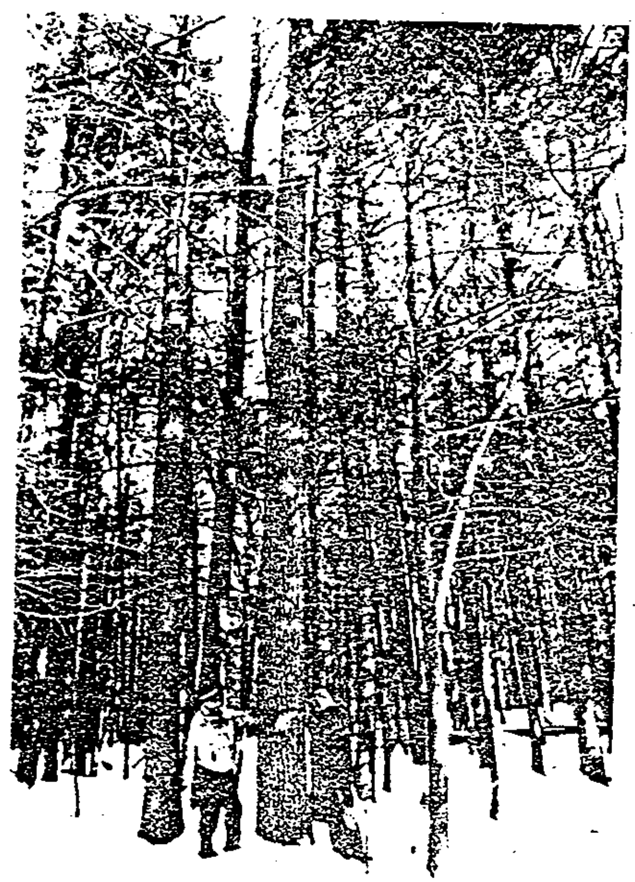
- Estimate top height of first 16′ log in tree.

- Place a log grade on this butt log of the tree, using the specifications for log grades noted in Table 2, Log Grade Specifications.

  Only the butt log need be graded when tree grading.

- Note scaling deductions as they might apply to the log grade.

- The grade of the butt log (first 16′) can be considered the grade of the tree.



Instrument Detection of Decay in Wood — The Shigometer

Experimental work by Dr. Alex Shigo, Chief Plant Pathologist, U. S. Forest Service, Durham, New Hampshire has been underway for some time to develop an instrument that can detect decay and possibly other imperfections in the log or tree. Measurements are made of the metallic ions in the wood, and wound tissue can be detected because of the greater concentration of metallic ions in this area. It is suspected that potassium ions are the principal ones detected.

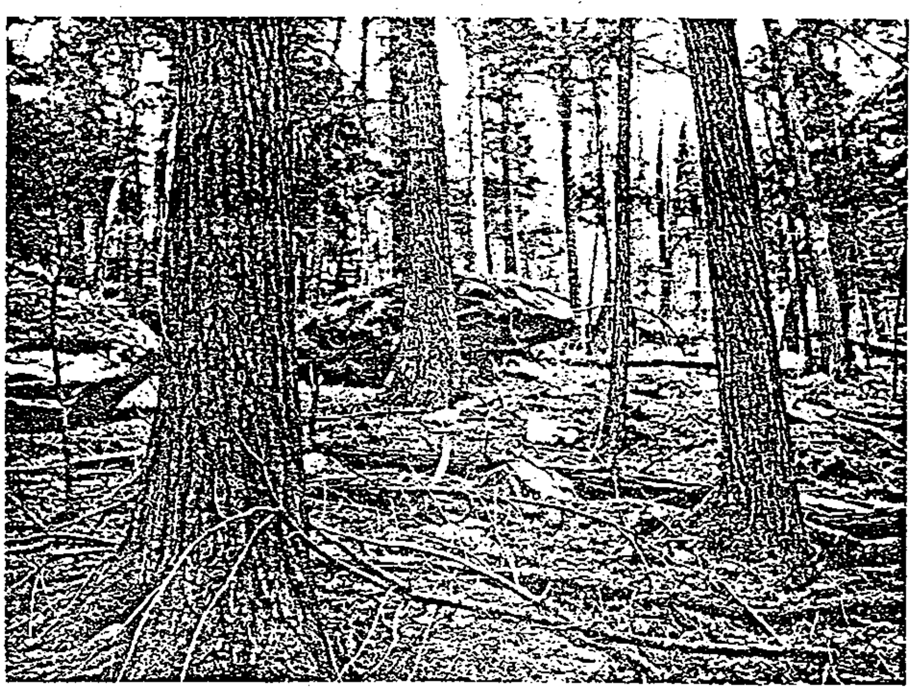
The GFA Demonstration Project supplied some hemlock sawlogs, and in cooperation with Dr. Alex Shigo, a measurement study was undertaken on both logs and the resulting lumber.

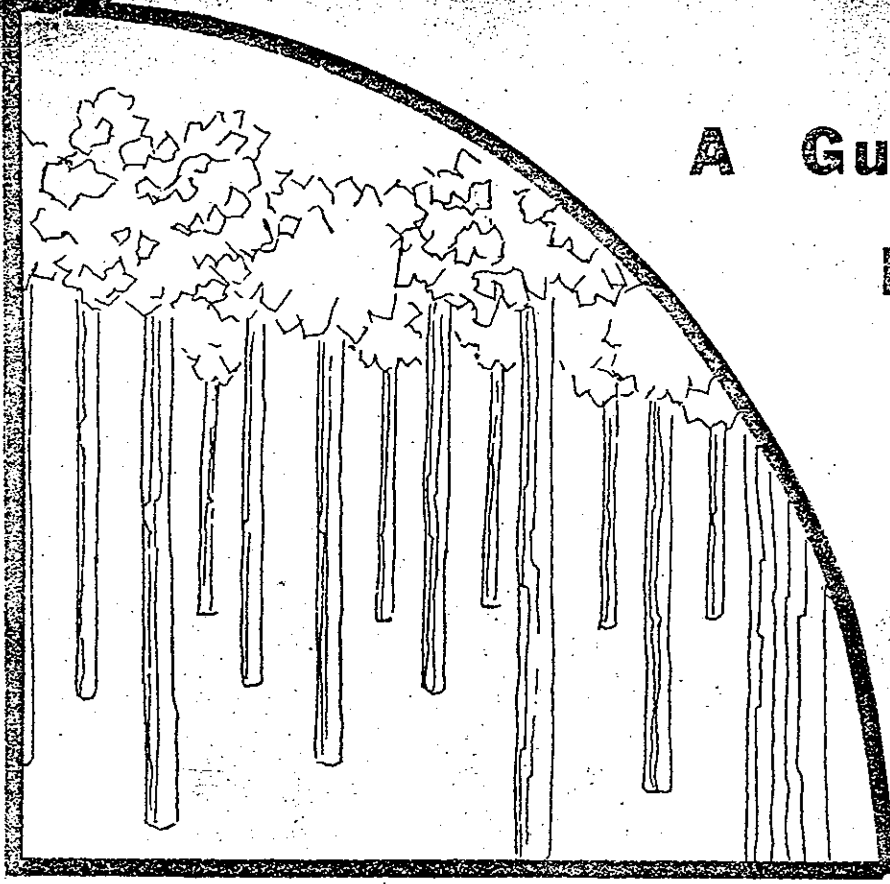
The demonstration involved 73 logs from 23 designated hemlock trees which were sawn by the University of New Hampshire sawmill into dimension lumber under the direction of the project staff. Measurements were taken with the Shigometer on each log and at several points on each piece of lumber and the data recorded. The lumber was dried to about 19% MC and then graded by the Chief Inspector for the Northeastern Lumber Manufacturers Association.

Results of the demonstration were promising, and it appears that a correlation exists between low meter readings taken midway between the bark and pith and the number of defective or low grade pieces of lumber. The presence of shake is also indicated by a correlation with changes in the meter readings.

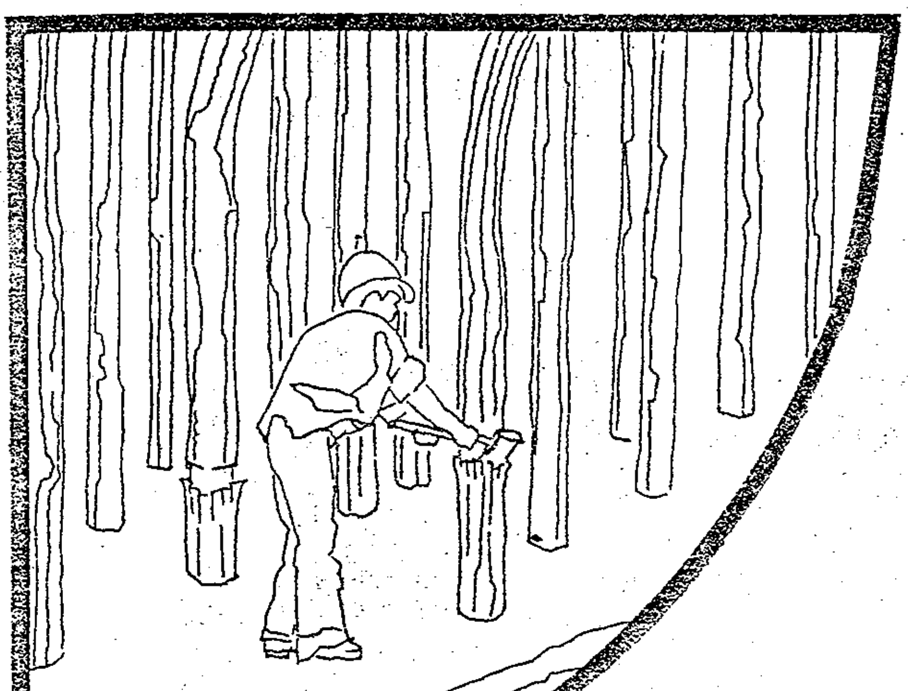
With the development of a better single instrument probe, Dr. Shigo hopes to be able to use the new equipment for additional tests on eastern hemlock. The results of the above demonstration have led him to believe that accurate predictions of wood quality can be determined by making only a few instrument measurements of standing hemlock trees.

Further information on the work of Dr. Alex Shigo can be found in his 1974 U. S. Forest Service Research Paper (in press) entitled "Detection of Discoloration and Decay in Living Trees and Utility Poles."





A Guide To - Hardwood Timber Stand Improveme



USDA, Forest Service
Northeastern Area
State & Private Forestry
Upper Darby, Pa. 19082

INTRODUCTION

This material was prepared to help the practicing forester identify factors that need be considered in: (1) preparing timber-stand-improvement prescriptions; and (2) spreading limited forestry funds over a larger area without significant reduction in benefits to the stands.

It is not the intent of this paper to provide hard and fast rules, but to provide information to supplement on-the-ground judgment of the forester.

DEFINITION AND SCOPE

Timber stand improvement (TSI) is a noncommercial operation that includes cleaning sapling stands, thinning pole and small sawtimber stands, removing cull trees in all stands, and finally, post-harvest treatments such as the removal of all stems 2 inches and larger after a regeneration cut or clearcut. Two timber types are considered: the upland central hardwoods and the northern hardwoods.

ECONOMICS OF CULTURAL TREATMENTS

Timber stand improvement is performed to shift growth to fewer trees of better form and higher value. These alterations in stand density and spacing not only improve the quality and composition of the stand, but also the growth of the residual trees, which ultimately results in a shorter rotation yielding the highest rate of financial return. Essentially then, the decision to perform TSI or not is an economic one made to obtain a higher return. Foresters are in agreement on this point, but equally important, they must also realize that economics may limit the extent of application. The failure to recognize these limits can cause money to be spent unwisely.

What are these limits or sideboards within which TSI expenditures should be contained if maximum values are to accrue to the landowner? Most are aware of the benefits derived from TSI in qualitative timber terms, but to establish areas on which the practice is desirable, and to what extent, a quantitive monetary evaluation must be made to establish dol-

METHODS OF STAND IMPROVEMENT

The greatest response of the residual stand, which is the intent of stand improvement, is generated by crown thinning (sometimes referred to as "crop tree release"). The crowns of dominant and codominant crop trees are released from side competitors, which are usually codominants or larger and strong intermediates. To carry TSI to the understory in hardwood stands is a luxury the forester can ill afford to prescribe, for the understory trees in such stands do not compete to the extent that an investment in their removal is justified. The pressing need now is for more forest management with limited funds, which dictates that all treatments be so regulated that economic objectives are attained; and this can best be accomplished by limiting TSI to crown thinning and to medium and better sites.

A. CLEANING OR THINNING SAPLING STANDS 2 TO 4 INCHES dbh

The crop tree selection method can be applied successfully in sapling stands. The best trees of the highest valued species are selected as crop trees, and adjacent competing trees are eliminated in their favor. This frees the crown of the crop tree and provides growing space.

Application

a. Begin thinning when the stand is 20 to 25 years old or when the crop trees can be recognized, which is usually when they are about 3 to 5 inches dbh.
b. As added insurance against loss of selected crop trees, where stocking allows, improve growing conditions for one alternate crop tree for each final crop tree selected. This means about 120 crop trees per acre should be selected for release.
c. Select the crop tree from dominants or codominants of desirable species with good stem and crown form and reasonably free of defect. If necessary to select intermediates for changing composition choose the strongest and best formed intermediates.
d. Free the crown to provide 3 to 4 feet openings between crowns. To be sure a crop tree retains position in the crown canopy, avoid making openings greater than 4 to 5 feet on more than 50 percent of its crown circumference even if it means leaving a tree of less desirable species or a side competitor.
e. Spacing of crop trees can be determined by the following formula:

$$\text{Spacing in feet} = \sqrt{43{,}560 \div \text{No. crop trees/acre}}$$

If 100 crop trees per acre are selected, for example, the spacing distance is about 21 feet.

Prescription

Pick one crop tree within each spacing distance and crown-release it. Pass over areas that have no qualifying trees. This mechanical method of thinning will reduce costs and improve effectiveness of TSI crews.

B. THINNING AND CULL TREE REMOVAL IN STANDS WHERE CROP TREES RANGE BETWEEN 6 AND 10 INCHES dbh

The objective in these stands is to improve growing conditions for desirable crop trees by removing competitors and undesirables much the same as by cleaning. The effort is made to achieve good spacing between crop-tree crowns while maintaining adequate stocking. This can be accomplished by following management guides.

Application

a. From plot data, determine "B" level. Do not reduce total stocking below this level. For northern hardwoods, this is between 55 and 75 square feet of basal area, which represents a measure of those trees in the main crown canopy only. For upland central hardwoods, the "B" level is from 45 to 65 square feet, which represents all trees 2 inches dbh and larger.
b. If it is impossible to reduce the stand stocking to the "B" level because of finances, landowner's choice, or other reasons, the selection of 40 to 80 crop trees per acre for release might be an acceptable alternative. The selection would be made in much the same way as in selecting trees for pruning. The selected crop trees should be crown-released on four sides, if possible, to 4 to 6 feet of opening between

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APPENDIX I

"B" LEVEL STOCKING AND CROP-TREE SPACINGS FOR AVERAGE MAIN STAND DIAMETERS

Average diameter of main stand*	"B" Stocking levels square feet of basal area per acre		Square spacing, main stand (nearest foot)	
Inches	*Northern Hardwoods*	*Upland Central Hardwoods*	*Northern Hardwoods*	*Upland Central Hardwoods*
6	55	45	13	14
7	60	50	14	16
8	65	55	15	18
9	70	60	17	20
10	75	60	18	21
11	75	65	20	23

* For upland central hardwoods, the average diameter of the stand as determined by the stocking guide includes trees 2 inches and larger. To determine the average diameter of the main stand, add 2 to 3 inches to the guide average and use this table. For northern hardwoods, the average diameter of the main stand is obtained directly from the stocking guide.

ESTABLISHING EVEN-AGE NORTHERN HARDWOOD REGENERATION BY THE SHELTERWOOD METHOD--A PRELIMINARY GUIDE

Richard M. Godman and Carl H. Tubbs

Shelterwood cuttings are proving to be one of the most reliable methods for establishing even-aged stands of northern hardwoods (fig. 1) (Behrend and Patric 1969, Curtis and Rushmore 1958, Leffelman and Hawley 1925, Metzger and Tubbs 1971, Tubbs and Metzger 1969). This system provides a partial canopy that encourages full stocking of desirable species, stimulates early seedling growth to shorten the establishment period, and restricts the intensity of competition from grasses and herbaceous plants. Other methods of establishing even-aged stands in the Lake States, such as heavy diameter-limit cutting and various forms of clearcutting, have generally given less consistent results (Metzger and Tubbs 1971). They have yielded great variation in both stocking and height development and frequently converted areas to grassy openings or patches dominated by partial stocking of pioneer species.

Shelterwood trials in northern hardwood types of the Lake States have all been successful in establishing even-aged reproduction although the length of time it takes has varied. Advantages of the shelterwood method are its adaptability to mechanized harvesting, its desirable esthetic appearance while a new stand is becoming

Figure 1.--*Shelterwood stand 3 years after the initial cut.*

Table 1.--*Crown area of northern hardwood species by diameter classes and theoretical stocking for different levels of crown cover*

D.b.h.	Crown area	Crown cover (percent) 50: Trees	50: Basal area	50: Spacing	60: Trees	60: Basal area	60: Spacing	70: Trees	70: Basal area	70: Spacing
	Sq ft	No.	Sq ft	Ft	No.	Sq ft	Ft	No.	Sq ft	Ft
1	20	1,089	6	6	1,306	7	6	1,525	8	5
2	37	589	13	9	706	15	8	824	18	7
3	56	389	19	11	467	23	10	544	27	9
4	78	279	24	12	335	29	11	391	34	11
5	104	209	29	14	251	34	13	293	40	12
6	133	164	32	16	196	39	15	229	45	14
7	164	133	36	18	159	43	16	186	50	15
8	199	109	38	20	131	46	18	153	54	17
9	238	92	40	22	110	48	20	128	57	18
10	279	78	43	24	94	51	22	109	60	20
11	325	67	44	26	80	53	23	94	62	22
12	373	58	46	27	70	55	25	82	64	23
13	422	52	48	29	62	57	26	72	67	25
14	480	45	48	31	54	58	28	64	68	26
15	536	41	50	33	49	60	30	57	70	28
16	598	36	51	35	44	61	32	51	71	29
17	662	33	52	36	40	62	33	46	73	31
18	728	30	53	38	36	63	35	42	74	32
19	803	27	53	40	32	64	37	38	75	34
20	881	25	54	42	30	65	38	35	76	36
21	952	23	55	44	27	66	40	32	77	37
22	1,035	21	56	46	25	67	42	30	78	38
23	1,120	19	56	47	23	67	43	27	79	40
24	1,207	18	57	49	22	68	45	25	79	42

Table 2.--*Crown area of basswood by diameter classes and theoretical stocking for different levels of crown cover*

D.b.h.	Crown area	Crown cover (percent) 50: Trees	50: Basal area	50: Spacing	60: Trees	60: Basal area	60: Spacing	70: Trees	70: Basal area	70: Spacing
	Sq ft	No.	Sq ft	Ft	No.	Sq ft	Ft	No.	Sq ft	Ft
1	11	1,980	11	5	2,376	13	4	2,772	15	4
2	22	990	22	7	1,188	26	6	1,386	30	6
3	33	660	32	8	792	39	7	924	45	7
4	43	506	44	9	608	53	8	709	62	8
5	54	403	55	10	484	66	10	565	77	9
6	69	316	62	12	379	74	11	442	87	10
7	86	253	68	13	304	81	12	355	95	11
8	103	212	74	14	254	89	13	296	103	12
9	126	173	76	16	207	92	14	242	107	13
10	153	142	78	18	171	93	16	199	109	15
11	181	120	79	19	144	95	17	168	111	16
12	207	105	83	20	126	99	19	147	116	17
13	241	90	83	20	108	100	20	126	117	19
14	274	80	85	23	95	102	21	111	119	20
15	312	70	86	25	84	103	23	98	120	21
16	349	62	87	26	75	105	24	87	122	22
17	388	56	88	28	67	106	25	79	124	24
18	427	51	90	29	61	108	27	71	126	25
19	470	46	91	31	56	110	28	65	128	26
20	518	42	92	32	50	110	29	59	128	27
21	567	38	92	34	46	111	31	54	129	28
22	614	36	94	35	43	112	32	50	131	30
23	665	33	94	36	39	113	33	46	132	31
24	712	31	96	38	37	115	35	43	134	32

Table 4.--*Comparison of three 1/10-acre plots marked to the same basal area but having different percentages of crown cover*

D.b.h.	Number of trees: Northern hardwoods	Basswood	Hemlock	Plot total: Basal area	Crown area[1]
				Sq ft	Sq ft
LARGER TREES OF MIXED CROWN WIDTH					
8	2			0.7	398
10					
12					
14			1	1.1	209
16		1		1.4	349
18					
20	1			2.2	881
Total				[2]5.4	[3]1,837
SMALLER TREES OF A SINGLE CROWN WIDTH					
8	2			0.7	398
10	1			.5	279
12	2			1.6	746
14	1			1.1	480
16	1			1.4	598
Total				[4]5.3	[5]2,501
SMALLER TREES OF A MIXED CROWN WIDTH					
8		2		0.7	206
10			1	.5	107
12		2		1.6	414
14		1		1.1	274
16	1			1.4	598
Total				[6]5.3	[7]1,599

1/ Average crown area per tree given in Column 2, tables 1, 2, and 3.
2/ Basal area per acre = 54 sq ft.
3/ Percent crown cover = $\frac{1,837}{4,356}$ = 42.
4/ Basal area per acre = 53 sq ft.
5/ Percent crown cover = $\frac{2,501}{4,356}$ = 57.
6/ Basal area per acre = 53 sq ft.
7/ Percent crown cover = $\frac{1,599}{4,356}$ = 37.

area that was cut in winter, and raspberries were dominant on 75 percent of the quadrats at the end of the third growing season. It appears that the summer-logged area will require a much longer time to establish regeneration because of competition from herbaceous vegetation. The stocking may also remain sparse because of seedling loss from skidding.

Geographical location and site also determine if competition from herbaceous vegetation will be harmful to regeneration. In the Upper Peninsula Experimental Forest raspberry growth fostered by heavy cuttings ultimately had little adverse effect on tree regeneration. Foresters must make use of local experience in deciding whether shrubs and herbaceous vegetation will be a significant factor.

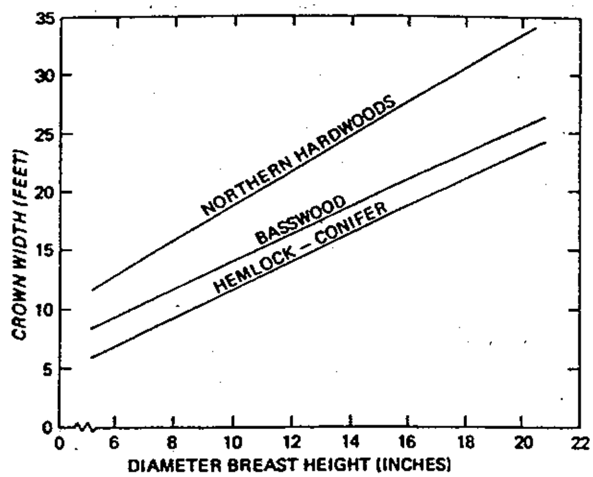

Figure 2.--*Average crown width by stem diameter and species group.*

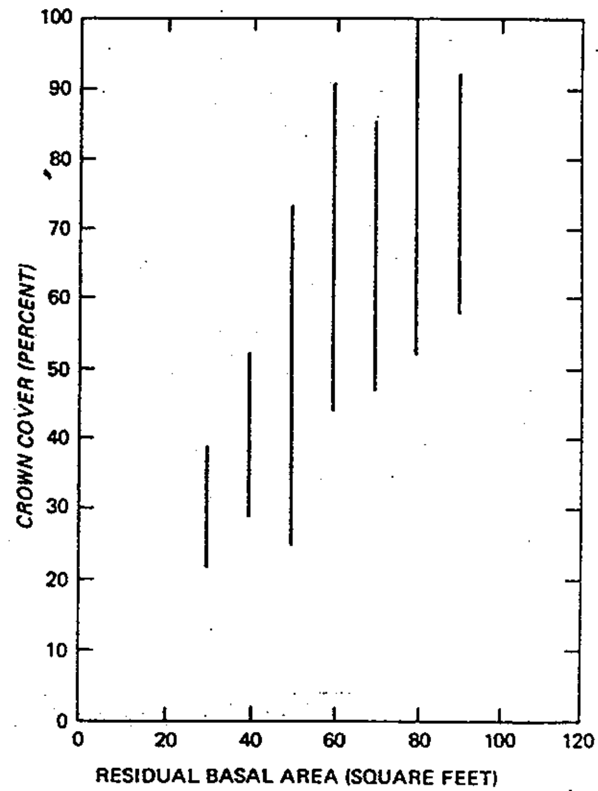

Figure 3.--*Observed variation in percent of crown cover associated with different basal area densities in northern hardwood stands.*

Overstory Removal

The shelterwood overstory should be harvested as soon as the established seedlings

Mounds need only be a foot or two in height and rounded or flat on top.

Prescribed fire is an inexpensive way to remove advanced growth and forest litter; in 1969 costs were estimated at less than $1 per acre in Ontario (Burton et al. 1969). To be most effective, burning should be done in the spring during or immediately after the leaf-out period when advanced seedling numbers can be drastically reduced.

Although burning has the virtue of being cheap and easier than scarifying on some sites, it has several shortcomings. The number of days that are conducive to spring burning are few. The resulting seedbed is dark colored and hot; on well-drained sites both germination and survival rates may be low (Tubbs 1969b). A recent trial has shown that fires hot enough to expose the mineral soil (which is more moist and cooler than burned litter) may kill overstory trees. In one study, this opened the canopy enough to encourage herbaceous species which reduced birch survival drastically. Overstory kill can be minimized by burning before harvesting when fuel quantities are low. Light burns cause no significant changes in nutrient status or soil microbial populations (Burton et al. 1969).

Killing advanced seedlings with foliage sprays during the growing season has resulted in increases of birch (Tubbs and Metzger 1969). Because the litter is not removed, however, only about half as much birch will become established as after scarification.

The First Cut

Overstory density is important to yellow birch establishment on most sites because of its influence on seedbed moisture, temperatures, and herbaceous competition. Full sunlight following clearcutting is detrimental to germination and establishment in most situations because yellow birch cannot tolerate the high temperatures and moisture conditions which result (Godman 1959, Tubbs 1969a). Open stand conditions promote raspberry growth and grass invasion which can also contribute to birch failures (Metzger and Tubbs 1971, Tubbs 1969a, Godman and Krefting 1960). After seedlings are well established, however, full sunlight promotes the best growth (Burton et al. 1969). Consequently, the first cut should provide the cool, moist conditions necessary for establishment while the second cut releases the seedlings. A wide range (from 30 to 70 percent) of overstory results in satisfactory establishment of yellow birch. In areas where development of heavy herbaceous competition is expected, heavy shade (up to 70 percent crown cover) will probably be necessary to control competition if birch is to succeed. More shade than this, however, generally results in poor seedling vigor.

Good birch sites are often moist so the most abundant species tend to be shallow rooted and subject to post-logging decadence. Prudence dictates that special attention be paid to leaving vigorous trees in the overstory, especially if a long establishment period is expected. Epicormic sprouts will develop but should not be important for short periods; when sprouts are small, these defects will be slabbed off along with defects from logging wounds (Meyer et al. 1966).

Because yellow birch seedlings compete poorly with sugar maple, some attempt should be made to discriminate against sugar maple in the overstory. Sugar maple normally does not produce moderate seed crops until reaching 10- to 14-inches d.b.h. (USDA Forest Service 1965) and the larger trees will obviously produce the most seed. Thus, where spacing permits, remove the largest sugar maples first.

Leaving many yellow birch in the overstory for seed probably will not increase birch stocking and may lead to losses from decadence and mortality (Jacobs 1960). Seed has been shown to be adequate 5 chains from the source (Benzie 1959). In another study enough seed was produced on a scarified area containing four trees per acre to provide over 1/2 million seedlings per acre (Godman and Krefting 1960). One seed-bearing birch per acre should provide adequate insurance against unfavorable climatic conditions or seed crop failures.

Seeding and Planting

Seeding and planting to augment natural regeneration seldom have been practiced. Earlier experimental evidence (Stoeckeler and Limstrom 1950) indicates that planting in open conditions often will be unsuccessful. However, recent trials have shown that yellow birch seedlings can be successfully planted on moist soils under a shelterwood overstory. Establishment can be improved by removing half the seedling stem before planting (Godman and Mattson 1971).

Direct seeding has been successful on small plots under a shelterwood canopy. Tree percent may be low, however, even on favorable sites (Tubbs 1969a). At least 1/4 pound of seed is needed per acre on scarified sites to get a dense stocking.[2] In the Upper Peninsula of Michigan seed sown before January germinates well the following spring; seed sown after this date germinates late in the summer (Tubbs 1964).

Overstory Removal

Overstories may be removed when the yellow birch seedlings average 2 to 4 feet in height.

2/ Number of seed varies from 330,000 to 1 million per pound.

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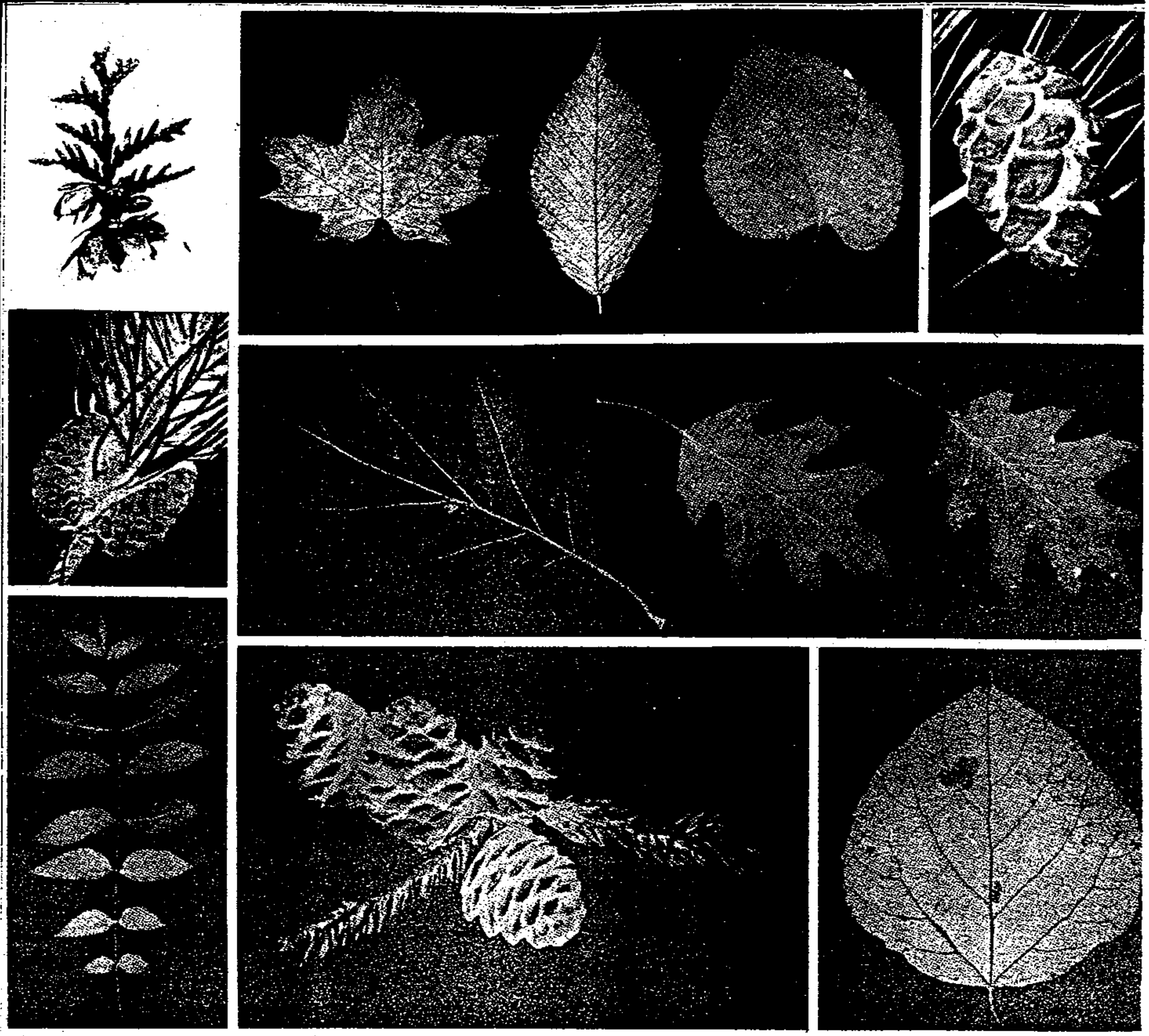

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manager's handbook for

NORTHERN WHITE-CEDAR IN THE NORTH CENTRAL STATES

GENERAL TECHNICAL REPORT NC-35

NORTH CENTRAL FOREST EXPERIMENT STATION FOREST SERVICE U.S. DEPARTMENT OF AGRICULTURE

CONTENTS

NORTHERN WHITE-CEDAR IN THE NORTH CENTRAL STATES

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SILVICAL HIGHLIGHTS

The northern white-cedar[1] type occupies 2 million acres of commercial forest land in the northern Lake States; three-fifths of this total occurs in Michigan. Northern white-cedar grows mainly on organic soil where its growth rate increases as the soil is more decomposed and has more actively moving soil water. White-cedar grows in pure stands but more commonly is mixed with such trees as balsam fir, black spruce, tamarack, and black ash. Northern white-cedar may perpetuate itself in pure stands, whereas other trees seem to gradually replace it in mixed stands, particularly after disturbances. White-cedar lives longer than associated trees, reaching ages of 400 or more years on organic soil sites.

Northern white-cedar produces good seed crops every 3 to 5 years. Germination and early growth are best on moist seedbeds such as rotten wood, compacted moss as in skid roads, and burned soils. Vegetative reproduction by layering is common on organic soil sites. Northern white-cedar can survive in the shade for several years and yet responds well to release at nearly all ages. So, depending on their history, white-cedar stands can be uneven-aged as well as even-aged.

The main damaging agents of northern white-cedar are wind, deer and hare, and impeded drainage. The relatively shallow root system of white-cedar makes it susceptible to uprooting where trees are exposed to the wind. Short trees and reproduction are often overbrowsed by deer and hare. Drainage impeded by roads and beaver has killed white-cedar and associated trees on thousands of acres of organic soil.

MANAGEMENT OBJECTIVES AND NEEDS

The assumed objective in managing the northern white-cedar type is to produce at least a moderate sustained yield of merchantable timber as efficiently as possible, while maintaining or increasing the quality and quantity of deeryards and other forest values. Some resource managers may be able to concentrate their efforts on either timber or deeryards. However, most managers will need to consider both because timber management and deeryard management are usually inseparable in the white-cedar type.

Wherever possible, the type should be managed in fairly large, even-aged stands because these are apparently best for both timber production and deeryards, and are well suited for efficient cultural operations and mechanized harvesting. Practices to enhance other wildlife habitat, water, and esthetics are limited, but will be discussed under "Other Resource Considerations" (p. 10), along with practices for managing deeryards.

The demand for *high quality* white-cedar timber is strong, but the type is being undercut in parts of the Lake States because many mature stands do not have enough such timber for a commercial harvest. Thus there is a need to practice more intensive management that will result in merchantable stands. It is especially important to obtain satisfactory reproduction promptly after harvesting on brushy areas. If not stocked early with trees, these areas convert to lowland brush and become difficult and expensive to reforest.

The white-cedar type is also generally valuable for deeryards in the northern Lake States, but some yards

[1] *For scientific names of plants and animals, see Appendix, p. 16.*

9. **Slash cover light** . . . . SPREAD SLASH EVENLY, USE NATURAL SEEDING
See "Slash Cover", p. 7 and "Natural Seeding", p. 8
9. **Slash cover heavy** 10
10. **Clearcut strips 1 or 2 chains[2] wide** . . . . SKID FULL TREES, USE NATURAL SEEDING
See "Reproduction Cutting", p. 6 and "Slash Cover", p. 7
10. **Clearcut strips 3 chains wide** . . . . BROADCAST BURN SLASH, USE NATURAL SEEDING
See "Broadcast Burning Techniques", p. 15

TIMBER MANAGEMENT CONSIDERATIONS

Controlling Growth and Composition

Site Productivity

The northern white-cedar type is found mainly on organic soil in the Lake States, but it also occurs on mineral soil. Growth rate varies greatly; height of dominant white-cedar trees at 50 years ranges from at least 40 feet on the best sites to less than 15 feet on the poorest. Mature, fully stocked stands of pure white-cedar (at least 80 percent) on good sites commonly yield 4,000 merchantable cubic feet or 50 cords per acre for trees 5.0 inches d.b.h. and larger. Much of this volume is in logs and poles, whereas many stands on poor sites produce only small posts. (See Appendix for site index curves and yield of white-cedar stands.)

Degree of decomposition, botanical origin, and natural drainage of the upper horizons of organic soil are good guides to site productivity, whereas total depth is a poor guide by itself. The best sites have moderately to well decomposed organic soil that is derived from woody plants or sedges and is neutral or slightly alkaline. However, the upper 4 inches on these sites may be poorly decomposed sphagnum or other mosses. The best sites have actively moving soil water and are usually near streams or other drainageways. In contrast, the poorest sites have poorly decomposed, acid soil that is derived from plants such as sphagnum moss throughout the whole root zone. These sites have little water movement (except during snowmelt) and are often far from drainageways.

Extensive management is recommended where the site index for white-cedar is less than 25. Stands on such sites are best suited for producing only small posts and deer browse, whereas stands on better sites should be managed to produce larger timber and deer shelter (in addition to posts and browse). Clearcutting in strips at rotation age, and slash disposal to ensure reproduction, are the only silvicultural practices recommended for poor sites (see p. 3, 6, 7).

[2] *One chain = 66 feet.*

The growth rate of white-cedar could undoubtedly be increased on organic soil sites in the Lake States by draining and fertilizing, but specific practices are presently lacking. They have not been developed mainly because the region's extensive upland forests produce sufficient timber, and probably at a higher economic return than lowland forests. However, with the increasing interest in the white-cedar type and the greater demands on land use in upland forests, there may be a need in the future to develop effective and environmentally acceptable ways to drain and fertilize organic soil sites.

The northern white-cedar type is common on mineral soil in the Lake States mainly on seepage areas and limestone uplands. Growth is usually faster than on organic soil, being best on mineral soil that is calcareous and moist but well drained.

Rotation

The best rotation for growing northern white-cedar varies greatly with site productivity and the management objective. White-cedar stands are usually considered mature and ready to harvest for timber when their mean annual growth for the main product peaks. The rotations at which this occurs for two common units of measurement are as follows:[3]

Site index	Merchantable cubic feet	Board feet
	––––– (Years) –––––	
40 (excellent)	70 to 90	110 to 140
30 (medium)	80 to 100	130 to 160
20 (poor)	100 to 140	130 to 160

These rotations have a range because the mean annual growth has practically the same maximum for a number of years. Therefore, the manager has considerable

[3] *See Appendix for tree dimensions included, site index curves, and timber yield.*

are the main species to control. Use a total rate of 3 pounds acid equivalent in at least 4 gallons of water per acre. Spray in early August, or when white-cedar has completed its new growth and yet shrubs and hardwoods are still susceptible.

Herbicide spraying should be done carefully, following all pertinent precautions and regulations. It is particularly important not to contaminate open water with herbicide, so do not spray vegetation around the borders of ponds, lakes, and watercourses. These guidelines will minimize the risk of adverse environmental effects on organic soil sites.

In older stands where northern white-cedar or its main associated trees are merchantable, it may be possible to thin commercially or at little cost. Thinning can improve both timber quality and deer use. If the slash is left so that it is available and not an obstacle, white-cedar and hardwoods cut in *winter* provide browse; deer also have space to move about more easily than in excessively dense, unthinned stands. For optimum deer shelter, deciduous trees (hardwoods and tamarack) should be cut or otherwise killed to obtain a closed canopy of evergreens (mainly white-cedar and black spruce). Balsam fir should be harvested *no later than* 70 years of age because butt rot makes this species especially susceptible to wind breakage after that.

The best available information indicates that middle-aged stands managed for timber can be initially thinned to a residual basal area of 130 square feet per acre and then rethinned every 10 years to at least as low as 90 square feet without affecting growth or mortality. The lighter first thinning is needed to maintain maximum growth. Good diameter growth of white-cedar can apparently be maintained through repeated thinnings that favor dominant and codominant trees. Research findings also indicate that advance tree reproduction and shrubs grow little unless the stand is rethinned to less than 150 square feet per acre (fig. 1).

Therefore, it is generally best not to thin below 150 square feet of basal area per acre. This provides an opportunity to improve the quality of the final harvest and to increase total yield without producing an undesirable undergrowth of balsam fir and shrubs, for example. Such thinning also provides deer shelter ranging from fairly good immediately after thinning to excellent toward the end of the thinning cycle.

Preparatory Treatment

The primary purpose of preparatory treatment is to control associated trees before the final harvest so that

Figure 1. — *Typical stand of northern white-cedar and some black spruce, with an undesirable undergrowth of balsam fir, 10 years after a second thinning to 130 square feet of basal area per acre.*

northern white-cedar will remain predominant in the next stand. Thus associated trees are "scarce" only if their reproduction, especially by vegetative means, will not become predominant. Although they can be easily overlooked, it is important to realize that a few mature trees per acre of certain species sometimes produce many seeds, suckers, or sprouts.

Preparatory treatment, like intermediate treatment, should usually be: (1) aimed at obtaining a mixed stand of 50 to 80 percent white-cedar and (2) limited to stands where intensive management for timber, deer habitat, or both can be justified. Since intermediate treatment tends to reduce the amount of undesirable associated trees, preparatory treatment will have the greatest value in mixed stands that have had no intermediate treatment.

Preparatory treatment should be done at least 5, and preferably 10, years before reproduction cutting to ensure control of undesirable trees. To minimize the establishment and growth of suckers, sprouts, and seedlings from these trees after treatment, it is apparently important to have a residual basal area of about 150 square feet per acre. Hardwoods are usually more important to control than conifers because they reproduce readily both vegetatively and from seed. Root suckers, such as those of balsam poplar, and stump sprouts are very competitive with white-cedar reproduction. Further, hardwoods (and tamarack) are deciduous and thus provide no winter shelter for deer.

Undesirable trees should be felled if they are merchantable or will provide deer browse; otherwise trees are short (less than 35 feet) to 2 chains wide where these trees are tall (more than 60 feet). Strips can probably be 1 chain wider and receive adequate seed if they have a mature stand of white-cedar on *both* sides. Since clearcutting is preferred to shelterwood for reproducing white-cedar, shelterwood strips should be only 1 or 2 chains wide to minimize the area they occupy.

The usual reproduction period between removing adjacent clearcut strips, and between seed cutting and final cutting in shelterwood strips, has been about 10 years. However, this period should be shortened or lengthened as needed, depending on results from reproduction surveys (see p. 8). A new even-aged stand can be obtained in less than 10 years or up to 20 years using alternate or progressive strips, respectively. If timber considerations or the risk of overbrowsing call for harvesting or reproducing a stand as rapidly as possible, do seed cutting in the shelterwood strips and remove the alternate or the second set of clearcut strips at the same time. Residual shelterwood trees should adequately seed these clearcut strips, thus substantially shortening the overall reproduction period.

Ways to make new harvest areas look better are discussed under "Esthetics" (p. 11).

Residual Stems

These are trees of any size down to 6 inches tall that are expected to or do survive clearcutting. They may be of any species or age, and of seedling or vegetative origin. Residual stems are "scarce" if they or their reproduction, especially by vegetative means, will not become dense enough to severely suppress reproduction of northern white-cedar or its valuable associate, black spruce. As mentioned under "Preparatory Treatment" (p. 5), it is important to consider the reproductive potential of associated trees, particularly hardwoods.

Residual stems should be relied on to reproduce a stand only if relatively young and healthy white-cedar stems are or will be predominant (at least 50 percent of basal area). Such stems are arbitrarily defined as being less than 50 years old and having well-developed crowns. In contrast, many of the white-cedar stems remaining after clearcutting are 50 or more years old or have poorly developed crowns (for example, from browsing). Old stems also tend to be of layer origin, which often results in poor form. Some old or unhealthy trees may grow satisfactorily after clearcutting and yield much deer browse, but young seedlings are preferred for producing timber and deer shelter. Therefore, residual stems should be saved to reproduce a stand only if: (1) 60 percent or more of the milacres[8] in the clearcut area will contain at least one young and healthy white-cedar *after* harvesting and (2) the cost of saving such stems does not exceed the cost of obtaining new white-cedar reproduction of equal density *and* size. Obviously, the stand must be harvested carefully and slash removed where it covers needed stems.

Residual stems of associated trees should be controlled enough that they or their reproduction will not severely suppress suitable residual stems (or new seedlings) *of white-cedar*. Undesirable trees should usually be felled if they will provide deer browse, otherwise they can be girdled. However, hardwoods should be treated with herbicide where experience indicates they will be a problem. Aerial spraying is recommended where residual hardwoods, especially of seedling or sapling size, are abundant (see p. 4); otherwise trees and stumps should be treated individually (see p. 6). Broadcast burning of slash is an efficient way to kill residual conifers, especially where many are of seedling or sapling size (see p. 15). Burning will kill back hardwoods, but herbicide is more effective on those that reproduce mainly from suckers or sprouts.

Slash Cover

This is "heavy" when slash hinders satisfactory reproduction by burying suitable residual stems or seedbeds (fig. 3, left). A heavy cover of slash is definitely detrimental, but a light cover is more favorable than practically none. Therefore, slash disposal is usually not needed in poorly stocked stands when the slash is spread evenly. Slash cover is also heavy when it creates an important fire hazard. However, the risk of fire is low on most white-cedar areas because they do not dry up much and there is little contact with human activities.

Broadcast burning is the preferred method of slash disposal except, of course, where shelterwood trees are present or residual stems are to be saved. Burning eliminates most slash, completely kills residual conifers, kills back hardwoods and brush, and probably improves seedbed conditions (fig. 3, center). However, because white-cedar has a short seeding range and space is needed for a slash-free alley around the perimeter of the strip, broadcast burning should be limited to strips 3 chains wide. (See Appendix, p. 15 for burning techniques.)

Full-tree skidding *in winter* is recommended for slash disposal on strips less than 3 chains wide. Stands

[8] *A milacre is 1/1,000 acre, usually 6.6 feet square.*

these trees. However, this method of controlling composition cannot be recommended until studies under way definitely show that such areas can be successfully reproduced to white-cedar by direct seeding.

Quaking aspen and paper birch not only reproduce well on slash-burned seedbeds on organic soil sites, but also fairly well on unburned seedbeds such as those resulting from full-tree skidding. These trees have much greater seeding ranges than black spruce and tamarack, so it is probably impractical to substantially reduce their natural seeding. Fortunately, aspen and birch are not expected to severely suppress northern white-cedar except on the best sites. Here herbicide spraying may be desirable to release white-cedar as prescribed and discussed under "Intermediate Treatment" (p. 4).

Controlling Damaging Agents

Wind

Breakage and uprooting of trees by wind can be important causes of mortality in older stands of the northern white-cedar type, but the loss has sometimes been overrated. The risk of wind damage is greatest in unmanaged mature stands of mixed composition. For example, balsam fir and black spruce are more susceptible to breakage or uprooting than white-cedar because they are usually taller and balsam fir commonly has butt rot, especially on the drier sites. Both breakage and uprooting occur mainly along stand edges exposed to the prevailing wind and in stands opened up by partial cutting. By using the rotations and cutting methods recommended in this handbook, wind-caused mortality should be minimal.

Deer and Hare

White-tailed deer and snowshoe hare commonly browse northern white-cedar so severely that a stand cannot become established successfully after reproduction cutting. However, as long as white-cedar stands can be established or maintained, browsing is usually considered beneficial to deer and hare – rather than damaging to the reproduction – because it provides much nutritious food.

The reproduction cutting system recommended earlier (p. 6) should minimize overbrowsing of young white-cedar if large patches (40 acres or more) of mature forest are completely cleared in 10 years or less. This is because: (1) deer and hare tend to avoid large openings, due to the lack of protective cover; (2) openings have deeper snow, which can deter deer in many parts of the northern Lake States; and (3) a great amount of browse is present in large young stands. Further information on how to minimize overbrowsing of white-cedar is discussed under "Deeryards" (p. 10).

Impeded Drainage

Poorly constructed or maintained roads have killed or reduced the growth of northern white-cedar and associated trees on thousands of acres of organic soil in the Lake States by impeding the normal movement of water. Beaver damming of natural watercourses or man-made drainage ditches has similar effects. Also, pipelines carrying natural gas and petroleum will cause damage unless cross drainage is provided.

Road-caused damage can be minimized by constructing and maintaining adequate collector and discharge ditches, and by using large culverts that are correctly positioned and maintained. Removal of beaver dams and judicious control of beaver can avert damage to valuable timber, deeryards, and the unsightliness of dying trees. Pipelines should have cross ditches about every 150 feet or less. These ditches can be through the backfill for pipe buried below ground or beneath pipe placed on the surface.

Other Agents

Wildfire easily kills northern white-cedar trees but good fire protection now results in little loss. During very dry periods fires can burn deeply in organic soil and become extremely difficult to put out. Biological agents other than deer and hare also cause damage to white-cedar. Unfortunately, their damage is often not recognized until the trees are cut, or if the damage is recognized, little is known about controlling it. Carpenter ants, both black and red, are the main insect enemies of white-cedar. They frequently attack partially decayed heartwood in living trees. Butt-rot fungi that cause a white stringy rot or a brown cubical rot are common in mature trees on the drier lowland sites. Woodpecker holes are the most common indicator that butt rot is present. Porcupines sometimes cause damage by girdling the stem, and red squirrels frequently eat flower buds and clip cone-bearing branches.

to be increased (see p. 4). And even then, all stems should not be killed because a mixture of shrubs and hardwoods with white-cedar and other conifers probably enhances wildlife habitat in general.

Some trout streams have their source in areas occupied by the northern white-cedar type or they pass through such areas. So, to keep the water cool, areas cleared for new stands should probably: (1) have an uncut border between them and the streams, (2) not exceed 40 acres each, and (3) total only a small proportion of the surrounding watershed.

Water

Current research findings indicate that clearcutting lowland conifers in strips or large patches, or broadcast burning the slash changes the quantity of water little. However, if a stream flows from or through a clearcut area, the water will have a higher concentration of certain nutrients for a few years with or without burning. Whether or not this increase in nutrients will have an important effect downstream, especially in lakes, is still unknown.

Esthetics

The manager can minimize the impact of harvesting on the esthetic appeal (fig. 5) of the northern white-cedar type by: (1) having harvest boundaries follow natural site or forest type lines and (2) removing heavy slash cover and otherwise leaving harvest areas neat. Slash can be removed by full-tree skidding and burned at the landing, or broadcast burned in the case of wide clearcut strips (see p. 7). Of course, as mentioned earlier, skidding of browse species should be delayed a few days if deer are in the vicinity.

Figure 5. – *The unusual bark and foliage patterns of northern white-cedar are esthetically appealing to many forest users, including hikers, snowshoers, and ski tourers.*

Table 1. – *Yield per acre of fully stocked, even-aged stands of northern white-cedar by site index and age*[1]

Age	Height of dominants and co-dominants	Trees 0.1 inch d.b.h. and larger: Average d.b.h.	Number	Basal area	Total volume	Merchantable volume		
Years	*Feet*	*Inches*		*Square feet*	*Cubic feet*[2]	*Cubic feet*[3]	*Cords*[4]	*Board feet*[5]
SITE INDEX 40								
60	47	6.2	850	180	3,490	2,460	31	2,840
80	56	8.7	470	195	4,200	3,540	45	9,540
100	64	10.7	320	200	4,700	4,180	53	15,600
120	69	12.4	250	205	5,040	4,560	58	19,900
140	72	13.6	210	210	5,270	4,800	61	22,790
160	75	14.5	180	215	5,420	4,950	63	24,410
SITE INDEX 30								
60	35	4.5	1,550	170	2,600	1,440	18	230
80	41	6.2	860	180	3,240	2,480	31	2,460
100	46	7.7	580	190	3,670	3,100	39	6,000
120	50	8.9	450	195	3,960	3,480	44	9,220
140	53	9.8	380	200	4,160	3,720	47	11,570
160	55	10.4	340	200	4,280	3,860	49	13,000
SITE INDEX 20								
60	22	3.0	3,120	155	1,690	280	4	--
80	26	4.2	1,740	170	2,180	1,120	14	120
100	29	5.2	1,180	175	2,500	1,700	22	740
120	32	6.0	930	180	2,720	2,050	26	1,680
140	34	6.5	790	185	2,860	2,280	29	2,590
160	35	6.9	720	185	2,960	2,410	30	3,220

[1]Values (except cords) adapted from Gevorkiantz and Duerr (1939) "Volume and yield of northern white-cedar in the Lake States", unpublished report on file at the North Central Forest Experiment Station, St. Paul, Minn. Values in the original report were for site indexes 41, 31, and 19; 40, 30, and 20 are shown here for convenience because the respective values are practically the same.

[2]Gross peeled volume of entire stem.

[3]Gross peeled volume between stump (height equal to d.b.h., in inches) and fixed top d.i.b. of 4 inches for trees 5.0 inches d.b.h. and larger.

[4]Gross rough volume obtained by dividing merchantable cubic-foot volume by 79, the assumed number of cubic feet of wood (inside bark) per cord.

[5]Volume (Scribner) between stump (height equal to d.b.h., in inches) and fixed top d.i.b. of 6 inches for trees 9.0 inches d.b.h. and larger.

Broadcast Burning Techniques

Initial research and experience in upper Michigan and related work in northern Minnesota indicate that northern white-cedar slash, whether pure or mixed with slash of associated conifers, can be broadcast burned safely and effectively on organic soil sites. So burning on such sites should be successful throughout the Lake States after resource managers gain some local experience.

If burning is planned (see "Key," p. 2, 3), strips 3 chains wide must be located and harvested in such a way that they can be burned safely and efficiently. The main requirements for setting up and conducting a successful broadcast burn on a clearcut strip are:

1. Locate strip on *undrained* organic soil to avoid deep ground fires that are difficult and expensive to put out. Unless burning is essential for site preparation, slash should be removed by full-tree skidding near drained organic soil, such as along ditches, and near upland sites. Burning near drained organic soil should be done only after the surface soil has been wet down thoroughly. A mineral soil firebreak should be constructed near upland sites.
2. Make edges of strip smooth and reasonably straight to avoid control problems resulting from sharp angles.
3. Cut all unmerchantable trees in the strip.
4. Plan cutting and skidding so as to distribute the slash evenly, thus ensuring that the fire will spread over the entire strip.
5. Leave a slash-free alley about 1/2 chain wide around the perimeter of the strip.
6. Burn slash the first or second year after harvesting.
7. Burn when conditions will ensure consumption of most slash less than 1 inch in diameter (see below).
8. Burn when the wind direction is parallel to the strip to avoid serious crown scorch or mortality. If this direction is uncommon, then use center firing when the wind speed is only 0 to 5 miles per hour.

Burning on organic soil sites will probably be most successful in July and August of the first year or in May of the second year. Research and experience indicate that burning severe enough to kill back residual hardwoods and shrubs or to improve moss seedbeds requires drier and hotter conditions than burning to just consume slash or kill residual conifers. Most burning has been done under the following conditions:

Time or weather variable	Burns in general	Severe burns
Time since rain ≥ 0.1 inch	3 to 10 days	≥7 days
Minimum relative humidity	30 to 60 percent	<45 percent
Maximum air temperature	60° to 90° F	≥80° F
Maximum wind speed	5 to 15 mph	5 to 15 mph

On mineral soil sites, broadcast burning should probably be severe enough to expose mineral soil if natural seeding is planned. However, local conditions and experience may indicate that mechanical ground preparation such as scarification is more efficient than burning.

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