A Silvicultural Guide for NORTHERN HARDWOODS in the Northeast

by William B. Leak
Dale S. Solomon
Stanley M. Filip

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RICHARD D. LANE, DIRECTOR

The Authors

WILLIAM B. LEAK, silviculturist, received his forestry training at the State University of New York College of Forestry at Syracuse, where he earned his Bachelor of Science degree in 1953 and his Master of Forestry degree in 1956. He joined the Northeastern Forest Experiment Station in 1956, working first at the Station's research unit at Burlington, Vermont. For several years he was located at the Northeastern Station headquarters in Upper Darby, Pennsylvania. He is now project leader of the beech-birch-maple silviculture study at Durham, New Hampshire. Mr. Leak wrote the text and prepared the prescriptions for this guide.

DALE S. SOLOMON, associate mensurationist, joined the Northeastern Forest Experiment Station in June 1962 after earning his Master's degree in forestry from Yale University. He had earned a Bachelor's degree in forestry from The Pennsylvania State University in 1961. Since 1962 he has worked on the Station's beech, birch, maple silviculture project of the research unit located at Durham, New Hampshire. Mr. Solomon developed the stocking, growth, and yield data used in this guide.

STANLEY M. FILIP, silviculturist, received his forestry training at The Pennsylvania State University. After earning his Bachelor of Science degree in 1939, he was self-employed as a consulting forester in Wilkes-Barre for 2 years. He was also an industrial forester for the Wilkes-Barre Chamber of Commerce and a farm forester for the U.S. Forest Service and the Pennsylvania Department of Forests and Waters. He joined the Northeastern Forest Experiment Station in 1946, working first at the Station's research unit at Kingston, Pennsylvania. He has been assigned since 1954 to the Station's New Hampshire research unit, now located at Durham. Mr. Filip was responsible for much of the applied silvicultural and management information used in this guide, including use of chemicals in northern hardwoods.

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in the Northeast

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Purpose and Scope

THE PURPOSE of this paper is to provide a practical guide to the management of northern hardwoods — principally beech, birch, and maple—in the Northeast. The guide was designed to provide the kind of information that is needed not only for long-term management planning, but also for short-term silvicultural prescriptions for specific timber stand conditions.

The guide is limited to silvicultural recommendations primarily for timber production. However, secondary forest uses such as recreation, water, and wildlife habitat are considered wherever pertinent.

The information in this guide applies directly to about 15 million acres of northern hardwoods in New England and New York, where northern hardwoods comprise nearly 35 percent of the commercial forest land area. Outside this area, the guide should be applied with caution.

The Northern Hardwoods

The northern hardwoods support a thriving industry in the Northeast. These hardwood forests produce millions of cubic feet of veneer logs, sawlogs, millwood, and pulpwood each year. They are also the resource base for a lucrative and growing recreation industry, the habitat for a variety of game animals and other wildlife, and a protective cover for the watersheds that serve many cities and towns.

COVER TYPES AND SPECIES

The primary cover type in the Northeast is the northern hardwood or beech-birch-maple type (fig. 1). The important timber species are sugar maple (*Acer saccharum* Marsh.), yellow birch (*Betula alleghaniensis* Britton), and American beech (*Fagus grandifolia* Ehrh.). The important associated species, which occur in lesser amounts, are red maple (*Acer rubrum* L.), paper birch (*Betula papyrifera* Marsh.), white ash (*Fraxinus americana* L.), eastern hemlock (*Tsuga canadensis* (L.) Carr.), balsam-fir (*Abies balsamea* (L.) Mill.), and red spruce (*Picea rubens* Sarg.).

The aspen-birch type commonly is associated with northern hardwoods in the New England - New York area. These are pioneer stands, characterized by a predominance of aspen (*Populus* spp.), paper birch, and gray birch (*Betula populifolia* Marsh.). Associates include red maple and other species found in the beech-birch-maple type.

Figure 1.—An uneven-aged northern hardwood stand.

Table 1.—*Silvical characteristics of the important species in the beech-birch-maple and associated types*

Species	Shade tolerance	Relative growth rate	Seeding frequency, good crops	Effective[1] seed dispersal	Minimum seedbed requirements	Sprouting vigor	Delayed germination
			Years	*Tree heights*			
Sugar maple	Tolerant	Medium	2–5	2–3	Light litter	Moderate	Possibly a small proportion
American beech	Tolerant	Medium	2–3	0–1	Light litter	Abundant root suckers	None known
Yellow birch	Intermediate	Slow to medium	2	2–4	Mineral soil or mixed mineral-humus	Very low	None known
Paper birch	Intolerant	Fast	2	2–4	Mineral soil or mixed mineral-humus	Moderate to low	None known
White ash	Intermediate	Medium to fast	3–5	2–3	Light litter	Moderate to high	Up to three-fourths germination second spring
Red maple	Intermediate	Medium to fast	1	2–3	Light litter	Very high	Small proportion germinate second spring
Aspen	Intolerant	Fast	4–5	—	Continuous moisture	Abundant root-suckering	None
Red spruce	Tolerant	Medium	3–8	2–4	Moist humus or mineral	—	None known
Eastern hemlock	Tolerant	Medium	2–3	2–4	Moist humus or mineral	—	None known

[1] Effective seed dispersal means that roughly 50 to 75 percent of the seed falls within the given distance.

The spruce-fir type also is associated with northern hardwoods at elevations near sea level in far northern New England and at elevations above about 2,000 feet in southern New England. White pine types intermingle with beech-birch-maple and aspen-birch, especially on sandy outwash material at lower elevations. Oak types occur on sunny, dry southern exposures within the northern hardwood region.

Characteristics of the important species in northern hardwood and the closely associated types that have a bearing on silvicultural treatment are outlined in table 1.

INSECTS AND DISEASES

Many insects and diseases cause damage to northern hardwood species. Only the most important are mentioned here—those the silviculturist ought to know about in evaluating the growth potential of individual trees.

Wood-decay fungi cause important losses in both volume and quality. The most important of these fungi are *Poria obliqua* (Per.) Bres. in birches, and *Polyporus glomeratus* Peck and *Fomes igniarius* (L.) Gill in maples and beech. In addition, several fungi cause discoloration, which makes the wood unsuitable for many quality products. Decay and discoloration fungi enter through wounds and dead branch stubs. The presence of large dead branch stubs on a tree strongly indicates that appreciable losses from decay and discoloration will be experienced.

The beech-bark disease is the most important lethal disease of beech. The beech scale *(Cryptococcus fagi* (Baer.)) punctures the bark, allowing a bark-killing fungus *(Nectria coccinea* var. *faginata)* to enter. Small vigorous trees sometimes survive the disease; large trees seldom survive.

Birch dieback has caused heavy mortality in both yellow and paper birch. The causes of this affliction have not been definitely determined. Although the disease has subsided, a recurrence is possible. A similar condition, commonly called post-logging decadence, often afflicts both paper and yellow birch after heavy partial cutting in northern hardwood stands.

In addition to the beech scale, one other insect deserves mention: the sugar maple borer *(Glycobius speciosus* (Say)). The larval galleries made by this insect result in partial girdles and cankers that permit the entrance of discoloration and decay organisms, and increase susceptibility to wind breakage. The incidence of borer damage seems to be greatest in open or heavily thinned stands.

Management Objectives

Management objectives in the northern hardwood region vary considerably. In developing an objective, the manager has to decide first whether he wants to aim toward a high proportion of top-grade products such as veneer logs, saw logs, and mill-wood, or concentrate on pulpwood and other bulk products.

A second basic decision—partly dependent upon the product objective—is whether to manage for a high proportion of tolerant species, intermediates, or intolerants.

Once a decision has been reached on product and species objectives, the manager must consider other timberland uses, as well as present stand and site conditions in arriving at a silvicultural prescription or long-term silvicultural program.

Silvicultural Systems

UNEVEN-AGED MANAGEMENT

Applicability

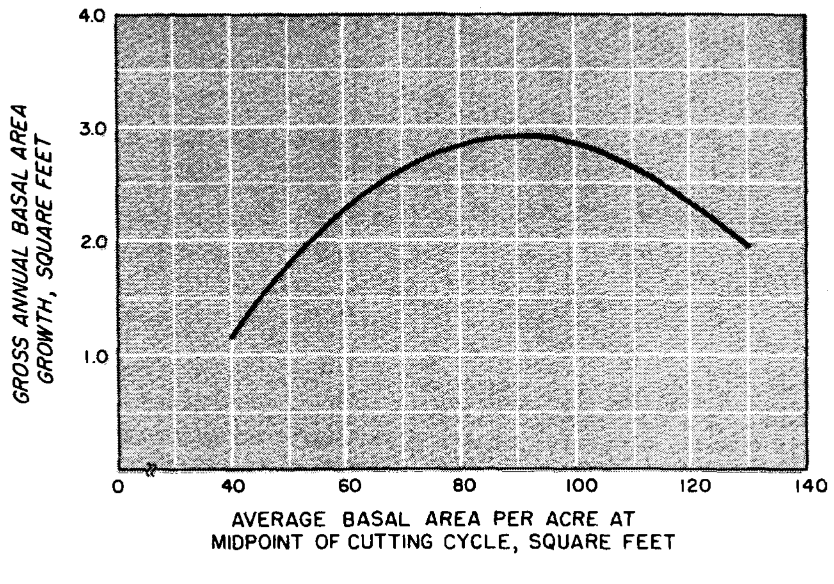
Uneven-aged management is implemented through selection cutting of individual trees or the harvesting of trees in small groups (two or three trees). Tolerant species (beech, sugar maple, hemlock, and spruce) are favored by this system. Intermediate species, primarily yellow birch, occur in small proportion, except where cutting has been unusually heavy. The system appears to be best adapted to producing sawlogs and veneer logs, with pulpwood as a byproduct.

Aesthetically, many people prefer selection cutting because a residual stand always covers the site and disturbance from logging is less apparent. However, few intolerant trees are reproduced by selection cutting, and, unless the cutting is very heavy, so as to result in an abundance of undergrowth, little browse may be produced for game animals.

Stocking, Structure, and Yields

Gross basal-area growth, as related to average basal area per acre, is illustrated in figure 2. Average basal area is the basal area at the midpoint of the cutting cycle. For example, a stand with a residual of 70 square feet that is expected to grow to about 90 square feet over the next decade would have an average basal area of about 80 square feet. This relationship applies to a fairly vigorous and well-balanced northern hardwood stand growing on an average site in the White Mountains of New Hampshire. Peak gross basal-area growth occurs between 80 and 100 square feet per acre in trees over 5.0 inches d.b.h. (diameter breast high). However, acceptable growth response occurs between 70 and 110 square feet per acre.

Figure 2.—Relationship of gross annual basal-area growth to average basal-area per acre for trees over 5.0 inches d.b.h. in uneven-aged northern hardwoods (average site).



For cutting cycles of 10 to 20 years, we recommend a residual basal area after cutting of 70 to 80 square feet. However, no cutting should remove more than about 40 square feet of basal area per acre.

Distribution of basal area and numbers of trees per acre for a typical stand at 80 square feet basal area is:

D.b.h. class (inches)	*Trees per acre (No.)*	*Basal area (square feet)*
6–10	60	20
12–16	30	28
18+	15	32
Total	105	80

In making a selection cutting, the manager should try to work toward this distribution of basal area among size groups. Numbers of trees in the 6- to 10-inch class often tend to be in excess of the recommended numbers, and it may not be commercially feasible to cut heavily in this size group.

Based on a gross annual growth rate of 2.75 square feet per acre for a stand with about 80 to 90 square feet average basal area, and an estimated 25 percent loss to mortality, the annual yield of a well-balanced stand is roughly 200 board feet of sawlogs and veneer logs plus 15 cubic feet of pulpwood. This total yield is equivalent to at least ½ cord annually. Since logging economics dictate a desirable cutting per acre of 6 to 10 cords, the appropriate cutting cycle would be 12 to 20 years.

Marking Guides

The success of uneven-aged management—both silviculturally and economically—depends to a large extent upon the choice and application of appropriate marking guides.

Marking guides are usually applied within limitations imposed by a minimum residual basal-area objective and, on the other hand, a minimum operable cut per acre. Once these limits have been defined, trees should be marked for cutting according to the following descending order of priority:

1. Salable trees, especially the valuable ones, that will not survive till the next harvest.

Table 2.—*Tree size objectives (d.b.h.) denoting peak of possible log-grade improvement (financial maturity) for northern hardwoods*

Species	Grade[1] potential	Predominant merchantable height	D.b.h. objective	Top d.i.b.
		Logs	*Inches*	*Inches*
Yellow birch	High	1	19	16
		2	22	16
	Medium	1	16	13
		2	18	12
Sugar and red maple	High	1	17	14
		2	20	14
	Medium	1	16	13
		2	18	12
Beech	High	1	16	13
		2	19	12
	Medium	1	15	12
		2	18	12
Paper birch	High	1	15	12
		2	15	8
	Medium	1	11	8
		2	12	6
White ash	High	1	15	12
		2	18	12
	Medium	1	15	12
		2	15	8

[1] High grade potential means that the first 1- or 2-log portion of the stem could produce grade 1 or veneer-grade logs. Medium grade potential means that the highest quality would be no more than grade 2. Grades are based on U.S.D.A. Forest Service standard specifications for hardwood factory lumber and veneer logs.

2. Salable trees that have reached the peak of merchantable volume growth, because of the progression of decay.

3. Trees of less desirable species; species that are not of primary interest within the current management objective.

4. Trees that have reached the peak of grade improvement. These trees are financially mature. Suggested tree-size objectives are given in table 2.

In addition, trees (such as wolf trees) that are affecting the growth of better individuals should be marked in preference to similar trees that are not greatly affecting other stems.

Timber Stand Improvement

Under individual tree selection and small group selection cutting, most of the necessary cultural work is provided for by the harvest cuttings when trees are marked down to about 8 inches d.b.h. However, during marking operations, cull trees should be marked for optional removal by the logging operator; or, as another alternative, the sale contract may require that the operator cut such trees—with an allowance on the stumpage for this work. After logging, any cull trees still remaining should be deadened, which can be done economically by applying a chemical.

Several chemicals and methods of application can be used effectively on the culls. For example, a mixture of 2,4,5-T ester and fuel oil can be applied with a tree injector in overlapping cuts made near the base of the tree. On trees up to 10 inches d.b.h., use a 40-pound aehg (acid equivalent per hundred gallons) dilution; on larger trees, use an 80-pound aehg dilution. Inject about 2 milliliters per cut. Normally, no timber-stand-improvement work in trees smaller than 6 to 8 inches d.b.h. will be justified, an exception being when a change in species composition is desired.

The time required to inject unwanted trees larger than 2 inches d.b.h. after a logging operation will range from 1 to 7 man-hours per acre. A fairly accurate estimate of treatment time, using an injector, can be made by applying the following equation:

$$Y = 1.31 + 0.0048\ X$$

where Y = man-hours per acre.

X = average size tree treated, multiplied by the number of trees treated per acre.

Regeneration

Selection cutting favors the tolerant species. Under light to moderate selection cutting, 80 percent or more of the regeneration (stocked-milacre basis) consists of beech and sugar maple, with some hemlock and spruce.

Conversion from Even-Aged to Uneven-Aged

Conversion from even-aged to uneven-aged management presents some special problems in marking and regeneration. Normally, a vigorous even-aged stand with a high proportion of intolerant-intermediate species should be maintained as an even-aged stand.

The general approach in converting a stand to the uneven-aged condition is to make a series of partial cuttings at 10- to 20-year intervals. Residual stocking should be between 70 and 80 square feet. The size distribution suggested on pages 6-7 should be gradually achieved.

These cuttings should gradually remove the shorter-lived species as they mature, as well as less desirable stems of the longer-lived species. Care should be taken to retain enough good stems (species and size) to maintain commercial cuttings at regular intervals. For example, you may want to retain some vigorous paper birch beyond maturity to ensure that commercial operations can be continued.

Regeneration sometimes is difficult during the conversion of a stand from even-aged to uneven-aged, especially on somewhat poorly drained or on excessively drained sites. Where weed species such as hobblebush and striped maple begin to fill in heavily, lighter cuttings (higher residual density) should be tried. On some areas, a heavy understory of beech may develop. Where the trend in regeneration appears to be unacceptable, reexamine the possibilities of even-aged management, using narrow strip cuttings (coupled with stump treatments) as described in the sections on even-aged management.

EVEN-AGED MANAGEMENT

Applicability

Even-aged management utilizes some form of clearcutting for the final cutting, and thus is particularly adapted to growing intermediate and intolerant species, commonly in association with tolerants. When used appropriately, even-aged management will produce high-grade sawlogs, veneer logs, and millwood. The system also is well suited to pulpwood production, particularly in view of the trend toward greater mechanization in the woods.

A regular schedule of planned clearcuttings—properly distributed throughout the forest in both space and time—favors most large and small game, provided that softwood deer yards are reserved.

Aesthetically, even-aged harvesting is unsightly for a few years, primarily because of the unattractive heavy slash (which cannot be removed economically) and the remaining unmerchantable trees. This aesthetic problem can be minimized by maintaining roadside strips, or possibly by using narrow strip cuttings, which are less objectionable than large clearcuttings.

Regeneration Cuttings

Complete clearcutting consists of removing all merchantable trees on an area, followed by mechanical or chemical removal of all unmerchantable trees down to 2 inches d.b.h. When clearcutting is done from about May to August, an adequate seed source (adjacent stand, or seed trees) should be within about 4 tree heights of all portions of the clearcutting. Cutting during other months—when a fair to good seed crop is available—usually will result in adequate seed from the harvested trees.

Complete clearcutting will result in regeneration composed roughly of two-fifths intolerants, one-fifth intermediates, and two-fifths tolerants. The presence of beech or sugar maple advance regeneration indicates that these species will be well represented in the future stand. Heavy advance growth of tolerant species or weed species will have an adverse effect upon birch regeneration.

Clearcutting of immature stands frequently leads to a high proportion of weed species, especially **Rubus** spp. and pin cherry. However, evidence to date indicates that these weed species do not entirely prevent regeneration of the commercial species, although growth is retarded. If an immature stand contains a high proportion of red maple, vigorous sprout clumps will result. These should be removed. If aspen is abundant in the clearcut stand, vigorous root suckering may result in an almost pure new stand of aspen.

Care should be taken to leave an uncut strip along main watercourses, and to place adequate water-bars on all skidroads to prevent soil washing. Skidroads should slope at 10 percent or less; they should not be laid out within 50 to 100 feet of temporary or main watercourses; and they should cross watercourses —if absolutely necessary—at a right angle.

Strip cutting consists of removing all merchantable trees in strips, followed by mechanical or chemical removal of trees down to 2 inches d.b.h. (fig. 3). We recommend removal in strips about 50 to 100 feet wide. These are usually laid out in an east-west direction, or—as a second choice—some direction that will facilitate harvesting. However, on poorly drained sites, it may be necessary to lay out the strips at right angles to the prevailing winds to help avoid windthrow—especially if the time interval between cuttings is too great to enable windthrow salvage.

First, every third strip is removed. Then 2 to 4 years later, one strip next to each initially cut strip is harvested; each second strip should be on the south or west side of the initial strip so that maximum protection against the hot sun is provided by the

Figure 3.—Strip cutting in an even-aged northern hardwood stand.

uncut strip. Then 2 to 4 years later, the final strips are removed. The final strip may be kept narrow, or seeded, or winter-logged, to facilitate regeneration.

Thus, the regeneration cutting extends over a 4- to 8-year period. Strip cutting appears to be more necessary for regenerating intermediate species (yellow birch and ash) than for regenerating intolerant species (paper birch especially). See **A Silvicultural Guide for Paper Birch in the Northeast.**[1] Furthermore, strip cutting may be more appropriate than large-scale clearcutting on excessively dry or wet areas, or where aesthetics are important.

If the harvested material is removed lengthwise down each strip, additional scarification probably will not be required. Usual precautions should be followed with regard to water-bars and limited cutting along main watercourses.

Patch cutting is the removal of all trees in areas of about 1/10 to ¾ acre in size. Silviculturally, patch cutting is desirable because it encourages regeneration of intermediate and intolerant species (the ratio depending upon patch size). However, because of difficulties in laying out, logging, and relocating patches, we generally recommend strip cutting, which equals patch cutting in silvicultural advantages and outweighs it in feasibility.

Shelterwood cutting has not been tested to any extent in northern hardwoods in the Northeast. No doubt shelterwood cutting of one form or another could be used to regenerate a mixture of tolerant and intermediate species, and—if the cuts were heavy enough—some intolerants as well. Specific recommendations on the use of shelterwood cutting must await further research.

Site Preparation Methods

Scarification prepares a favorable seedbed and thus promotes germination and establishment of paper and yellow birches. Where adequate scarification—about 50 percent of the area scari-

[1] Marquis, David A., Dale S. Solomon, and John C. Bjorkbom. A SILVICULTURAL GUIDE FOR PAPER BIRCH IN THE NORTHEAST. U.S.D.A. Forest Serv. Res. Paper NE-130, 47 pp., illus. NE Forest Exp. Sta., Upper Darby, Pa. 1969.

fied or disturbed—is not obtained as a byproduct of harvesting activity, or where the site is not naturally moist (for example, a large opening on a south slope), you should consider a special scarifying operation.

Scarification can be done with a track-type tractor and blade or rock rake (toothed blade). The objective should be to mix mineral soil and humus. Completely exposed mineral subsoil results in poor survival and growth. Scarification or disturbance of approximately 50 percent of an area requires about one to two D-6 tractor-hours per acre.

Removal of all unwanted stems (down to 2 inches d.b.h.) is required after clearcutting and strip cutting if the production of quality material is the objective. This can be done economically by applying a chemical. Several chemicals and methods of application can be used effectively. A mixture of 2,4,5-T ester and fuel oil can be applied with a tree injector in overlapping cuts made near the base of the tree. On trees up to 10 inches d.b.h., use a 40-pound aehg (acid equivalent per hundred gallons) dilution; on larger trees, use an 80-pound aehg dilution. Inject about 2 milliliters per cut.

The time required to chemically treat trees larger than 2 inches d.b.h. that are left after clearcutting and scarification will range from 1 to 5 man-hours per acre. A fairly accurate estimate of treatment time, assuming an injector is used, can be made by applying the following equation:

$$Y = 0.88 + 0.0041\ X$$

where Y = man-hours per acre.

X = average size tree treated, multiplied by the number of trees treated per acre.

After clearcutting, strip cutting, and so on, red maple stumps usually will sprout prolifically, especially from stumps smaller than 12 to 14 inches. Where potentially troublesome red maple stumps are abundant, we recommend treating them during the first or second growing season after cutting. Use a backpack spray apparatus to basal-spray all sprouts with a mixture of 2,4,5-T ester in fuel oil, making sure to drench the root collars. A 16-pound aehg dilution should be used.

If you treat only the vigorously sprouting stumps, it will require 1 to 2 man-hours per acre to stump-treat an average clearcut area.

Stocking Guides

Stocking guides for even-aged northern hardwoods (poletimber and larger)—based on numbers of trees, mean diameter, and basal area—are given in figure 4. These guides apply to the main crown canopy; they include intermediate to dominant trees that are in or touching the overstory. The B level represents minimum stocking for adequate growth. The C level represents the point where 10 years of growth will raise the stand to the B level. The A level represents an average unmanaged stand. Thus, stands above the A level are overstocked. Stands between the A and B levels are adequately stocked. Stands between the B and C levels are potentially adequately stocked. And stands below the C level are understocked.

Stocking guides for unmanaged, even-aged regeneration-sapling stands of northern hardwoods are given in table 3. Average numbers of acceptable stems required to produce at least B level stocking are given, together with high-confidence numbers—the numbers required to produce a well-spaced stand of acceptable stems, at least equivalent to B level stocking, with a high degree of confidence. Separate numbers of stems are given for all commercial hardwoods, and for intolerants-intermediates. We emphasize that the numbers in table 3 apply to acceptable stems of growing stock (considering species objectives, form, disease, and defect) in uncut stands.

Intermediate Cuttings

Cleaning or thinning is feasible under two situations: (1) when a noncommercial operation will increase net growth in volume and value sufficiently to make it a sound investment; and (2) when a commercial operation is possible.

Cleaning and thinning efforts should favor the selected crop trees, particularly by freeing the crowns on all sides. Normally this will require removal of one or two stems around each crop

Figure 4.—Stocking guides for even-aged northern hardwoods, based on number of trees in the main canopy, average diameter, and basal area per acre. Stands above the A line are overstocked. Stands between the A and B lines are adequately stocked. Stands between the B and C lines should be adequately stocked within 10 years. And stands below the C line are definitely understocked.

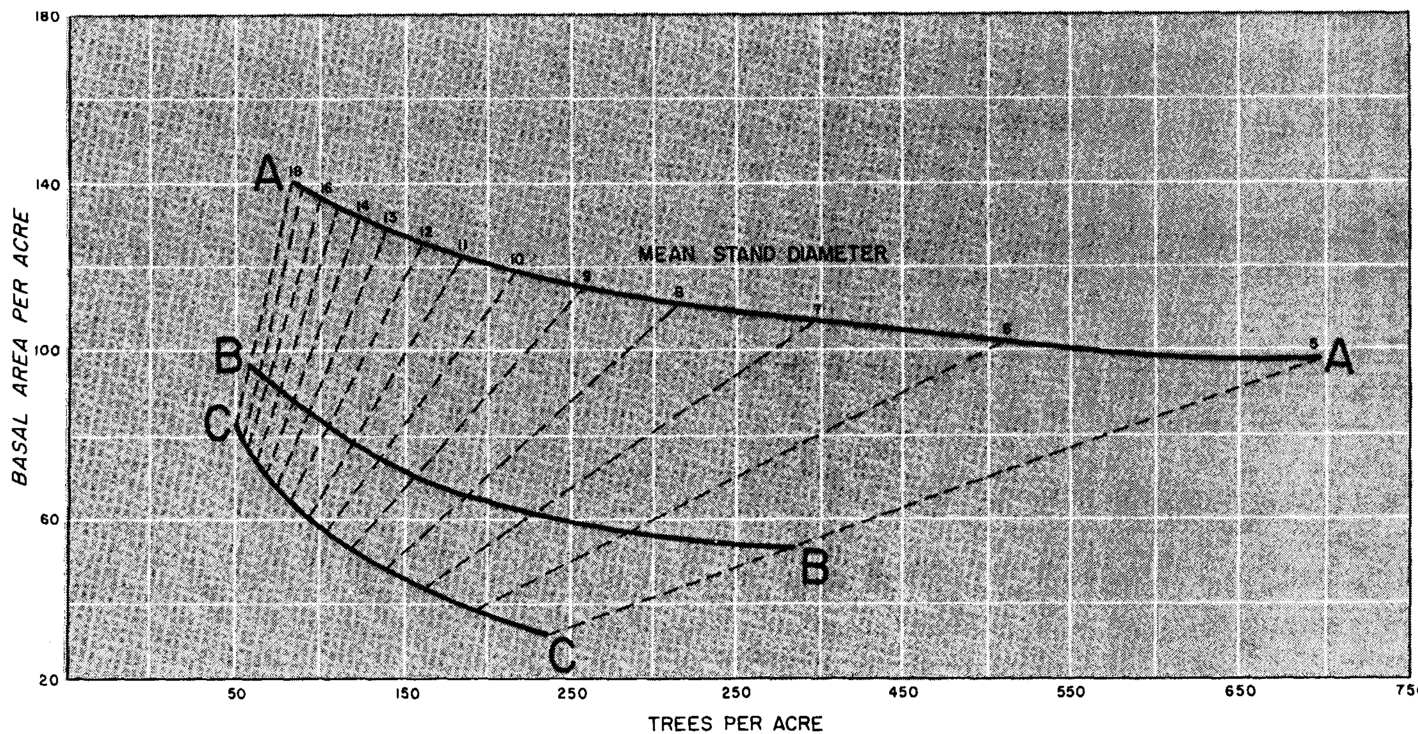


Table 3—*Number of acceptable stems of growing stock per acre, for given average stand diameters, required to meet at least B level stocking when the stand reaches 5.0 inches*[1]

Mean stand d.b.h. (inches)	Average	High-confidence
	No.	*No.*
ALL COMMERCIAL HARDWOODS		
1.0	2,050	3,480
2.0	1,390	2,320
3.0	890	1,550
4.0	580	770
INTOLERANTS-INTERMEDIATES		
1.0	1,430	2,320
2.0	1,040	1,930
3.0	730	1,160
4.0	540	770

[1] Based on stems 0.6 inch d.b.h. and over.

tree in the older stands, and one to four stems around each crop tree in the young stands.

The number and type of crop trees will depend upon the long-term silvicultural plan for the stand. If you plan to grow a crop of intolerant species, and then regenerate the stand, intolerant species should be selected as crop trees. See the recommendations given in **A Silvicultural Guide for Paper Birch in the Northeast.**[1]

In mixed stands, it is often reasonable to plan on an early medium-to-light harvest of intolerant species followed by a final harvest of intermediate or tolerant species. In such cases, you should select a number of intermediate and tolerant crop trees between the B line and A line to obtain the expected mean harvest diameter. In releasing such trees, paper birch should be retained—and released if no better crop tree is present—until they are merchantable and can form the basis for a commercial thinning. Growth of these paper birch would be improved indirectly by release of the longer-lived crop trees.

In all thinning, the B line would be used to set the minimum residual stocking on the entire stand (all stems in the overstory or main age class).

We recomemnd treatment at about 10-year intervals, or as soon after 10 years as feasible. Cleaning or thinning should not begin before the stand reaches about 20 years.

In the field, thinning may be controlled by using practical guidelines on selecting crop trees and then releasing them. Acceptable crop trees are those of desirable species and good form and quality. More specifically, these crop trees should be:

- First priority: yellow birch, paper birch, sugar maple, and white ash. Second priority: other commercial species such as beech, red maple, oak, and hemlock.
- Dominant or codominant trees, and sometimes intermediate sugar maple or yellow birch.
- Trees that are free of sound or rotten defects such as rotten seams or holes, forks, severe crook in first log, damaged or defective crown, sapsucker injury, coarse branches, and so on.
- Trees that are reasonably windfirm—well anchored and without excessive lean. Avoid trees perched on stumps or large rocks.
- Seedlings or seedling sprouts. Avoid rootsuckers and stump sprouts if possible.

After the approximate number of crop trees to be released is decided upon, the spacing of crop trees can be determined by:

$$\text{Spacing} = \sqrt{43560 \,/\, \#\ \text{crop trees}}$$

Try to pick about one crop tree within each spacing distance, passing over areas that have no qualifying trees. The number of trees to remove per acre equals the number in the stand minus the number at the B line. The average number of competing trees to remove per crop tree would equal the number of competing trees per acre divided by the number of crop trees.

An example of the instructions to a field crew would be: "Pick about one crop tree every 7 paces, and remove on the average two competing trees per crop tree." By using instructions of this nature, field crews can release the desired number of trees, well-spaced throughout the stand; and they can also achieve a desired residual basal area per acre with minimum supervision and training.

Pruning has seldom been tried on a commercial scale in northern hardwoods. However, the possibilities seem good. Sugar maple and yellow birch are the only species that warrant pruning, because of their value and relatively slow natural pruning. Pruning should be restricted to vigorous crop trees on good sites. The number of trees to prune should not exceed the B line at the expected harvest diameter.

Pruning about one full log on a 3- to 4-inch tree appears to be feasible and worthwhile. Ordinarily only a few branches need be removed. At least one-third of the tree should remain in green crown. If possible, trees with branches less than 1½ to 2 inches in diameter should be pruned because wounds of this size heal most rapidly. We estimate that 10 to 20 trees could be pruned per man-hour.

Rotations and Yields

Final yields in cubic feet and board feet are given in table 4 for stands of given mean diameter. These yields apply to well-stocked mixed stands of northern hardwoods at site index 60 (b.h. age 50) for sugar maple. Approximate yields for a different site are given by multiplying each yield by S.I./60. Yields for stands that are understocked (as evidenced by basal area) or defective should be reduced accordingly.

Estimated numbers of years to reach a given mean diameter are given for a range of site indexes, and for unmanaged and managed conditions. Managed growth rates are considered attainable under current feasible levels of management intensity.

D.b.h. size objectives—by species, expected merchantable height, and grade potential—are given in table 2. The stand is at maturity when average diameter of the main overstory has reached, or is within 2 to 4 inches of, the appropriate size objective. For pulpwood production, trees over 16 inches d.b.h. frequently are uneconomical to handle. Thus, we recommend

Table 4.—*Yields per acre for a given mean stand diameter, and years to reach a given mean diameter by site index for both managed (thinned) and unmanaged stands of mixed northern hardwoods*

Mean d.b.h. (inches)	Volume per acre		Basal area	Site index					
				50		60		70	
				Managed	Unmanaged	Managed	Unmanaged	Managed	Unmanaged
	Bd. ft.	*Cu. ft.*	*Sq. ft.*	*Years*	*Years*	*Years*	*Years*	*Years*	*Years*
5.0	—	1,900	95	44	59	38	50	33	44
6.0	—	2,142	102	56	74	46	61	39	52
7.0	3,782	2,332	106	67	89	56	74	45	60
8.0	5,456	2,530	110	77	103	66	88	53	71
9.0	7,182	2,736	114	93	124	77	102	62	82
10.0	9,088	2,950	118	112	149	89	118	71	94
11.0	11,050	3,146	121	134	179	99	132	80	106
12.0	13,200	3,375	125	—	—	110	147	88	117
13.0	15,544	3,612	129	—	—	122	163	97	129
14.0	16,048	3,799	131	—	—	137	182	107	142
15.0	16,698	4,020	134	—	—	—	—	118	157

an average diameter of 10 to 12 inches where pulpwood production is the primary objective.

We have little data on long-term intermediate yields from managed (thinned) stands. However, from computer synthesis of available yield data, we believe that in addition to the final harvest yields given in table 4, an intensive thinning schedule will produce intermediate yields at least equal to the table 4 volumes. In other words, intermediate yields will about double the production.

Stand Evaluation and Prescription

DIAGNOSIS

Reproduction Stands and Sapling Stands

For our purposes, a reproduction stand is one that averages less than 1.5 inches d.b.h. A sapling stand is an even-aged stand between about 1.5 and 4.5 inches average diameter (fig. 5). We assume that even-aged management is planned for such stands, at least at the outset. Under present management intensities, reproduction and small sapling stands are seldom scheduled for silvicultural treatment. However, it is often desirable to assess the adequacy of stocking and species composition in such stands so that the success of past regeneration cuttings can be determined. Furthermore, timber stand improvement sometimes is required in such stands to maintain adequate stocking and species composition. Growth response is excellent at this young age; and pruning is most feasible during this period.

In diagnosing the stand, first estimate mean diameter of the trees over 0.5 inch for: (1) paper birch (and aspen, if commercially desirable), and (2) all commercial species. This can be based on a few plot measurements.

Then locate one plot center per acre up to a maximum of 50, and keep count of the number of plot centers.

Take one circular 6.0-foot-radius plot per location.

Classify each plot as one or more of the following:

Figure 5. — Even-aged sapling stand of northern hardwoods.

- **Unstocked**—no acceptable stems (stems that will produce better-than-pulpwood trees).

- **Stocked**[2]—has the following numbers of acceptable stems, or potential crop trees, of any commercial species:

Mean d.b.h. *(inches)*	*Stems per plot* *(No.)*
1.0	5+
2.0	4+
3.0	2+
4.0	1+

- **Stocked with paper birch**[2]—has the following number of good paper birch stems.

[2] If numbers of stems per acre are known, adequacy of stocking for any species or species group can be judged from table 3, which shows numbers required to meet B level stocking. Numbers required to meet C level stocking—minimum acceptable numbers—are approximately 50 to 60 percent of those shown in table 3.

Mean d.b.h. (inches)	*Stems per plot (No.)*
1.0	4+
2.0	3+
3.0	2+
4.0	1+

- **Minimum stocking**—has at least one acceptable stem per plot.

A suggested tally sheet for recording this information is given in the appendix; counts are converted to percentages by dividing by number of plots and multiplying by 100.

Estimate site index (base age 50) for: (1) paper birch and (2) yellow birch or sugar maple, whichever is predominant, by determining b.h. age and total height for at least 10 stems of each species. Determine site index for each stem from the curves in figure 6, and then average the results for each species. In reproduction stands, site measurements may not be feasible, in which case you will have to judge the site from either knowledge of the area or measurements in adjacent stands.

In mixed stands, it may be helpful to use the measured site index for one species to predict the site index of another. Figure 7 shows the relationship among site indexes (base age 50 years) for paper birch, yellow birch, sugar maple, and white ash. For example, if the measured site index of yellow birch is 60, then the comparable site index for paper birch will be about 65; for sugar maple 61; and for white ash 69.

Poletimber and Sawtimber Stands

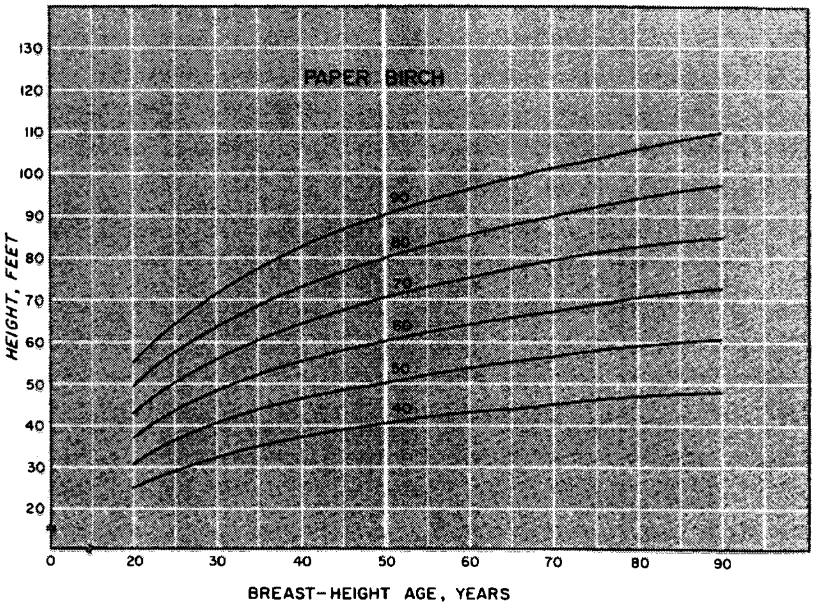
These are stands with average diameters of larger than 4.5 inches for the trees in the overstory or main crown canopy. They may be either even-aged or uneven-aged.

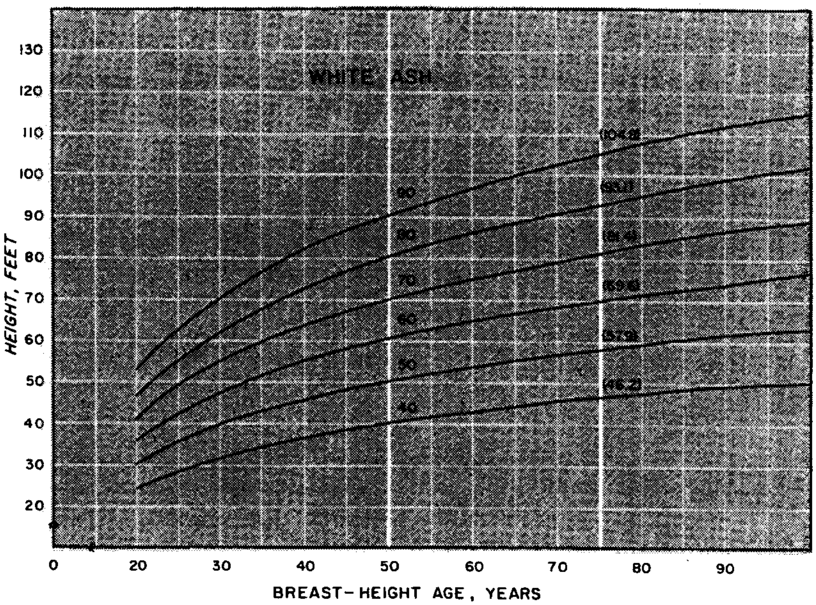
In diagnosing the stand, first classify it as even-aged (one main age class recognized) or uneven-aged (more than one distinct age class recognized).

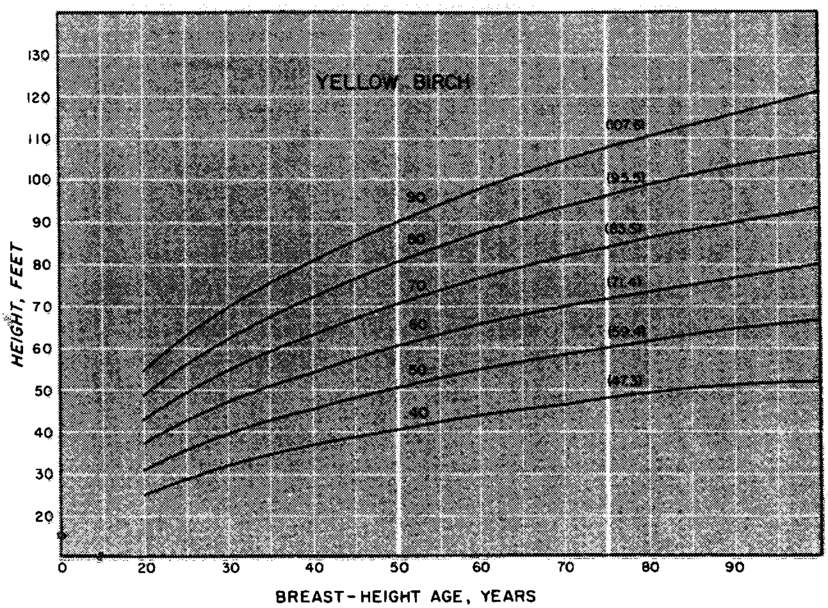
And you should decide next whether the objective for the area is uneven-aged management or even-aged.

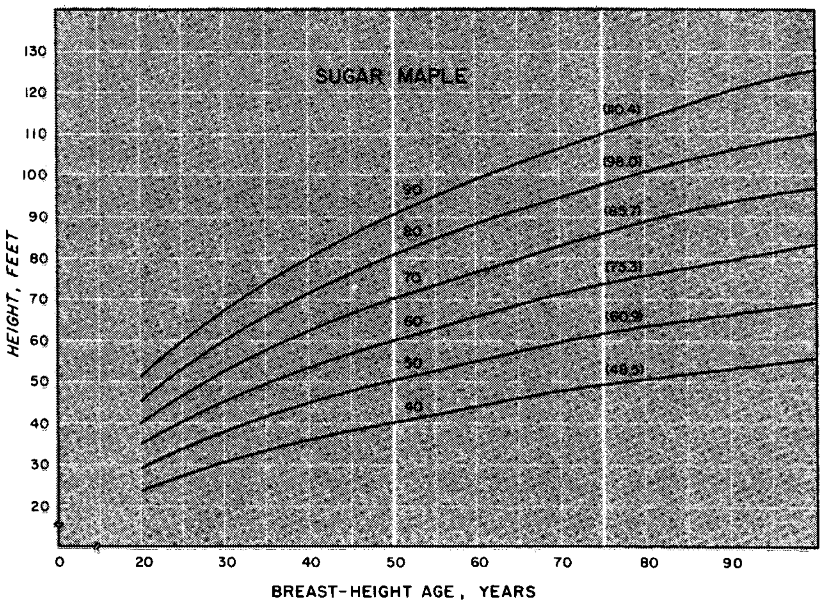
Take one systematically located sample point per acre up to a total of 50 points. With a 10-factor prism, record tree counts

Figure 6.—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 for yellow birch, sugar maple, and white ash.






YELLOW BIRCH
HEIGHT, FEET
130
120
110
100
90
80
70
60
50
40
30
20
(107.6)
(95.5)
(83.5)
(71.4)
(59.4)
(47.3)
90
80
70
60
50
40
0
20
30
40
50
60
70
80
90
BREAST-HEIGHT AGE, YEARS


SUGAR MAPLE
HEIGHT, FEET
130
120
110
100
90
80
70
60
50
40
30
20
(110.4)
(98.0)
(85.7)
(73.3)
(60.9)
(48.5)
90
80
70
60
50
40
0
20
30
40
50
60
70
80
90
BREAST-HEIGHT AGE, YEARS

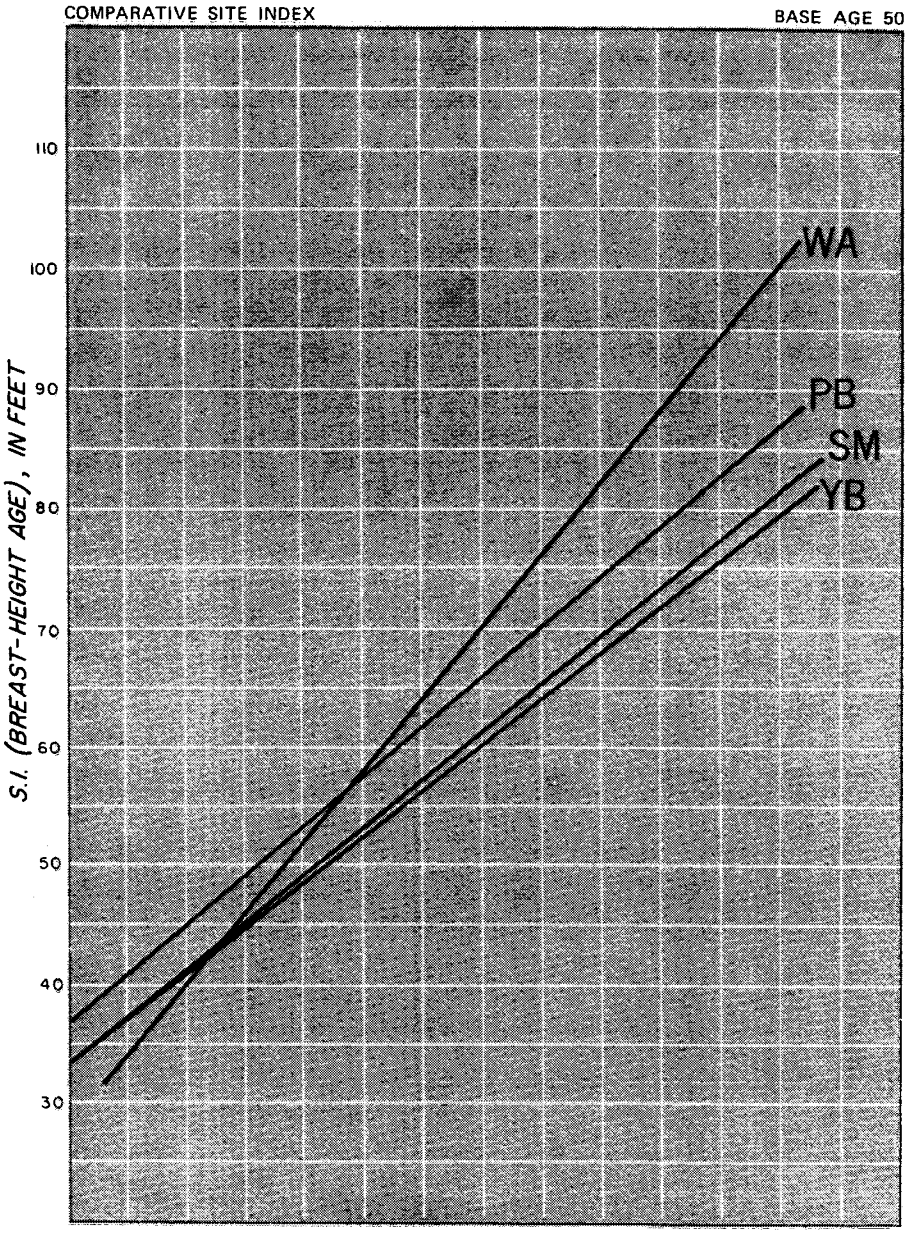


Figure 7.—Relationships among site indexes (base age 50) for four northern hardwoods. To estimate site index of species X from site index of species Y: find known site index on curve for species Y; move vertically up or down to curve until you locate species X; read horizontally across to the left to find estimated site index for species X.

in the classes indicated below, and summarize for the area as follows:

Class	*No. trees per acre*	*Basal area**	*Mean d.b.h.**
Paper birch acceptable stems	—	—	—
Other acceptable stems	—	—	—
Undesirable stems	—	—	—
Total	—	—	—

* Basal area is the average count times prism factor, and the mean d.b.h. is found by dividing basal area by number of trees per acre and, using table 5, converting from basal area back to mean d.b.h. Or, you can use figure 6 to estimate mean d.b.h. from basal area and number of trees. A convenient tally sheet for recording this information is given in the appendix. (In uneven-aged stands, mean diameter need not be calculated.) See table 5 for basal area-d.b.h. conversions.

Undesirable stems are those that will not make saw log or veneer log material now or in the future (but may qualify as pulp).

Table 5.—*D.b.h.-basal area table*

D.b.h.	Basal area per tree	D.b.h.	Basal area per tree
Inches	*Square feet*	*Inches*	*Square feet*
1.0	0.0055	11.5	0.7213
1.5	.0123	12.0	.7854
2.0	.0218	12.5	.8522
2.5	.0341	13.0	.9218
3.0	.0491	13.5	.9940
3.5	.0668	14.0	1.0690
4.0	.0873	14.5	1.1467
4.5	.1104	15.0	1.2272
5.0	.1364	15.5	1.3104
5.5	.1650	16.0	1.3963
6.0	.1963	16.5	1.4849
6.5	.2304	17.0	1.5763
7.0	.2673	17.5	1.6703
7.5	.3068	18.0	1.7671
8.0	.3491	18.5	1.8667
8.5	.3941	19.0	1.9689
9.0	.4418	19.5	2.0739
9.5	.4922	20.0	2.1817
10.0	.5454	20.5	2.2921
10.5	.6013	21.0	2.4053
11.0	.6600	21.5	2.5212

In even-aged stands, the count should include only those trees with crowns in or touching the main overstory—only those intermediate to dominant trees that comprise the main portion of the stand.

In even-aged stands, determine b.h. age and total height for 10 stems or more of (1) paper birch and (2) yellow birch or sugar maple (whichever is predominant).

Judge whether a commercial cutting is now feasible, based on volume, quality, accessibility, markets, and so on. Note whether this cutting would be restricted to either a partial cutting or a clearcutting.

CHOICE OF PRESCRIPTION

The Key

Use the following key to identify the condition and find the appropriate prescription for treatment of that condition. The key to the prescription is the letter (A, B, C, etc.) at the right. Details of the prescriptions are presented in the next section.

Condition	Prescription
I	
REPRODUCTION OR SAPLING STANDS	
(mean d.b.h. up to 4.5 inches)	
1. 50 percent or more of the plots (6.0-foot-radius) stocked with paper birch; or management for paper birch primarily is desired	A
1. Less than 50 percent of the plots (6.0-foot-radius) stocked with paper birch; or management for paper birch is not desired.	
2. 50 percent or more stocked (all commercial species).	
3. Yellow birch-sugar maple site index $>$ 55	B
3. Yellow birch-sugar maple site index $<$ 55	C
2. Less than 50 percent stocked (all commercial species).	
3. 50 percent or more of the plots have minimum stocking.	
4. Yellow birch-sugar maple site index $>$ 55	D
4. Yellow birch-sugar maple site index $<$ 55	E

Condition	Prescription

3. Less than 50 percent of the plots have minimum stocking . . . . F

Condition | Prescription

II
POLE OR SAWTIMBER STANDS

(mean d.b.h. of overstory more than 4.5 inches)

1. Stand condition uneven-aged (more than one primary age class).
  2. Objective: uneven-aged management (tolerant species).
    3. Basal area per acre of acceptable stems (better-than-pulpwood potential) less than 40 square feet . . . . . . G
    3. Basal area per acre of acceptable stems 40 square feet or more.
      4. Total basal area per acre 100 square feet or more.
        5. Commercial cut feasible . . . . H
        5. Commercial cut not feasible I
      4. Total basal area per acre less than 100 square feet I
  2. Objective: even-aged management.
    3. Clearcutting commercially feasible.
      4. Objective: intermediate species, especially yellow birch, in mixture with tolerants and some intolerants . . . . J
      4. Objective: intolerant species, especially paper birch, in mixture with tolerants and intermediates . . . . . . K
    3. Clearcutting not feasible L
1. Stand condition even-aged (one main age class).
  2. Objective: uneven-aged management, tolerant species . . M
  2. Objective: even-aged management.
    3. Stocking of paper birch 50 percent of B line (poletimber stands) or 50 percent of total basal area (sawtimber stands); or management for paper birch primarily desired . . . . N
    3. Stocking of paper birch less than 50 percent of B line (poletimber) or 50 percent of total basal area (sawtimber); or management for paper birch primarily not desired.

Condition	Prescription
4. Stocking of acceptable stems (better-than-pulpwood potential) other than paper birch less than C line	O
4. Stocking of acceptable stems other than paper birch above C line.	
5. Stand mature.	
6. Objective: intermediate species, especially yellow birch, in mixture with tolerants and some intolerants	J
6. Objective: intolerant species, especially paper birch, in mixture with tolerants and intermediates	K
5. Stand not mature.	
6. Total stocking less than halfway between A and B lines	P
6. Total stocking halfway between A and B lines or more.	
7. Commercial thinning feasible now or within 10 years	Q
7. Commercial thinning not feasible now or within 10 years.	
8. Site index of yellow birch-sugar maple > 55	R
8. Site index of yellow birch-sugar maple < 55	S

Prescriptions

These prescriptions are aimed toward production of saw logs, veneer logs, and millwood. Only commercial operations are recommended for pulpwood.

A. Use the prescriptions in *A Silvicultural Guide for Paper Birch in the Northeast.* If 50 percent or more stocked with paper birch, the stand should develop naturally into a poletimber stand with at least C level paper birch stocking.

B. This young stand probably will develop into an adequately stocked poletimber stand. Timber stand improvement (cleaning) is not urgent;

but for added growth, it would be desirable in a sapling stand. If cleaning is done, consider pruning a number of yellow birch and sugar maple crop trees equal to or less than B line at expected harvest diameter.

C. This young stand probably will produce an adequately stocked poletimber stand. Timber stand improvement (cleaning) is not urgent, and probably is not justified because of low site quality.

D. This young stand probably will not develop naturally into an adequately stocked poletimber stand. Since site quality is reasonably good, timber stand improvement (cleaning) is required and justified to produce an adequately stocked poletimber stand. Release crop trees (other than paper birch) at least equal in number to those at B line for expected harvest diameter. In addition, release up to 100 paper birch crop trees per acre, if available, for an early commercial cutting. In sapling stands, consider pruning a number of yellow birch and sugar maple crop trees equal to or less than B line at expected harvest diameter.

E. This young stand probably will not develop naturally into an adequately stocked poletimber stand. Since the site is fairly poor, timber stand improvement is not high priority. Plan on allowing the stand to develop until an early clearcutting operation is commercially feasible.

F. Stocking of this young stand is too poor to produce an adequate stand. No timber stand improvement is warranted. Plan on a clearcutting as soon as commercially feasible.

G. This stand is poorly stocked with quality stems. Reconsider the possibilities of clearcutting, in one form or another, and starting even-aged management.

H. Apply selection or small-group selection cutting, leaving about 70 to 80 square feet of basal area per acre in trees 6 inches d.b.h. and over.

I. Normally, no treatment should be considered for the next 10-year-period. However, if the stand consists of larger culls overtopping better younger growing stock, remove the culls chemically or by girdling.

J. Apply a progressive strip cutting, or a clearcutting with reserved yellow birch seed trees (1 to 2 trees per acre).

K. Apply a clearcutting, using reserved paper birch seed trees if logging is done between early May to mid-August.

L. Wait 10 to 20 years if merchantability is improving, then reconsider for strip cutting or clearcutting. However, if the stand is overmature and defective — if merchantability will not improve — remove the stand in strips or completely by cutting, girdling, or chemical means.

M. Apply partial cutting at 10- to 20-year intervals to remove shorter-lived species as they mature. As conversion to tolerant species progresses, follow recommended marking guides and stocking levels for uneven-aged management.

N. See *A Silvicultural Guide for Paper Birch in the Northeast.*

O. Stocking of species other than paper birch is inadequate. Plan to harvest paper birch when it reaches merchantable size; clearcut or strip cut remainder of stand at the same time, or later as soon as commercially feasible.

P. Do nothing now; reexamine in 10 years.

Q. Apply a commercial thinning now or within 10 years, reducing stocking to the B level (plus an allowance of perhaps 10 square feet for logging damage).

R. Because of reasonably good site and stocking, this stand warrants precommercial thinning. Reduce stand to B line (no logging damage allowance). Favor intermediate and tolerant crop trees equal in number to those between B and A lines for expected mean harvest diameter. Retain paper birch for early commercial harvest.

S. Do nothing now; wait until commercial thinning is feasible.

■

Appendix

TALLY SHEET FOR REPRODUCTION OR SAPLING STANDS

Class	Count[1]	Percent
Unstocked		
Stocked		
Stocked with paper birch:		
Minimum stocking		

Number of plots:

Site index trees:

Age

Height

Site index

Stand type: ☐ Reproduction

☐ Sapling

[1] One plot may be counted in more than one class.

Figure 8.—A suggested dot-count tally sheet for reproduction or sapling stands.

TALLY SHEET FOR POLETIMBER AND LARGER STANDS

D.b.h. Inches	Conversion,[1] trees per acre	Paper birch			Other acceptable stems			Undesirable		
		Tree count	Average count[2]	Trees per acre	Tree count	Average count	Trees per acre	Tree count	Average count	Trees per acre
2	458									
4	115									
6	51									
8	29									
10	18									
12	12.7									
14	9.4									
16	7.2									
18	5.7									
20	4.6									
etc.	etc.									
Total										

Stand class: ☐ Even-aged

☐ Uneven-aged

Commercial cutting: ☐ Feasible

☐ Not feasible

Number of points:

Site index trees:

Age

Height

Site index

[1]The number of trees conversion (10 factor) provides the number of trees per acre by multiplying the conversion times the average count.

[2]Average count = total count for each diameter class/number of points.

Figure 9.—A suggested tally sheet for poletimber and larger stands.

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