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

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Abstract

A revision of the 1969 silvicultural guide for northern hardwoods, provides up-to-date information on both even-age and uneven-age silviculture and management for beech-birch-maple, beech-red maple, and mixedwood stands in the Northeast.

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COVER—Many-aged northern hardwood stand after improvement cutting, Bartlett Experimental Forest

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.

Mixedwood (hardwoods with primarily spruce, hemlock, or balsam-fir) stands have at least three origins: (1) partial or heavy cutting of softwood stands, which allowed hardwood invasion to occur; these stands appear as the beech-red maple cover type with a softwood component or understory; (2) forest succession on abandoned fields, which tends to favor increased proportions of white pine, hemlock, spruce (red or white), or balsam-fir even on good hardwood sites that normally would support the beech-birch-maple type; and (3) diverse site conditions, e.g., shallow or rocky soils interspersed with better soils, which results in groups of hardwoods and softwoods. Because of different origins, successional trends in mixedwood stands may be toward tolerant softwoods, hardwoods, or maintenance of the mixedwood character.

Type	*Distinguishing Factors*
Beech-birch-maple	1. Fifteen percent or more sugar maple in overstory and/or understory. 2. Sugar maple more abundant than red maple. 3. Less than 25 percent softwoods in overstory or understory. 4. Commonly found on well- to moderately well-drained fine-textured till soils.
Beech-red maple	1. Less than 15 percent sugar maple in overstory and understory. 2. Red maple more abundant than sugar maple. 3. Less than 25 percent softwoods in overstory and understory. 4. Commonly found on soils that are wetter, drier, more shallow to bedrock or pan, rockier, or more poorly aerated than those supporting beech-birch-maple stands.
Mixedwood	1. Softwoods (primarily spruce, hemlock, or balsam-fir) account for 25 to about 65 percent of the overstory and/or understory. 2. No specifications on the relative proportions of sugar maple and red maple. 3. Found on a wide variety of soils due to the varied past history and origin of mixed-wood stands.

Note that certain intolerant or intermediate species—paper birch, yellow birch, aspen, etc.—are not indicative of site condition.

Silvicultural opportunities differ for each subtype. The beech-birch-maple type regenerates and produces large, high-quality hardwoods such as sugar maple, yellow birch, or, in some areas, white ash. The beech-red maple type commonly produces smaller, lower grade sawlogs. However, such areas can produce acceptable boltwood stems (birches) or aspen for wildlife; oak sawlogs are a possibility in certain parts of the northern hardwood region. In many mixedwood stands, the possibilities for hardwood products are similar to those for the beech-red maple subtype. Here, volume production can be increased by gradually favoring the softwood component. However, due to the variable origin of mixedwood stands, large high-quality hardwoods can be grown on some sites.

Silvical characteristics of the important species found in these three types are outlined in Table 1. The shade-tolerance categories of tolerant, intermediate, and intolerant indicate whether the species can regenerate and persist under conditions of heavy, moderate, or no shade, respectively. Moderate shade would be about 30 to 70 percent crown cover.

The categories of early height growth indicate the general ability of a species to outgrow its associates up through the sapling stage with no overhead competition. For example, aspen grows very fast and seldom needs release from associated species to maintain a dominant position, and red maple normally is outgrown by aspen and paper birch. Sugar maple and beech are outgrown by most other hardwood species even when free of competition.

The relative site requirements vary by species. White ash, and sugar maple to a slightly lesser extent, are most abundant and reach best development on the best soils. Conversely, spruce, hemlock, and white pine are common and grow to fairly large size on soils that are shallow, rocky, sandy, or wet. Paper birch, red maple and aspen, though fast growers on good sites, can be reproduced and grown fairly successfully on poor sites.

The natural pruning categories refer to a species' relative ability to produce clear boles. The softwoods, as well as sugar maple and beech, only produce clear boles at an early age under conditions of high stand density. However, paper birch, white ash, and aspen produce clear straight boles at only 50 to 60 percent of maximum stand density.

Protection

Diseases and insects are the two important problems. Fire damage and prevention have a minor impact on silvicultural methods in northern hardwoods and related types.

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

Few silviculturalists can develop expertise in entomology or pathology. However, they should be able to: (1) recognize threats to quality and vigor; (2) apply silvicultural and utilization methods that will minimize losses; and (3) know when to seek expert advice on potential outbreaks. Beyond this section, few references will be made to specific insects and diseases. However, many of the silvicultural practices described later relate to potential stand quality and risk.

Microorganisims that cause decayed and discolored wood, one of the most widespread problems in both hardwoods and softwoods, enter through dying or damaged roots, stems, or branch stubs. Other fungi cause collar cracks in birches and root rot and basal decay in many other species. For details on discoloration, decay, and other defects, see Shigo and Larson (1969) and Shigo (1983).

To limit losses in stand volume and quality from decay and discoloration, silvicultural methods should be directed toward (1) removing defective trees during harvest operations, (2) encouraging the development of small limbs and early natural pruning by maintaining fairly high stand densities in sapling and pole stands (or consider artificial pruning), and (3) minimizing logging damage to roots, stems, and branches. Decay and discoloration associated with wounds or branch stubs usually do not enter into wood formed after the wound occurs or after the branch dies.

Nectria cankers are common in many hardwoods, and *Eutypella* canker is found on maples. Associated decay is limited, but wind breakage is common and the cankers often cause quality defects in the most valuable parts of the bole.

Beech-bark disease is the most lethal disease of beech. The beech scale (*Cryptococcus fagi* (Baer)) punctures the bark, allowing a bark-killing fungus (*Nectria coccinea* vac. *faginata*) to enter. Small vigorous trees sometimes survive the disease, though quality may be severely reduced. Large trees seldom survive. Significant tree-to-tree variation is evident in susceptibility to both the scale and the *Nectria* fungus. Trees exhibiting the characteristic red fruiting bodies should be harvested without delay.

The saddled prominent (*Heterocampa guttivitta*) is the most serious defoliator of beech-birch-maple stands. White ash and red maple sometimes escape attack, but most other hardwoods can be heavily defoliated. The outbreaks occur on about a 10-year cycle, and last 1 to 3 years. Defoliation in 2 successive years may be followed by widespread mortality and growth losses, as well as degrade (e.g., stain) from secondary insects and organisms. Aerial chemical sprays have proven effective in limiting damage by the saddled prominent.

Gypsy moth (*Lymantria dispar*) is the most serious defoliator of oak in central to southern New England. Grey birch, aspen, and sometimes other hardwoods are frequently defoliated as well. White pine and hemlock associated with oak stands also are defoliated during severe attacks. Outbreaks generally last 1 to 3 years. Mortality and/or growth loss in oak can be significant after two or more defoliations. There is some indication that degrade from insects (e.g., oak borer) may increase in trees weakened by defoliation. Insecticidal and biololgical aerial sprays are effective.

Larval galleries of the sugar maple borer (*Glycobius speciosus*) result in partial girdles and cankers that allow the development of decay and discoloration and increase susceptibility to wind breakage. Up to 50 to 60 percent of the sugar maple in a stand may be affected, with an average of two to three significant cankers per tree. Contrary to earlier recommendations, exposure of trees by cutting apparently does not increase susceptibility to damage by the sugar maple borer.

Management Objectives and Approaches

In developing a long-range timber management objective for an entire forest property, the owner or manager should first decide on product and species goals. A common product objective is high-quality material for veneer logs, sawlogs, and boltwood combined with utilization of the poorer quality material for pulp or fuelwood. A second objective on certain industrial lands or private ownerships might be maximum production of wood for fiber and/or fuel. Other product objectives include high-intensity management for veneer logs, or production of small logs and boltwood. The choice of species or species group is closely related to the desired product, and is concerned with what species to favor in improving and regenerating the stand.

Two primary factors affecting the choice of product and species are (1) current and projected markets, and (2) the capability of the land to grow certain products and species. Once the product and species objectives are set, a preliminary decision can be made on appropriate silvicultural systems for the property. For tolerant species and high-quality products, one standard approach in the Northeast has been uneven-age management using individual-tree selection or some form of partial cutting. For quality products from intolerant and intermediate species, a common approach is even-age management using clearcutting and intermediate treatments. Even-age management with clearcutting is best suited to the mechanized production of fiber or fuel.

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

Table 3.—Net annual growth per acre over a 9-year period of sawtimber (10.5 inches plus) and total stand (4.5 inches plus), by residual basal area and amount of sawtimber in a second-growth beech-red-maple stand (approximate site index 55 for sugar maple) (Solomon 1977)

Residual basal area (ft^2)	Residual sawtimber		Net growth				Accretion	
	Percent	Basal area	Sawtimber[a]		Total		Sawtimber[b]	
			Square feet	Board feet	Square feet	Cubic feet	Square feet	Board feet
40	30	12	1.4	126	2.2	53	.51	46
	45	18	1.3	117	2.0	48	.68	61
	60	24	0.5	45	1.8	43	.69	62
60	30	18	1.3	117	1.7	41	.55	50
	45	27	1.7	153	2.3	55	.76	68
	60	36	1.6	144	2.0	48	.88	79
80	30	24	2.0	180	1.7	41	.64	58
	45	36	1.6	144	1.7	41	.71	64
	60	48	1.0	90	1.2	29	.92	83
100	30	30	1.9	171	1.7	41	.70	63
	45	45	1.6	144	1.2	29	.88	79
	60	60	1.1	99	0.9	22	1.07	96

[a]Includes only the sawtimber portion of the stem.
[b]Based on conversions of 90 board feet and 24 ft^3 per square foot of basal area.

growth generally are best between 40 and 60 ft^2 of residual basal area per acre. Board-foot growth, however, is best between 60 and 80 feet of basal area provided that at least 25 to 35 ft^2 of basal area in sawtimber is maintained. With these fairly low sawtimber basal areas, much of the sawtimber growth is ingrowth into the larger sizes rather than accretion. Accretion tends to rise as the basal area in sawtimber approaches 50 to 60 ft^2; however, mortality and lower sawtimber ingrowth reduce the net sawtimber growth. Retention of live branches is noticeable at 60 ft^2 basal area, indicating that timber quality development should be best at residual basal areas of 70 to 80 ft^2.

On better sites, those supporting beech-birch-maple stands, experience indicates that higher amounts of residual sawtimber could be maintained that produce high-quality sawtimber growth.

Stocking and Structure

Recommended minimum residual basal areas in trees 5.0 inches and larger in d.b.h. are:

Type	*Residual Basal Area (ft^2)*
Beech-birch-maple	70 (65–75)
Beech-red maple	70 (65–75)
Mixedwood	100 (80–120)

The mixedwood goal applies to residual stands with 25 to 65 percent softwood in trees 5.0 inches and larger in diameter. A range in basal area is given to encourage flexibility. On good sites, those with an abundance of quality timber, residual basal areas above the suggested range may be specified. However, residual basal areas below the suggested range may impair quality development.

Stand structural goals for uneven-age management are specified by the maximum size tree to leave, and the diameter distribution. Diameter distributions are approximated by a reverse J-shaped curve, with a slope defined by q—the quotient between numbers of trees in successively smaller d.b.h. classes.

The structural goals in this guide are based on a range in q from 1.3 to 1.7, and a maximum tree size (for general planning purposes) of 20 inches d.b.h.:

q	*Approximate percent sawtimber*
1.7	45
1.5	55
1.3	70

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 1.—Cutover stand of northern hardwoods with low to moderate proportion of sawtimber. Immediate residual goals in such stands would be 30 to 40 ft^2 of sawtimber or a q or 1.7 to 1.5. A good northern hardwood site with good-quality sugar maple, this area could support more sawtimber (lower q) in the future.

Cutting Cycle

The cutting cycle—the years between harvests on the same area—is determined by accessibility, the need for an economic harvest, timber growth, and quality. Based on an average basal growth rate for northern hardwoods of 2 ft^2/acre/year a residual stand of 70 ft^2 will grow to 100 ft^2—a reasonable maximum—in about 15 years. At that time, a cut of about 30 ft^2 (8 to 9 cords) will be available. With good accessibility, high timber values, or high risk of damage from insects or diseases, the cutting cycle might be lowered to 10 years. Under opposite conditions, cutting cycles of up to 20 years sometimes are used. With long cutting cycles, the total residual basal areas in Table 4 can be lowered to minimums of 60 to 65 ft^2 for hardwood and about 75 to 80 ft^2 for mixedwood, proportioning the reductions among size classes.

Marking Guides

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

Marking guides can be developed from a prism inventory of the stand, classifying the trees by d.b.h. and condition classes:

1. Acceptable Growing Stock: Trees with the potential to produce sawlog or better quality material, now or in the future, and that are in vigorous condition. These can be subdivided into mature (based on biological or financial maturity) and immature. Suggested tree sizes denoting financial maturity are shown in Table 5.

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 5.—Tree-size objectives (d.b.h.) denoting peak of possible log-grade improvement (financial maturity) for northern hardwoods (high and medium-grade potential reflect the marker's best judgement on tree condition and site potential for that species)

Species	Grade potential[a]	Log section[b]	D.b.h. objective
			Inches
Yellow birch	High	1	18
	High	2	20
	Medium	1	16
	Medium	2	18
Sugar and red maple[c]	High	1	18
	High	2	20
	Medium	1	16
	Medium	2	18
Beech	High	1	16
	High	2	18
	Medium	1	14
	Medium	2	16
Paper birch	High	1	16
	High	2	16
	Medium	1	12
	Medium	2	12
White ash	High	1	18
	High	2	20
	Medium	1	16
	Medium	2	18
Red spruce	Medium or better	Any	14–16
Hemlock	Medium or better	Any	18–20

[a]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 USDA Forest Service standard specifications for hardwood factory lumber and veneer logs.

[b]Predominant merchantable height.

[c]In many areas, red maple has medium-quality potential at best, so d.b.h. objectives commonly are 14 to 16 inches.

This hypothetical northern hardwood stand has 57 percent of the basal area in sawtimber. A stand with a q of 1.5 has approximately 55 percent of the basal area in sawtimber, so a structural goal of q = 1.5 would be a reasonable first choice (see tabulation for percent sawtimber). However, in looking at the tree condition classes, a reasonable set of marking guides might be:

1. Remove high-risk timber in the 12- to 14-inch class.

2. Remove high-risk timber in the 16+ class.

3. If a cordwood market were available, remove defective trees in the 6- to 10-inch class

Application of these marking rules would leave a residual stand as follows:

D.b.h. class (inches)	*Mature*	*Immature*	*Defective*	*Total*	*Goal (q = 1.7)*
	- - - - - -ft² of basal area/per acre - - - - - -				
6–10	—	40	—	40	38
12–14	—	10	10	20	18
16+	5	5	5	15	14
All	5	55	15	75	70

This residual stand is close to the structural goal of q = 1.7 in Table 4, and the stand contains a high proportion of vigorous growing stock.

An alternative approach is to follow generalized marking rules related to stand condition (Table 6). With 65 ft^2 of sawtimber, the hypothetical initial stand qualifies as beech-birch-maple large sawtimber. Total initial basal area is more than 100 ft^2, so a cut is warranted using either single-tree or group selection. The suggested residual basal area is 75 ft^2, with 40 to 55 ft^2 of sawtimber. In this example, the use of Table 6 leads us into leaving a little more sawtimber basal area (8 to 23 ft^2 more), and a corresponding smaller amount of poletimber, than is suggested by the prism-plot summary of the actual condition of the growing stock.

Noncommercial Work

Noncommercial stand improvement work is minimal with uneven-age management because each harvest operation provides the opportunity to improve the stand by removing marginal or submarginal trees. However, three types of noncommercial work are possible.

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.

1. *Cull Removal*: Culls to be removed should be designated during marking. Residual culls should be included in defining the residual basal area and structure—because they influence growth, regeneration, and quality development. Elimination of understory culls is of doubtful value because of their abundance, slow growth, and high mortality. Keep in mind the importance of reserving some cull trees, especially the large ones, for wildlife. More than 30 species of birds and 20 mammals use culls in New England for feeding, nesting, or denning.
2. *Two-Inch Removal*: When group selection is applied, and the saplings or small poles within a group are of undesirable species or quality, complete stem removal down to about 2 inches d.b.h. is recommended. Generally, this is most easily done during the logging operation, though a separate postlogging treatment also is possible using chemical or mechanical methods.
3. *Group Stand Improvement*: Groups of saplings or small poles resulting from previous group-selection cuttings may be dominated by stems of low-quality or undesirable species. If less than about 40 percent of the overstory stems are minimally acceptable, consider a noncommercial weeding/cleaning to be carried out in the substandard groups. This work is expensive and should be restricted to those instances where the site is good and a marked increase in stand value will result. The operation should be the minimum required to create an overstory with at least 40 to 50 percent of the stems in acceptable species and quality.

Regeneration

Under single-tree selection, more than 90 percent of the regeneration will be tolerant species. Under group selection, based on groups averaging about one-half acre in size with all stems larger than 2 inches removed, about one-third of the regeneration will be of intermediate or intolerant species (Table 7). In larger groups up to about 2 acres in size, the intolerant and intermediate species should account for one-half of the regeneration. Limited experience indicates that the proportion of intolerants (e.g., paper birch) may equal the proportion of intermediates in groups two-thirds of an acre or larger in size.

Species composition of the regeneration under single-tree selection is closely related to the advance regeneration. Areas to be regenerated to sugar maple or softwoods should show evidence of these species in the existing advance regeneration. To be considered well established, a hardwood or hemlock stem should be 3 to 4 feet tall; a spruce or fir, about 1 foot tall.

Under group selection, the presence of residual tolerant stems in the seedling, sapling, or small-pole sizes will limit intolerant or intermediate regeneration. In regenerating birch under group selection, advanced regeneration larger than 2 inches d.b.h. should be sparse, or it should be removed in creating the opening (Fig. 3). Snow-free logging generally is more effective than winter logging in reducing unwanted advanced growth.

Table 7.—Species composition of stocked mil-acres, 10 to 15 years after cutting in beech-birch-maple stands, by tolerance group and cutting method

Tolerance group[a]	Clearcutting	Group selection	Single-tree selection
		Percent	
Tolerant	43	62	92
Intermediate	19	34	7
Intolerant	38	4	1

[a]Tolerant: beech, sugar maple, eastern hemlock, and red spruce (also balsam-fir if present); intermediate: yellow birch, white ash, and red maple; intolerant: paper birch and aspen.

Group openings in poletimber stands do not always regenerate well—especially on sites that are extremely wet or dry—and are not recommended. Regeneration in groups receives more snow damage than in clearcuttings, apparently due to the extra snow that drifts into small canopy openings. But research has indicated that less than 10 percent of the groups in hardwood and mixedwood stands were in poor condition due to snow damage.

Border-tree quality is a consideration in group selection because border trees may tend to retain live limbs or produce epicormic sprouts. Poles or small sawtimber of hardwood species should not be left as border trees without trainers or buffer trees if they have (1) clear boles but small live crowns; or (2) lower live limbs that will seriously detract from quality if allowed to persist. White ash and paper birch are least likely to produce epicormic sprouts, but live limbs on any hardwood or softwood species will remain alive for a substantial period of time if exposed to full sunlight.

What constitutes adequate stocking in the seedling and sapling size classes of an uneven-aged stand? This question has not been answered completely for New England hardwood and mixedwood stands. However, in extensively

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 4.—Clearcutting in northern hardwoods with essentially complete removal of the understory.

degrade when left as residuals to increase the tolerant component of the new stand. Clearcutting boundaries can be designed to follow natural stand or topographic boundaries to minimize adverse esthetic impacts.

Progressive stripcutting is a variation of clearcutting that is especially well suited to the regeneration of yellow birch and other intermediate species. Strips 50 to 100 feet wide are laid out along the contour. In the first cutting, every third strip is removed; 2 to 4 years later, one strip next to each initially cut strip is removed. After another 2- to 4-year interval, the final strips are cut. Trees down to 2 inches d.b.h. are removed or felled. The material generally is skidded down the strips currently being cut, which results in a high degree of scarification and the removal of most undergrowth.

In mixedwood stands on wet areas, where windthrow would be a threat under unevenage or shelterwood systems, narrow strips (30 to 50 feet wide) sometimes are used to help perpetuate a softwood component. Winter logging usually is advisable in these areas, and softwood regeneration is most probable if the strips contain established softwood seedlings.

In the Northeast, the shelterwood system commonly is applied in two cuts: an initial seed cut (Fig. 5) and a final removal cut. Where the objective is to regenerate tolerant species and little or no advanced regeneration is present, an initial light preparatory cut also may be desirable to stimulate seed production of desirable species and the establishment of small seedlings. For tolerant regeneration, the seed cut should retain about 80 percent crown cover

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.

Dense, undesirable understory vegetation will hinder the establishment of regeneration under the shelterwood system. Methods for dealing with this problem include understory biomass operations, broadcast chemical treatments, and the mechanical or chemical treatment of individual unwanted stems.

The shelterwood system is a good option in mixedwood stands, especially those with high sawtimber potential. This system can be used to increase the tolerant softwood component; to maintain windfirmness if high residual crown cover is maintained; and to allow for the use of large equipment that tends to destroy understory saplings and poles.

Regeneration

Species favored by clearcutting and dense or open shelterwood cutting are summarized in Table 2. Clearcuttings commonly have 20,000 to 30,000 or more stems per acre 1 foot tall or taller at 5 years of age. Species composition is more important than numbers. About two-thirds of the milacres on clearcut areas generally are dominated with intolerant or intermediately tolerant species, though the proportion based on total numbers is less. If advanced regeneration of tolerants larger than 2 inches d.b.h. is retained, a somewhat lower proportion of intolerants-intermediates will result. Tolerant softwoods seldom regenerate well following clearcutting unless well-established regeneration is present—a type of natural or unplanned shelterwood.

One approach to evaluating regeneration following clearcutting is to take a series of circular plots, each 1/700 to 1/1,000 acre in size (8.9 to 7.4 feet in diameter). These plot sizes represent the area occupied by each tree when the stand reaches 4 to 6 inches d.b.h. (quadratic mean stand diameter or tree of average basal area) in the northern hardwood and mixedwood stocking guides (Figs. 6–7). Determine and record the dominant free-to-grow species—the species that will dominate the plot using all available information on tolerance, relative growth rate, longevity, etc. If the proportion of plots dominated by desirable species exceeds 60 percent (many plots contain more than one commercial stem), this would be equivalent to B-line stocking or better. Stocking of 40 percent would be about equivalent to C-line stocking. By also recording the desired species present that are not free to grow, it is possible to determine whether the species potential of each plot could be improved by a weeding operation. For example, a plot might be dominated by free-to-grow aspen; if removed, the plot might be dominated by paper birch. In summarizing the data, it is then possible to examine stocking of acceptable species both with and without treatment. If the without-treatment stocking is less than C line, but the with-treatment stocking is well above the C line, a weeding/cleaning operation should be considered.

Data from shelterwood cuttings in the Lake States indicate that at least 5,000 well-distributed seedlings per acre, 3 to 4 feet tall, should be present before the removal cut. After the removal cut, the regeneration can be evaluated using the plot system described for clearcutting.

In the past, scarification has been recommended for yellow and paper birches since most studies show much higher stocking of these birches on scarified seedbeds. However, scarification operations are expensive and difficult to justify. Recent experience indicates that summer logging, which encourages a small amount of scarification from the logging operation, does not necessarily produce more birch than winter logging.

Scarification during the seed cut of a shelterwood has been recommended in the Lake States for regenerating hemlock. In the Northeast, certain sites—notably the wetter ones—appear to develop a strong understory of hemlock without scarification. However, on drier mixedwood sites where little or no advance regeneration of hemlock is present, scarification during the shelterwood seed cut would appear to be helpful.

Planting is seldom done on a commercial scale in northern hardwoods and related types in the Northeast. However, where seed sources of desired species are lacking or genetically improved trees are desired, planting can be done successfully. We recommend container-grown stock for rapid growth and minimum mortality. The planting site needs to be freed of brush or sod—by mechanical or chemical means—to at least 3 to 4 feet around each seedling location. Posttreatment release often is necessary. In some areas, it also will be necessary to control damage from deer, rabbits, and mice. Yellow and paper birches, spruce, and hemlock all are possible planting candidates.

Stocking

Stocking guides for even-aged hardwood stands are given in Figure 6 and for mixedwood stands in Figure 7. The guides apply to the main crown canopy, i.e., excluding the suppressed trees. Mixedwood stocking applies to stands with 25 to 65 percent softwoods in the main crown canopy. The A lines represent the average density of undisturbed even-aged stands. The B lines represent the minimum density for maximum basal area or cubic-foot growth. The charts were developed from both simulated and remeasured plot data which show that maximum growth per acre occurs at about 55 to 65 ft^2 of basal area in hardwoods. The C line represents minimum stocking—the minimum amount of acceptable growing stock to make the stand worth managing. The C line is roughly 10 years' growth below the B line. Growth per acre (in basal area or cubic feet) is a little lower at the C line than the B line, and diameter growth more rapid.

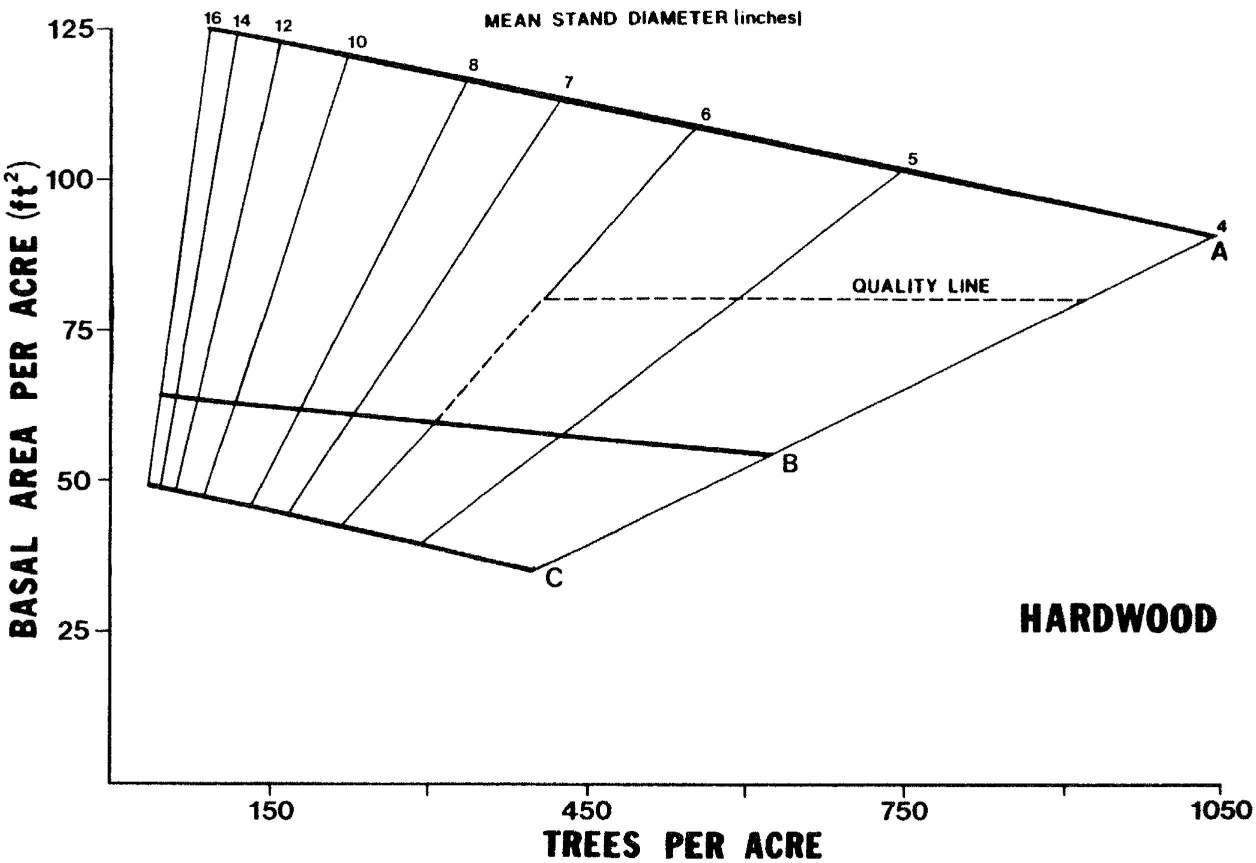

Figure 6.—Stocking guide for main crown canopy of even-aged hardwood stands (beech-red maple, beech-birch-maple) shows basal area and number of trees per acre and quadratic mean stand diameter. The A line is fully stocked, the B line is suggested residual stocking. The C-line is minimum stocking. The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

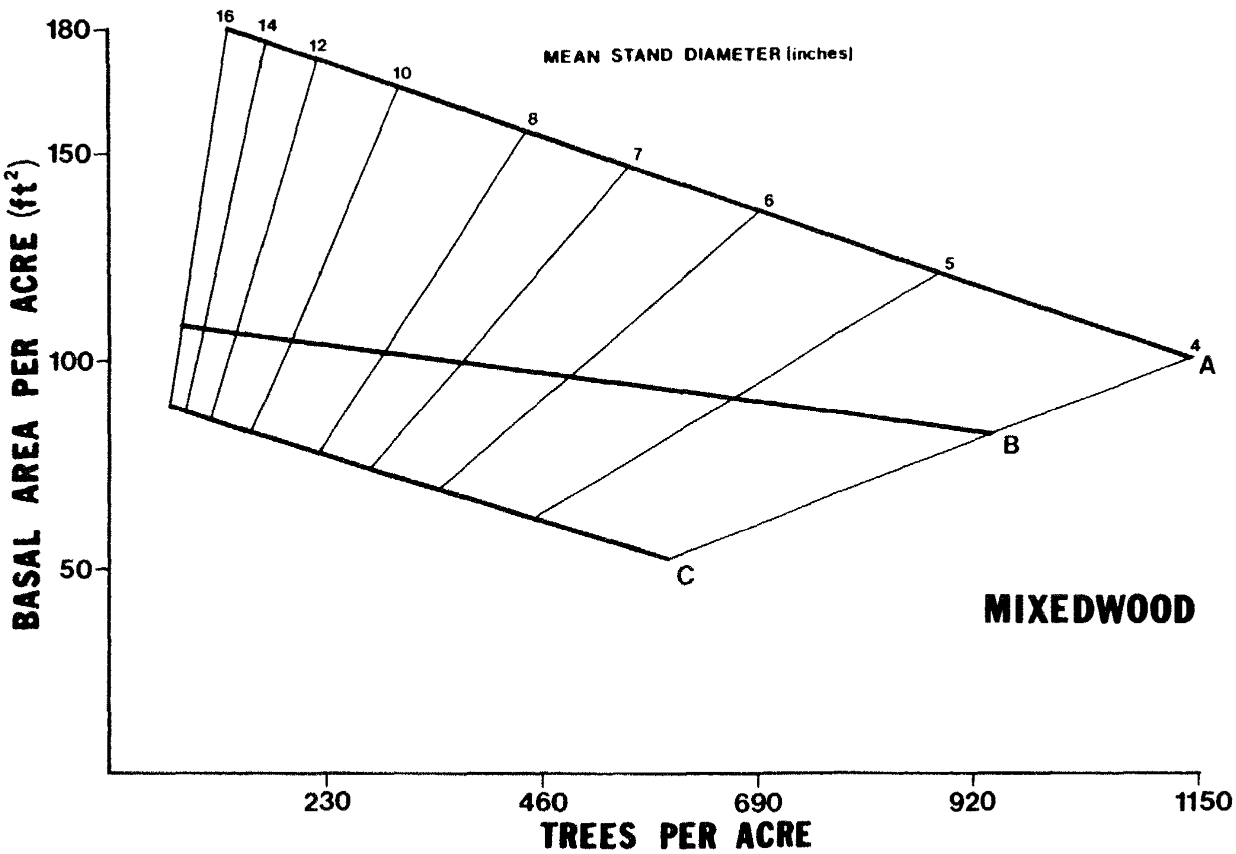

Figure 7.—Stocking guide for main crown canopy of mixedwood stands (25 to 65 percent softwoods) shows basal area and number of trees per acre and quadratic mean stand diameter. The A line is fully stocked, the B line is suggested residual stocking, the C line is minimum stocking.

near the mixedwood A line for stands with a mean stand diameter less than 6 inches.

Growth, Yield, and Rotation

Board-foot and cubic-foot volumes per acre for unmanaged hardwood stands are given in Table 8, based on simulation (Solomon and Leak 1985). These are gross yields with no deduction for cull or defect. Cubic volumes of mixedwood are at least 15 to 25 percent greater than hardwood yields, and board-foot volumes may be proportionately even greater. However, precise estimates of mixedwood yields are not yet available. Yields of intensively managed hardwood stands are simulated in Table 9. These yields are for stands kept at 80 ft^2 or more of basal area until the mean stand d.b.h. reached 6 inches, and then thinned to B-line density when stand basal area was about two-thirds the distance from B line to A line. Hardwood yields represent the maximum attainable under intensive silviculture in a natural stand and total managed yields at about 100 years of age are 50 to 90 percent greater than unmanaged yields. In applying both the managed and unmanaged yield tables, deductions from gross yields must be made for sound and rotten cull, logging waste, poor stocking, and nonforest acreage.

The site indexes in Tables 8 and 9 are for sugar maple, base age 50. Sugar maple sites of 70 and above commonly occur in New England on soils enriched by organic matter or derived from rich bedrock (e.g., limestone) or alluvium. Sugar maple and ash are common on such sites. Sites of 60 to 70 typically are beech-birch-maple sites; the soils are well- to moderately well-drained, fine-textured tills. Sites of

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)	Site 50			Site 60			Site 70		
	Age	Cubic feet	Board feet	Age	Cubic feet	Board feet	Age	Cubic feet	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.

Table 9. Volumes per acre in cubic feet (4.0-inch top) and board feet (8.0-inch top) for intensively managed even-aged hardwoods

Mean d.b.h. (inches)	Site 50 Age	Site 50 Cumulative thinnings Cubic feet	Site 50 Cumulative thinnings Board feet	Site 50 Standing Cubic feet	Site 50 Standing Board feet	Site 50 Total Cubic feet	Site 50 Total Board feet	Site 60 Age	Site 60 Cumulative thinnings Cubic feet	Site 60 Cumulative thinnings Board feet	Site 60 Standing Cubic feet	Site 60 Standing Board feet	Site 60 Total Cubic feet	Site 60 Total Board feet	Site 70 Age	Site 70 Cumulative thinnings Cubic feet	Site 70 Cumulative thinnings Board feet	Site 70 Standing Cubic feet	Site 70 Standing Board feet	Site 70 Total Cubic feet	Site 70 Total Board feet
	Years							*Years*							*Years*						
4.0	35							30							25						
6.0	57	226		1158		1384		48	269		1418		1687		40	315		1657		1972	
8.0	74	1012	726	996		2008	2698	61	1243	895	1189	2211	2432	3106	50	1439	1075	1426	2760	2865	3835
10.0	89	1012	726	1608	4694	2620	5420	72	1243	895	1912	5471	3155	6366	59	1439	1075	2222	6400	3661	7475
12.0	105	1520	2211	1725	6409	3245	8620	83	1854	2680	2039	7375	3893	10005	68	2148	3171	2395	8807	4543	11978
14.0	124	2128	4596	1738	7502	3866	12098	95	2602	5633	2011	8449	4613	14082	77	3019	6650	2389	10139	5408	16789
16.0	147	2786	7435	1469	6340	4255	13775	107	2602	5633	2449	10289	5051	15922	85	3019	6650	2868	12203	5887	18853
18.0								119	3394	8960	2085	8760	5479	17720	92	3915	10465	2446	10446	6361	20911

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 10. Sample cumulative tally for a 10- or 20-factor prism (example for two plots)

BA Factor		Diameter at breast height (inches)												
10	20	2	4	6	8	10	12	14	16	18	20	22	24	26
No. trees							*No. trees per acre*							
1		458	115	$51^{X\prime}$	$29^{\prime}$	$18^{\prime}$	13^{0}	9^{0}	$7^{\prime}$	6^{M}	5	4	3	3
2	1	917	229	$102^{X\prime}$	57^{0}	$37^{\prime}$	$25^{\prime}$	19^{0}	14^{0}	11^{0}	9	8	6	5
3		1375	344	153	$86^{\prime}$	$55^{\prime}$	38^{0}	$28^{\prime}$	21^{0}	17	14	11	10	8
4	2	1834	458	204	115	$73^{\prime}$	51^{0}	37^{0}	29	23	18	15	13	11
5		2292	573	255	143	92^{0}	64	47	36	28	23	19	16	14
6	3	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	4	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	5	4584	1146	509	287	183	127	94	72	57	Tally		No.	
11		5042	1260	560	315	202	140	103	79	62	Legend		Plots	
12	6	5501	1375	611	344	220	153	112	86	68	′Acceptable		. .	
13		5959	1490	662	372	238	165	122	93	74	0 Unacceptable			
14	7	6417	1604	713	401	257	178	131	100	79	X Suppressed			
15		6875	1719	764	430	275	191	140	107	85	M Mature			
Trees/acre:				51	43	46	25.5	18.5	10.5	5.5	Total = 149			
BA/acre:				10	15	25	20	20	15	10	Total = 105			

Trees/acre: Add the last numbers used in each column and divide by the number of plots.

BA/acre: Add the number of entries; multiply by the BA factor; and divide by the number of plots.

BA factor 10: Use the numbers consecutively in each column. For example, one 10-inch tree in a plot represents 18 trees per acre; two 10-inch trees represents 37 trees.

BA factor 20: Use the second number of each pair in a column. For example, one 10-inch tree in a plot represents 37 trees per acre; two 10-inch trees represents 73 trees.

Site-Index Trees:	*Species*	*Age*	*Height*	*Type:* Beech-birch-maple
	SM	70	70	

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 ft^2 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.

Table 12.—Summary table for uneven-aged or even-aged stand diagnosis (example from Table 10)

D.b.h. class (inches)	Mature	Immature	Defective	High risk	Cull	Total	Possible residual goals (Q=1.5-1.7)		Possible marking goals	
	-Ft-									
	UNEVEN-AGED									
6–10		40	10			50	30	38	20	12
12–14		10	30			40	20	18	20	22
16+	5	5	15			25	20	14	5	11
All	5	55	55			115	70	70	45	45

Initial % Sawtimber = 57 Initial Q = 1.5

EVEN-AGED

Tree condition	Initial stand	Residual goal	Marking goal
	-Ft²-		
Mature	5	5	0
Immature	45	45	0
Defective-high risk	55	14	41
All	105	64	41

No. Trees	*149*	*Commercial Cutting*	*Mature D.b.h. (inches)*
MSD	*11.4*	___ Feasible	20 – SM, YB, WP, Hem
A line BA	*112*	___ Not feasible	18 – Be, WA, RO
B line BA	*64*		16 – RS, RM
C line BA	*48*		12 – PB, Asp., BF
Quality line BA	___		
Bole Condition:	___ Clear merchantable length		*Site-Index Trees*
	___ More natural pruning needed		*Species* *B* ___ ___
			Age *70* ___ ___
			Height *70* ___ ___
			Site *60* ___ ___

Reproduction or Sapling Stands (Mean d.b.h. of Overstory Less Than 4.0 Inches)

1. 40 percent or more of the plots stocked with a desirable free to grow stem (untreated). A

1. Less than 40 percent of the plots stocked with a desirable free to grow stem (untreated).

2. More than 40 percent, preferably more than 60 percent, of the plots stocked with a desirable stem not free to grow. B

2. Less than 40 percent of the plots stocked with a desirable stem not free to grow. C

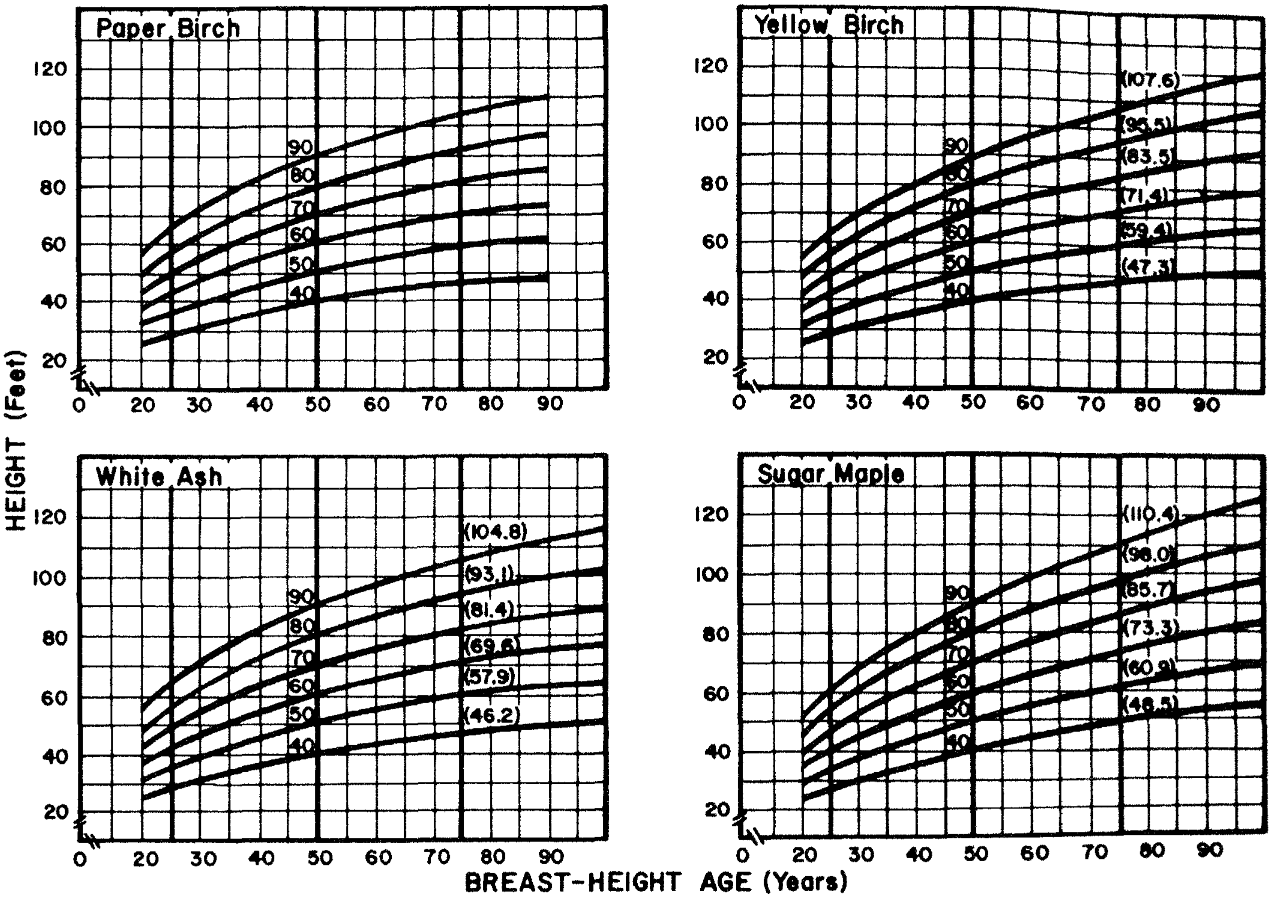

Figure 8.—Site-index curves (breast height age 50) for paper birch, white ash, yellow birch, and sugar maple in Vermont and New Hampshire. Values in parentheses are for site-index breast height age 75 (Curtis and Post 1962b).

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

COMPARATIVE SITE INDEX BASE AGE 50

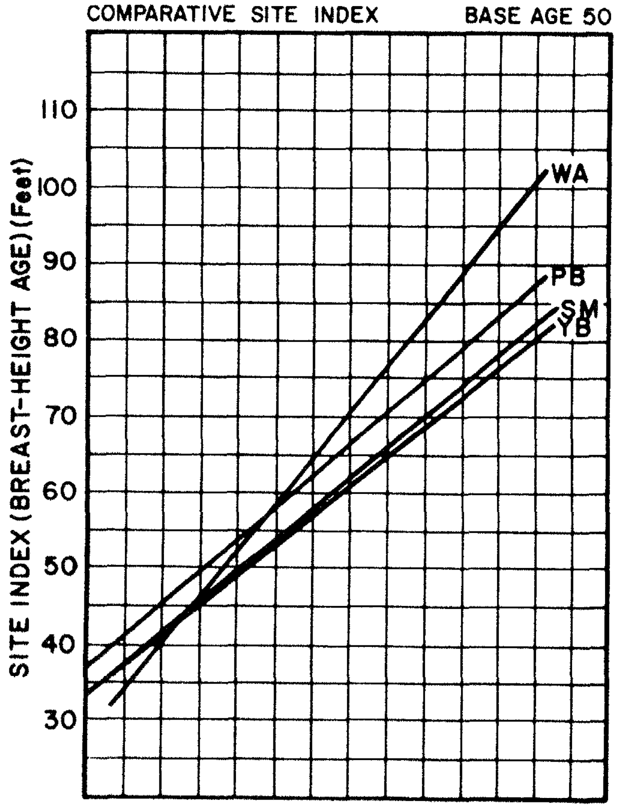

Figure 9.—Relationships among site indices (base age 50) for white ash, paper birch, yellow birch, and sugar maple. To estimate site index of species X from site index of species Y: find known site index on curve for species Y; move vertically up or down to curve until species X is located; read horizontally across to the left to find estimated site index for species X (Curtis and Post 1962a).

2. Stocking of acceptable growing stock more than C line
   3. Stand mature[1]
      4. Objective: intolerant and intermediate species — J
      4. Objective: tolerant species — K
   3. Stand not mature
      4. Stand more than 6 inches mean stand diameter and adequate clear length developed
         5. Total stocking more than halfway between A and B lines
            6. Commercial thinning feasible now or within 10 years — L
            6. Commercial thinning not feasible now or within 10 years — M
         5. Total stocking less than halfway between A and B lines — N
      4. Stand less than 6 inches mean stand diameter, or clear length not well developed
         5. Total stocking more than Quality line
            6. Light commercial thinning feasible now or within 10 years — O
            6. Light commercial thinning not feasible now or within 10 years — P
         5. Total stocking less than Quality line — Q

[1]Mature: (1) at rotation age, (2) at mature size, based on product objectives, or (3) 50 percent or more of the basal area in mature trees.

Prescriptions

A. This young stand should develop naturally into an adequate pole stand with at least C-line stocking of desirable species. Noncommercial treatment is not required.

B. This young stand will develop into a pole stand with C line stocking of desirable species only if cleaned precommercially. Benefits and costs of such treatment should be examined using all available information on site, species response, and managment objectives. Apply the treatment if warranted.

C. Even if cleaned precommercially, this young stand will not develop C-line stocking of desirable species. Reexamine the stand in 10 to 20 years to determine the best treatment options—including the possibility of biomass harvesting for fuel or fiber.

D. This stand has suitable quality, structure, and basal area to implement uneven-age management. Develop and apply marking guides to meet goals for residual basal-area structure, tree condition, and regeneration. Consider both single-tree and group selection.

E. This stand has suitable quality and structure to implement uneven-age management. But stand density is not critically high. Reexamine in 10 to 20 years, unless the possible loss of valuable high-risk trees warrants immediate harvest cut by selection or group-selection methods.

F. This stand has suitable quality and density to initiate uneven-age management, but sawtimber stocking is low. Apply a commercial improvement cut, removing lower quality overstory stems, leaving a residual basal area of about 65 to 70 ft^2 (hardwood) or 80 to 100 ft^2 (mixed wood) per acre plus any allowance for logging damage.

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 increased 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 into 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.

The system becomes more complicated when there are inaccessible or less productive areas on a long cutting cycle, and productive or accessible areas on a short cutting cycle. Detailed scheduling is required to assure that roughly equal yields are harvested each year. A more formal approach is to divide the inaccessible lands into a number of cutting units equal to the number of years in the long cutting cycle, and also to divide the accessible lands into a number of cutting units equal to the years in the short cutting cycle. Then, each year, both an inaccessible and an accessible unit are cut. This approach tends to regulate both yields *and* access costs.

With even-age management, there are two components to the yield: harvest-cutting and thinning yields. In theory, an even-aged forest is fully regulated when it has roughly equal acreages in each 10- or 20-year stand age class from the youngest class up to the class representing the planned rotation age. As with uneven-age management, it sometimes is practical to: (1) divide the entire property into type or accessibility classes, (2) set an appropriate rotation age and thinning interval for each class, and (3) work toward an balanced age distribution in each type of accessibility class. To develop a balanced age distribution, harvest an acreage per year equal to the total acreage divided by the planned rotation age. If the entry period for harvest cutting is more than 1 year, multiply by the number of years in the entry cycle to determine the acreage to harvest at each entry.

Thinned acreage commonly is 2 or 3 times the harvest acreage, though thinned volume may be between 50 and 100 percent of the harvest yields. In an unbalanced even-aged forest, the thinning yields will be variable because: (1) the acreage in each age class will be unequal, and (2) the quality and stocking of some acres in each age class may not warrant thinning.

Economic Considerations

With moderately intensive silviculture, managed stands can yield at least 50 percent more volume than unmanaged stands. Although the increased physical yields seem worth pursuing, the financial returns from those yields may not be. The following discussion explores the economic effectiveness of applying silvicultural guidelines in the management of northern hardwood forests.

We develop a generalized case to trace the changes in timber values that we might expect in northern hardwood stands over long periods of time under various management strategies. We also assign estimates of stumpage values and their costs to the volume yields indicated in Appendix Tables 20–23, and then compare the resulting timber values. Methods for testing the economic effectiveness of managing a particular stand are available elsewhere (Leak 1980).

Hardwood Diversity

In any discussion of northern hardwoods and associated types, we must first emphasize their diversity. Each species has its own package of characteristics as to strength, workability, appearance, and appeal. Market prices attest to this and tend to differentiate relative values among species.

Eastern hardwood stands also are diverse in product potential. Figure 10 depicts a hierarchy of relative product values, along with a general woods-run volume distribution that is typical of many eastern hardwood stands. Although the actual values vary from one stand to another because of species and size mix, logging conditions, and markets, the relative value differences among products often are large (DeBald 1981).

Timber size and quality are especially important in northern hardwoods. Figure 11 shows the relative values of trees by both diameter and butt-log grade. The increased value through increased size suggests concentrating growth on selected fast-growing crop trees. The large differences in tree values from one butt-log grade to another indicate the importance of concentrating growth on trees that are likely to impove in grade.

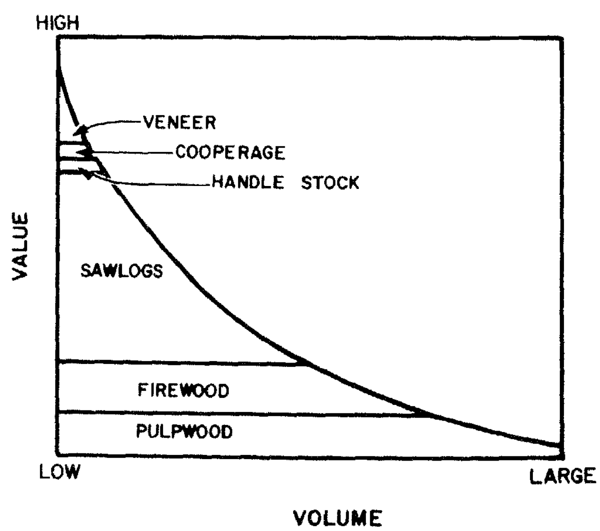

Figure 10.—Typical value/volume hierarchy, eastern hardwood stands.

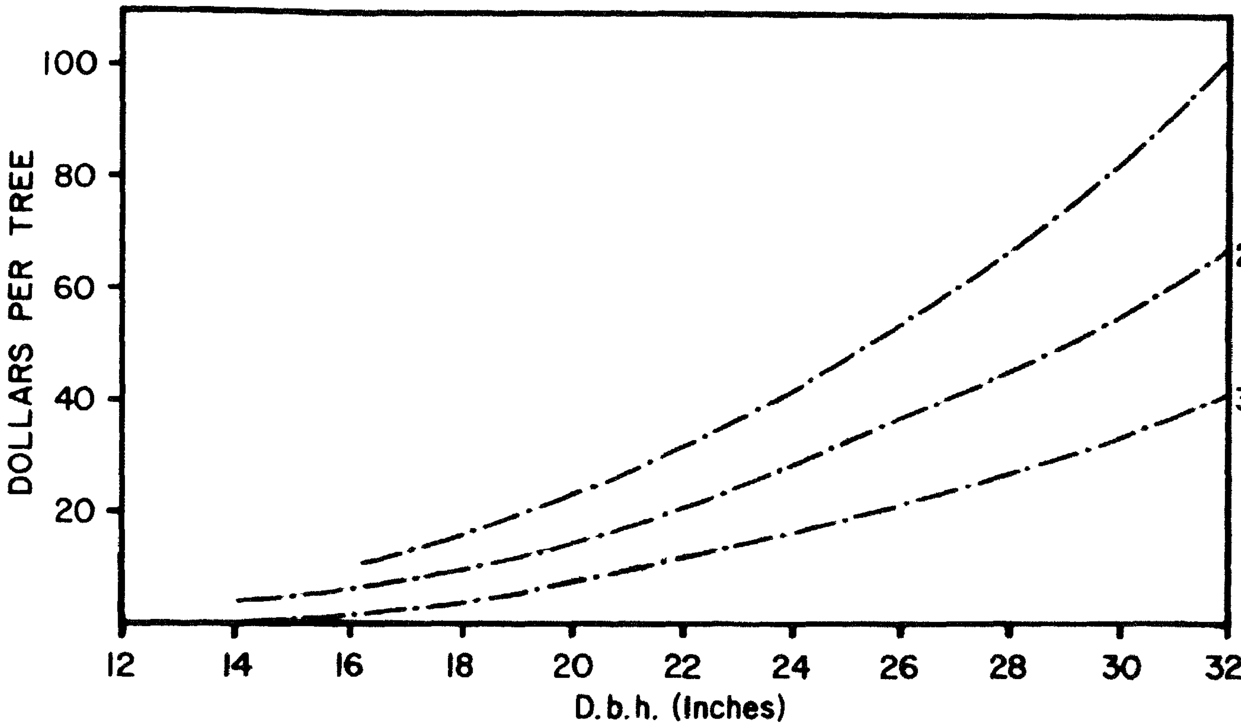

Figure 11.—Relative values of two-log hard maple trees, by butt-log grade.

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

Next, we must assign dollar values to potential products. Recent stumpage prices in New Hampshire indicate a wide range in values by product class and highlight the value premiums for higher value products (Table 14). They also point to the importance of encouraging the development of high-value species.

To evaluate the development of quality over long and varying timespans, we should include price-change expectations in our valuations. Let's use real rates of price change—rates over and above inflation. Using real prices eliminates the need to make an additional guess at expected long-run inflation rates and reflects the fact that hardwood lumber-price trends often exceed inflation rates. Let's use the stumpage prices in Table 14 for a base and project them to increase in real value as follows:

Log quality	*Real rate of increase (%)*
Veneer and high	3
Medium	2
Low	1
Pallet stock	0.5

We can then assign estimates of dollar values to both the thinnings and the standing volumes shown in Tables 20-23—in real terms. The results will portray the benefits of quality development and our expectations of how silvicultural treatments can enhance the development of quality.

But every benefit has its cost. We need, then, to also consider the costs of maintaining and managing a timber stand—again, over long and varying timespans. So, let's assume an annual real cost of $1 per acre for such things as property taxes and maintaining boundaries. Although the annual cost is common to each of the management strategies, the total costs will vary depending on the timespans that the management strategies cover. Let's assume, further, that consulting forester fees account for 10 percent of timber-sale proceeds, a 30-percent income tax bracket, and capital gains treatment of 40 percent.

Table 14.—Recent typical sawtimber stumpage prices (adapted from Engalichev 1984)

Product class	White ash	Hard maple	Yellow birch	White birch	Red oak	Other
			Dollars/M bf			
Veneer	135	90	115	110	170	45
Sawtimber						
High quality	120	90	105	85	135	40
Medium quality	90	65	80	65	100	30
Low quality	70	50	65	55	75	25
Pallet stock	25	25	25	25	25	25

Net Present Values

But we also must consider the time value of money. For most of us, a dollar in hand today is worth more than a dollar to be received (or spent) 5 years from now. How much more depends on the rate of return (cost of capital) that we assume. The values in Table 15, for example, are net present values, the result of discounting expected net future values and expected future costs all back to year zero at a rate of 4 percent, then subtracting the discounted costs from the discounted values. Discounting to year zero converts varying timeframes to one common point in time and allows us to analyze stand-value development over time. The resulting net present values express all amounts in equivalent terms—today's dollars at time zero.

Comparison of different thinning regimes suggest that silvicultural activities aimed at improving product mix can result in a substantial increase in value yields (Table 15). The more we improve the potential product mix, the greater the value yield.

Although much of the increased value results from improved product mix, the timing of value yields also is important. The time required to reach a given mean stand diameter is considerably shorter with management than it is without management. Holding costs, then, are lower. But more important, the discounting period for managed stands of a given mean diameter are much shorter than they are for unmanaged stands of the same diameter. Note that even if product mix were not improved by thinnings (Table 15, Column A), the net present values of managed stands are much higher than those for unmanaged stands. The time value of money is extremely important.

The value of timber removed in thinnings also is important. The cash flows that they generate add greatly to the overall value yields from managed stands. In many managed stands, the net present value of timber sold from thinnings amounts to almost as much as the net present value of the standing timber.

The prospect of building up higher timber values faster, combined with cash flows from thinnings, suggests that managing northern hardwoods can be worthwhile. Depending on the degree of improvement in product mix, the value yields of managed stands can be dramatically higher than those of unmanaged stands.

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.

the real rates.[2] For example, if we expected a 7 percent rate of return over over a span of years, along with an average inflation rate of 4 percent, the nominal IRR would be approximately 11 percent. The tough (if not impossible) part of making the conversion is trying to predict future inflation rates.

The differences in possible value yields, with and without management, seem wide enough to demonstrate the economic effectiveness of adopting silvicultural guidelines in the management of northern hardwood forests generally, and to warrant taking a closer look at the management potentials of individual stands, specifically.

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[2]Actually, we would use the formula $(1+n)=(1+r)*(1+i)$ when n, r, and i are the decimal equivalents of the nominal (or market), real, and inflation rates, respectively. Conversions between real and nominal rates should be made by multiplying and dividing, not by adding and subtracting.

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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 19.—Cumulative percent crown cover for beech, 10-factor prism

D.b.h. (inches)	Tree count 1	2	3	4	5	6	7
2	52	105					
4	30	59	89	118			
6	23	47	70	93	117		
8	21	41	62	82	103		
10	19	38	57	76	95	114	
12	18	36	54	72	90	107	
14	17	34	51	69	86	103	
16	17	33	50	67	83	100	
18	16	33	49	65	81	98	114
20	16	32	48	64	80	95	111
22	16	31	47	63	78	94	110
24	15	31	46	62	77	93	108
26	15	30	46	61	76	91	107

Definitions of Simulated Thinning Regimes

1. No Thinning: Stands were allowed to develop naturally.

2. Quality-line Thinning (Fig. 1): Up to 6 inches mean stand diameter, stands were thinned once to 80 ft^2 of basal area. Above 6 inches mean stand diameter, stands were thinned to B line whenever the basal area reached 30 ft^2 above the B line (approximately 2/3 the way from B line to A line)

3. 7-inch Thinning: Stands were thinned to B line after mean stand diameter reached 7 inches and whenever the basal area exceeded the B line by 30 ft^2

4. 9-inch Thinning: Stands were thinned to B line after mean stand diameter reached 9 inches and whenever the basal area exceeded the B line by 30 ft^2

All runs began at 4.0 inches mean stand diameter, 91 ft^2 of basal area per acre, and ages of 25, 30, and 35 years, respectively, for site indices 70, 60, and 50 feet (site index for sugar maple at breast-height age 50). Stands were grown to 18.0 inches mean stand diameter. Quality I has sawtimber potential; quality II is pulp potential or cull.

Table 20.—Residual volumes per acre, by species and quality class (I and II), for no thinning and site index 60

Mean d.b.h. (inches)	Age	Residual basal area	White ash I	White ash II	Sugar maple I	Sugar maple II	Yellow birch I	Yellow birch II	Paper birch I	Paper birch II	Other I	Other II	Combined I	Combined II	Combined A
	Years	*Ft²*	*Board feet/acre*												
4	30	91	—	—	—	—	—	—	—	—	—	—	—	—	—
6	49	102	—	—	—	—	—	—	—	—	—	—	—	—	—
8	67	107	49	49	646	441	742	484	357	285	289	218	2083	1477	3560
10	87	110	98	98	1295	883	1487	969	441	352	580	437	3901	2739	6640
12	114	113	163	163	2167	1478	2488	1622	—	—	971	731	5789	3994	9783
14	157	116	218	218	2890	1970	3318	2164	—	—	1295	975	7721	5327	13048
16	196	118	221	221	2936	2002	3371	2198	—	—	1317	991	7845	5412	13257
18	230	119	224	224	2972	2026	3412	2225	—	—	1332	1003	7940	5478	13418

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.

Table 23.—Residual and cumulative thinned[a] volume per acre for 9-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	67	107			49	49	—	—	645	441	—	—	742	484	—	—	357	285	—	—	—	—	—	—	—	2078	1477	3555
10	83	77	1	69	113	—	7	631	1545	—	9	693	1700	—	4	418	689	—	3	312	699	—	24	2123	2147	4746	—	4746
12	98	97	1	69	234	—	7	631	3177	—	9	693	3498	—	4	418	145	—	3	312	1444	—	24	2123	2147	8498	—	8498
14	110	89	63	69	279	—	862	631	3795	—	950	693	4177	—	126	418	—	—	393	312	1726	—	2394	2123	4517	9977	—	9977
16	125	77	157	69	243	—	2126	631	3315	—	2342	693	3650	—	126	418	—	—	968	312	1509	—	5719	2123	7842	8717	—	8717
18	192	93	157	69	294	—	2126	631	3992	—	2342	693	4395	—	126	418	—	—	968	312	1817	—	5719	2123	7842	10498	—	10498

[a] Three thinnings at mean d.b.h. 9.1, 11.6, and 14.7 inches.

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A practical guide to the management of northern hardwoods for timber production in New England and New York. Both even-age and uneven-age management are considered, and specific treatments are prescribed for a range of stand conditions and management objectives.

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