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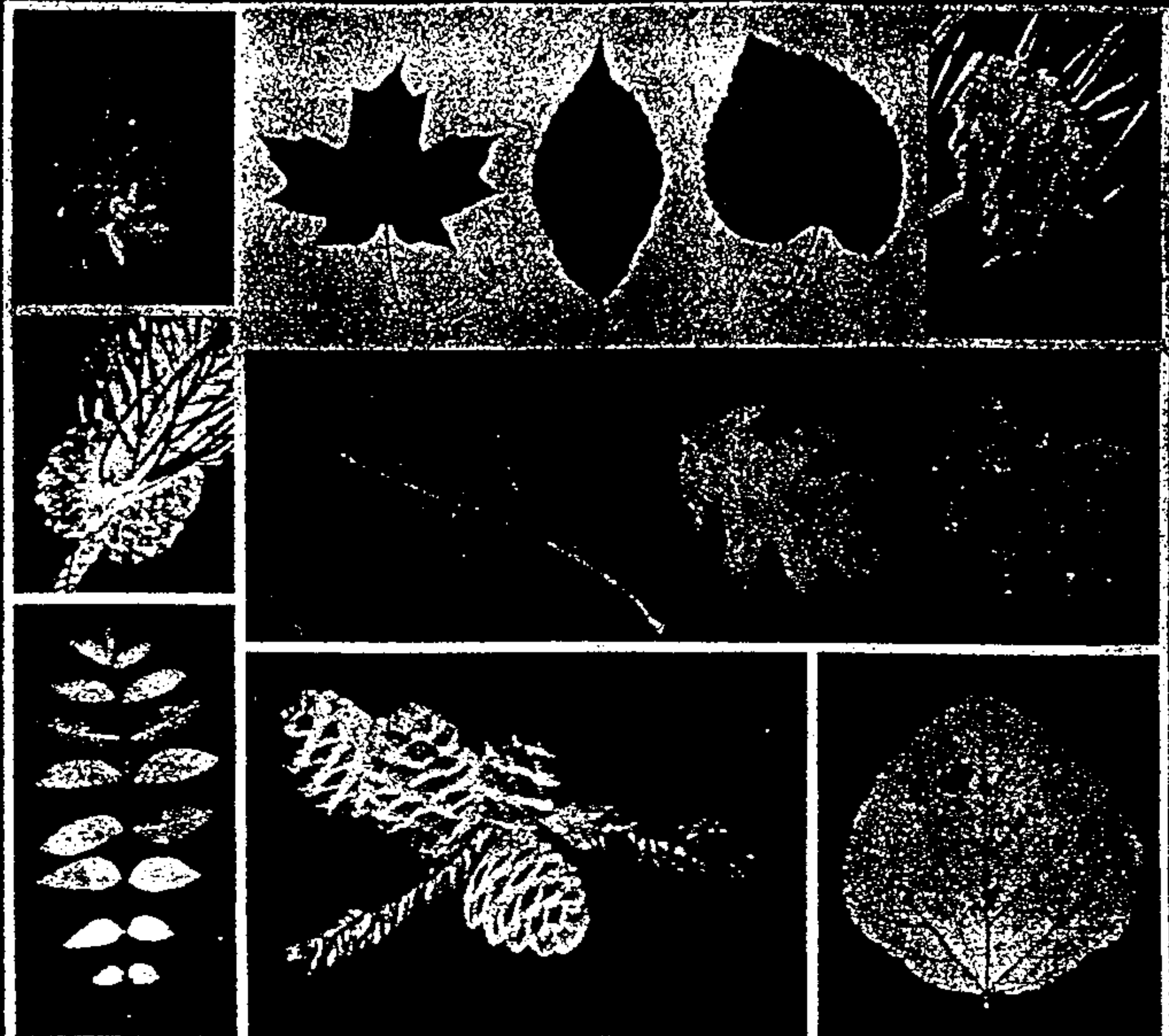

manager's handbook for

NORTHERN HARDWOODS IN THE NORTH CENTRAL STATES

Other Manager's Handbooks are:

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Forest Service — U. S. Department of Agriculture
1992 Folwell Avenue
St. Paul, Minnesota 55108
Manuscript approved for publication September 30, 1975

1977

FOREWORD

This is one of a series of manager's handbooks for important forest types in the north central States. The purpose of this series is to present the resource manager with the latest and best information available in handling these types. Timber production is dealt with more than other forest values because it is usually a major management objective and more is generally known about it. However, ways to modify management practices to maintain or enhance other values are included where sound information is available.

The author has, in certain instances, drawn freely on unpublished information provided by scientists and managers outside his specialty. He is also grateful to the several technical reviewers in the region who made many helpful comments.

The handbooks have a similar format, highlighted by a "Key to Recommendations". Here the manager can find in logical sequence the management practices recommended for various stand conditions. These practices are based on research, experience, and a general silvical knowledge of the predominant tree species.

All stand conditions, of course, cannot be included in the handbook. Therefore, the manager must use technical skill and sound judgment in selecting the appropriate practice to achieve the desired objective. The manager should also apply new research findings as they become available so that the culture of these important forest types can be continually improved.

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NORTHERN HARDWOODS IN THE NORTH CENTRAL STATES

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Northern hardwoods, broadly defined, cover as much as 100 million acres in the Eastern United States and Canada. They are an important source of several valuable timber species, and provide esthetic, wildlife, and recreational resources for many people living nearby in eastern and midwestern population centers.

The management situation for northern hardwoods has changed since early marking guides were published 20 years ago. Until recently, most of the research done in the Lake States focused on the individual tree selection method. So we have the greatest knowledge of, and experience with, this method. But we have started doing more research into even-age practices to increase the number of silvicultural alternatives available. Even-age practices may increase efficiency in harvesting and stand tending, help provide a variety of wildlife habitats, and improve species composition.

In this handbook we attempt to present the best information now available on both even-age and all-age management so the forest manager has the choice of the one that best fits his conditions and management objectives.

SILVICAL HIGHLIGHTS

Northern hardwoods are composed of several forest types, and can be split into two groups: types that are largely composed of sugar maple and other climax species growing on well-drained sites; and types that are composed of subclimax species growing on less well-drained or excessively drained sites. In the Lake States both groups would eventually become stands with significant amounts of red maple[1] or sugar maple, or beech. (In the Lake States beech does not extend beyond eastern Wisconsin and the central Upper Peninsula of Michigan.) Northern hardwoods merge with boreal forest types in the north and central hardwoods in the south.

The major northern hardwood species are generally shallow-rooted, long-lived, and respond to release at advanced ages. The commercially important species range from moderately to very shade tolerant. The long-term ecological trend in northern hardwoods is toward sugar maple, sugar maple-beech, or maple-basswood cover types, which are climax. The most slowly changing type is elm-ash, which may be climax on poorly drained sites; the most rapidly changing types are on the better-drained sites. Partial cutting or similar disturbances normally speed the change toward climax.

The major hardwoods are prolific but sometimes irregular seeders. Maples reproduce easily from seedlings after any overstory disturbance that leaves partial shade; other species such as yellow birch and eastern hemlock require in addition some

[1]*For scientific names of plants and animals, see Appendix, p. 27.*

sort of seedbed disturbance for good reproduction (except on wetter sites).

Sprouting ability varies among northern hardwoods. Beech, the elms, basswood, and red maple are prolific sprouters; yellow birch seldom sprouts. Young trees sprout more prolifically than older trees. Only the sprouts of basswood, and seedling and small sapling sprouts (up to 2 inches d.b.h.) of other species, are considered desirable for reproducing northern hardwood stands.

Basswood rates the highest — and sugar maple the lowest — in general tree quality (considering stem straightness, forking, growth rate, and tolerance); other species are intermediate. Epicormic branching — a common cause of poor form — is frequent in northern hardwoods that have been badly suppressed and then heavily released.

MANAGEMENT OBJECTIVES

Northern hardwood tracts can be managed for any one of several objectives, including timber, water, wildlife, or recreation; or for any combination of these. Owners who manage for timber, for example, include those consuming stumpage themselves, or selling stumpage in a variety of markets, for a variety of products and species. Likewise, recreation management can be complex and include practices for parks, roadsides, streamsides, and the protection of wintering deer herds. In short, stand conditions, site, and tree size alone do not dictate the techniques to be used; the many possible products or management objectives must be considered.

DESCRIPTION OF NORTHERN HARDWOOD TYPES

To use this handbook, first select the forest type in the following list that comes closest to the one being considered, and read the description of the type on the page indicated. Then, considering the site, the mix of species, and the economic limitations, decide what your objective in managing the stand will be. And, with help from the type description, decide whether to use even-age or all-age techniques to achieve your management objective. Then turn to the Key to Recommendations on page 6.

Sugar Maple, Sugar Maple-Basswood, Sugar Maple-Yellow Birch

These are the types in which sugar maple trees make up 70 to 75 percent of the stand. In the sugar maple-basswood, and sugar maple-yellow birch, basswood and yellow birch would comprise 20 percent or more of the stand, respectively. These types could be managed for any of the usual objectives — timber, pulp, wildlife, esthetics.

Selection, shelterwood, or clearcutting can all be used to regenerate stands, depending on conditions. Selection leads to many-sized stands and results in a predominance of tolerant species. Shelterwood also leads to tolerant species; shelterwood with scarification and removal of advance regeneration leads to a mixture of moderately tolerant and tolerant species. Where sites are favorable for species other than sugar maple, both shelterwood and selection procedures will result in moderate numbers of species other than maples. Shelterwood will be of use in concentrating browse and creating overstory openings where wildlife is important. Clearcutting is generally undesirable if timber is the objective. However, clearcutting is useful for wildlife browse and for converting the stand to less tolerant species in the southern and eastern portions of the range of northern hardwoods.

In the Upper Great Lakes area consider options carefully before scarifying or clearcutting on very light soils (sands), very heavy soils (silt or clay loams), or other areas that are prone to invasions by undesirable grass and brush (fig. 1). Such drastic procedures frequently fail to result in regeneration on these sites.

Figure 1.—*Removing overstories before the advance regeneration is large enough may result in grass and brush patches.*

Beech-Sugar Maple

In this type beech makes up 20 percent or more of the stand, and sugar maple most of the remainder. Stands of this type can be managed for the usual objectives, except that in some areas beech is less valuable for timber than sugar maple. However, beech mast is valuable for wildlife.

Light selection cuttings favor beech reproduction; heavy selection cuttings (i.e., leaving saw log stands of only 50 square feet of basal area) discriminates against beech reproduction. In other respects management techniques that apply to the foregoing sugar maple types also apply here.

Aspen-Northern Hardwoods

Typically, aspen predominates in the overstory in this type, while northern hardwoods are invading the understory. Options include: (1) maintaining and managing aspen for timber, pulp, or wildlife by complete clearcutting (Perala 1977); (2) converting to northern hardwoods for timber or wildlife using the shelterwood or selection system; or (3) maintaining a mixture of aspen and northern hardwoods for wildlife or esthetic objectives. To maintain the mixture on the same area, aspen can be interspersed with northern hardwoods in clearcut strips or blocks, while the northern hardwoods are managed as given above.

Paper Birch, Paper Birch-Aspen, Paper Birch-Northern Hardwoods

These types range from pure paper birch to paper birch mixed with aspen, to paper birch mixed with — and converting to — northern hardwoods on the better sites. Stands of these types could be managed for sawtimber and veneer (if the site index is 60 or more), for pulpwood, or for their esthetic appeal.

Where birch and aspen are mixed and the birch site index is less than 60, the stands should be clearcut as in the case of aspen stands (Perala 1977). Progressive strip clearcutting and scarification of sites having a site index of 60 or more will reproduce paper birch on mineral soils.

Red Oak-Northern Hardwoods

This type contains 20 percent or more red oak mixed with other northern hardwood species. Stands of this type could be managed for any of the usual objectives, however, none of the known regeneration methods maintains or increases the amount of oak in the stand. Selection cutting leads to northern hardwoods the fastest. Clearcutting is not recommended.

Hemlock-Northern Hardwoods

Hemlock is a prominent species in this type. Sugar maple is less common; yellow birch, black ash, red maple, and elm are commonly mixed with the hemlock.

Any of the usual objectives could be managed for in stands of this type. To maintain the same composition of hemlock and hardwoods, use the shelterwood method with site preparation. To gradually increase the more tolerant hardwoods reproduce the stand using the selection method. Group selection in combination with individual tree selection appears to increase the proportion of yellow birch in this type.

Lowland Hardwoods

These wet site stands are characterized by varying mixtures of red maple, black ash, yellow birch, and elm; conifers such as balsam, hemlock, spruce, and cedar are usually present. Lowland hardwoods commonly intergrade with swamp conifer types and the hemlock-northern hardwood type. The types are frequently intimately mixed over large areas.

Stands of lowland hardwoods could be managed for any of the usual objectives. If timber is the objective, and species composition and site are relatively good, use individual tree selection. Pockets of hemlock-hardwoods within predominantly lowland hardwood areas should be managed the same way unless wildlife and esthetic appeal are the management objectives. In the latter case regenerate using the shelterwood method with ground preparation to maintain the hemlock.

Lowland hardwoods are often defective on poorer wetter sites. These sites can either be converted to spruce or be reproduced using the shelterwood method.

When swamp conifers form the majority of the stand, regenerate by clearcutting strips 1 tree-height in width if less than 30 square feet of basal area of conifers remains in the strip, and 2 tree-heights in width if more than 30 square feet of basal area remains (Johnston 1977a, 1977b).

Previously Unmanaged Second-Growth — Any Type

Past extensive use of northern hardwood forests have left many stands in relatively poor condition for intensive management. These kinds of stands are termed "second-growth" by many foresters. They are typically rather even-size, pole-size or smaller, with a scattered overstory poorly formed or defective saw logs. Stands are often primarily sugar maple but may be composed of any mixture of species; some stands have originated mostly from sprouts. Grassy or brushy openings may be common.

Before unmanaged second-growth pole stands (defined here as having less than 50 square feet basal area of saw log-size trees — these at least 10 inches d.b.h.) can be brought under either even-age or all-age management, their quality must be improved. The following improvement scheme is for second-growth stands composed primarily of high-value hardwoods. Aspen and white birch mixtures are considered elsewhere.

Make an initial improvement cut concentrating in the most abundant size class (5 to 9 inches d.b.h.) also removing the most defective and poor quality stems of all sizes. A cut that leaves 80 to 85 square feet (5 inches d.b.h. +) in the residual stand with the major cut in the poles is optimum for most species groups other than hemlock or basswood. Subsequent cuts at 10- to 15-year intervals should aim at an all-size structure for all-age practice (see table 1, p. 19, Appendix) while even-age thinning should lead to an even-sized stand (see figs. 6, 7, 8, p. 20, 21, 22, Appendix).

KEY TO RECOMMENDATIONS

After having read the description of the type being considered, go to the section in this key that best describes the size tree and stocking (*seedling — well-stocked, sapling — well-stocked, pole — well-stocked, sawtimber — well-stocked, any size — understocked*) in the stand being considered. In that section find the statement that best describes the stand, and turn to the recommendation number indicated on page 7. The recommendations also refer you to pages in the *all-age* and *even-age* management sections for details of techniques, or to figures in the appendix. (Note that in the key, the first six recommendations — for seedling and sapling size stands — all recommend *even-age* practices. Not until stands reach pole size should *all-age* practices be considered.)

Seedling — well-stocked *(less than 1.4 inches d.b.h.)*	*Recommendation Number*
1. Stands without overstories	1
2. Stands with scattered overstories of less than 40 square feet:	
a. Scattered aspen or red maple overstories	3
b. Other overstory species	2

Sapling — well-stocked
(1.5 to 4.5 inches d.b.h.)

1. Stands with yellow birch and/or basswood or red maple sprout clumps	4
2. Stands without sprouts or yellow birch	5
3. Stands with scattered overstories of less than 30 square feet	6

Pole Stands — well-stocked
(4.6 to 9.5 inches d.b.h.)

1. Less than 100 square feet basal area per acre	7
2. More than 100 square feet basal area per acre:	
a. Yellow birch (20 percent or more)	8
b. Hemlock (50 percent or more)	9
c. Northern hardwoods (other than those listed)	10
d. Aspen-northern hardwood	11
e. Paper birch, paper birch-northern hardwoods:	
Less than site index 50	12
Site index 50 to 60	13
Site index 60 and better	14
f. Sugar maple-basswood	15
g. Sugar maple-beech	16

Saw Log Stands — well-stocked
(9.6 inches d.b.h. and up)

1. Northern hardwoods (red oak-northern hardwoods, lowland hardwoods, sugar maple types):	
a. Less than 80 square feet saw log basal area	17
b. More than 80 square feet	18
2. Sugar maple-beech	19
3. Paper birch site index 60 or better	20
4. Paper birch-northern hardwoods	21
5. Hemlock, hemlock-hardwoods	22

Any size — understocked

Less than 40 square feet of poles or saw logs or less than 1,000 well-spaced saplings or 5,000 well-spaced seedlings	23

LIST OF RECOMMENDATIONS— ALL-AGE AND EVEN-AGE

1. Do nothing now; review when stand reaches sapling size.
2. When reproduction reaches 4 feet in height and is 50 percent or better stocked with desirable species, remove or kill the overstory (p. 11).
3. When reproduction reaches sapling size, remove overstory, poison red maple stumps if necessary (p. 10).
4. Thin yellow birch (p. 10) and sprout clumps (p. 10).
5. Do nothing now; review when stand reaches pole size.
6. Remove or kill overstory.
7. If stands are to be managed under the all-age system, do nothing until stands reach 100 square feet basal area. If stands are to be managed under even-age system, follow even-age stocking levels (Appendix, p. 20).
8. To encourage yellow birch:
   a. In even-age stands do timber stand improvement work (TSI), releasing birch and discriminating against sugar maple (p. 10).
   b. If all-age stands are to be developed, do TSI, favoring any high-quality stem of any desirable species, especially yellow birch of any size (p. 9).
9. To encourage hemlock do TSI, following even-age stocking levels (fig. 8, Appendix), discriminate against sugar maple first; then other hardwoods (p. 10).
   To develop hardwood stands do TSI when stands reach 100 square feet (4.6 inches d.b.h. and over) favoring any high quality stem of desirable species; use either even-age or all-age techniques (p. 9, 10).
10. To maintain even-age stands do TSI, using the even-age stocking guide (fig. 6, Appendix).
    To develop all-age stands do TSI when stands reach 100 square feet, using all-age techniques (p. 9).
11. a. To maintain aspen, clearcut (Perala 1977).
    b. If the understory is northern hardwood, convert to northern hardwoods by making partial cuts (p. 10 and p. 12).
    c. If the stand is a mixture of northern hardwoods and aspen poles, convert to northern hardwoods (p. 10 or fig. 6, Appendix); discriminate against aspen.
12. a. Clearcut before age 60 (p. 13).
    b. If understories of desirable tolerant species are present, make partial cuts (p. 10).
13. Same as 12 except that one thinning is possible (p. 13).
14. Thin from below if markets are available. Discriminate against other hardwoods to maintain paper birch (p. 13); favor other hardwoods to convert to northern hardwoods (p. 10).
15. In stands with 50 percent or more basswood, cut when stands reach about 130 square feet or over (p. 11 or fig. 7, Appendix). In stands with less than 50 percent basswood, cut when stands reach 100 square feet or over (p. 9 or fig. 6, Appendix).
16. To discriminate against beech, reduce residual basal area to 60 square feet cutting as much beech as possible (p. 9 or fig. 6). To maintain or increase beech, leave residual stands with 85 square feet or more (p. 9 or fig. 6, Appendix).
17. Reexamine in 10 years if even-age (fig. 6, Appendix) or follow all-age guides (p. 9).
18. To maintain or develop even-age stands of tolerant hardwoods, thin according to even-age stocking guides (fig. 6 and 7, Appendix) and regenerate using shelterwood techniques (p. 11).
    To maintain or develop all-age stands of tolerant species, make selection cuts at about 10-year intervals (p. 9).
19. To reduce beech stocking, make selection cuts to 50 square feet of basal area per acre in saw log-size stems cutting beech whenever possible.
20. To maintain paper birch, strip clearcut with site preparation (p. 13).
21. To convert to northern hardwoods, make partial cuts (p. 10, 11).
22. a. To maintain hemlock, thin until rotation age following even-age techniques (fig. 8, Appendix) then use shelterwood techniques with site preparation and artificial seeding to regenerate (p. 12).
    b. To maintain yellow birch, thin until rotation age using even-age techniques, discriminate against sugar maple (fig. 6, Appendix) use shelterwood techniques with site preparation (p. 12).
    c. To convert to even-age tolerant hardwoods, thin to northern hardwood standards (fig. 6, Appendix) use shelterwood without site preparation (p. 11).
    d. To convert to all-age stands of northern hardwoods, use selection techniques (p. 9).
23. Do nothing if hardwood or wildlife production is the goal. Convert to appropriate conifer if immediate production is required (p. 13).

Developing Balanced Size Classes

All-age silviculture is a good choice if tolerant species are expected to dominate the stand (fig. 2). Individual tree selection is the recommended cutting method; group selection is sometimes used in conjunction with individual selection.

To develop balanced size classes for good growth and highest-quality yields consistent with management goals, use the following procedure.

Stocking Level

Try to maintain stocking at 70 square feet per acre in trees 10 inches d.b.h. and over when cutting cycle does not exceed 15 years. This is the optimum stocking of northern hardwoods for maximum board-feet growth of high-quality saw logs on average sites. For timber management do not cut below 50 square feet per acre or above about 95 square feet per acre.

Maximum Tree Size

Cut trees when they are financially mature or at times when removal will benefit the surrounding stand, or when a combination of these considerations seems optimum. Set goals for stocking level and tree size for all cutting units regardless of their present size-class distribution.

Size-Class Distribution

Use a tested, empirical size-class distribution (table 1, Appendix) as a marking guide to maximize board-foot growth, or calculate a size-class distribution for this purpose (see Appendix, p. 19). (If you calculate a size-class distribution, note that large

Figure 2.—*Selection stand of sugar maple and associated species. After one cut the stand resembles a shelterwood; several periodic cuts are necessary to develop good size class structure.*

ratios between size classes lead to many small trees, while small ratios lead to greater numbers of large trees.)

Size-class distributions are guidelines only; the size classes can be rather broad. In general in unregulated stands, the heaviest cut will be in the over-abundant size classes, while in regulated stands some trees will be cut in all the merchantable size classes. Experience has shown that 4- or 5-inch d.b.h. classes are precise enough for field work. The initial development of stands understocked with saw logs requires only two classes (saw logs and poles).

Cutting Cycle

Choose cutting cycles so that stands are cut when they reach 90 to 100 square feet. Normally this will occur between 8 and 12 years after the stand has been cut to not less than 60 to 70 square feet of residual basal area per acre. In stands overstocked with poles, these figures apply to trees 5 inches d.b.h. and up. In saw log stands they apply to all trees 10 inches d.b.h. and up.

The cutting cycle length in years divided into the number of acres of land equals the annual cutting area.

Regenerating and Treating All-Age Stands

Saw Log Stands: At Least 50 Square Feet Basal Area; Trees 9.6 Inches d.b.h. or More

Harvest mature timber. Do not reduce saw logs below 50 square feet per acre or leave above 90 square feet per acre. (These figures may be exceeded on very good sites or where short cutting cycles are possible or where significant numbers of conifers or small-crowned hardwoods such as basswood are present.)

Cut in all merchantable size classes in regulated stands. Cut trees first that may not survive the cutting cycle, followed by defective trees (table 2, Appendix), then trees whose economic potential has been realized. In all removals consider the effects on the remaining trees. In deficient size classes of unregulated stands, remove only those trees that have no potential for further economic growth or are interfering with the growth of a better tree (p. 24, Appendix). Cutting in the sapling class is not necessary; cutting in the pole class should be for improvement or occasionally thinning where large groups of overstory trees were removed.

Hemlock-hardwood.—In stands overstocked with saw logs first cut back to 100 to 150 square feet of basal area per acre. A salvage should be planned within 5 years after the first cut in overmature stands. Subsequent cutting of these stands should reduce the stand to 80 square feet of residual basal area per acre in trees 10 inches and larger. The cutting cycle should average about 10 years.

Pole Stands: Less Than 50 Square Feet Basal Area Per Acre; Trees 4.6 to 9.5 Inches d.b.h.

The cut should normally be concentrated in the pole class. Only the poorest saw logs should be cut. Stands should be entered when a sufficient number of trees have acceptable merchantable lengths. The amount of cutting in the pole size class is keyed to the amount of merchantable saw log overstory. This is necessary to obtain the largest amount of board-foot growth in the shortest time and to quickly develop size-class distributions capable of sustained yields of high-value saw log products.

Use the guidelines in the tabulation below to maximize board-foot production as the stand develops. Reducing pole components of stands to the smaller of the basal areas will increase individual tree growth rates; choosing the higher figure will aid tree quality but reduce individual tree growth rates.

If saw log (10 inches d.b.h.) basal area is:	*Leave indicated basal area in poles 5 to 9 inches d.b.h.*
(Square feet per acre)	
0	60 to 85
20	40 to 65
40	30 to 50
50	20 to 40

It should be emphasized that as much of the merchantable saw log overstory should be kept as possible.

Initially remove saw log-sized trees only because of risk or cull. Board-foot growth increases as the saw log basal area increases; board-foot growth increases sharply when the pole class is thinned if merchantable saw logs are not removed. For example, a stand containing 20 square feet of saw logs and 70 square feet of poles may grow as much as 200 board feet per acre, and in 10 years the saw log component will increase to about 40 square feet. If the original 20 square feet of saw logs are removed, the growth will be less than 100 board feet per acre. After the saw log component reaches 60 square feet or over, then saw log growth can be harvested without reducing future yields in many cases.

Aspen or Paper birch-Northern hardwoods.—Paper birch or aspen on northern hardwood sites may be converted to northern hardwoods by partial cutting. The partial cutting should follow northern hardwood guides for total stocking, i.e., leave 70 to 85 square feet per acre in trees 4.6 inches d.b.h. and larger, discriminating against white birch or aspen.

EVEN-AGE SILVICULTURE

Even-age silviculture can be used for both shade tolerant and those tree species less tolerant of shade; reproduction methods include shelterwood and clearcutting. The former method can be used with site preparation to improve the proportion of moderately tolerant species and to improve harvesting efficiency; the latter method for the reproduction of intolerant species.

Because less is known about even-age procedures, recommendations are more tentative than for all-age procedures. Optimum stocking, rotation, and thinning schedules have not been studied for all species. Rotation may be as short as 50 years for fiber products or as long as 200 years for eastern hemlock when esthetics is an important management goal. Rotation lengths of red and sugar maple and yellow birch can vary from 90 to 120 years depending on site and the intensity of management.

Tending Even-Age Stands

Seedling-Sapling Stands

The objective is to maintain composition and remove overstory competition.

First, remove or kill scattered overtopping trees, both cull and sound. Yellow birch saplings should be crown-released between 10 and 20 years of age. Cut trees whose crowns are within 5 feet but not more than 10 feet of the crown of the birch. Trees to be released should be at least codominant and unforked.

Sapling-size basswood and red maple sprout clumps should be thinned to two or three of the straightest, least-defective stems. Release of saplings of other hardwood species ordinarily will not be practical.

Pole Stands

Markers have several silvicultural objectives to keep in mind. Remove trees with little growth and grade potential to upgrade the stand and reduce mortality, and release trees with good potential to increase growth without substantial quality loss. Keep stocking that will maintain productivity.

Begin releasing pole stands when clear lengths are adequate for management purposes (normally 1-1/2 logs in height). First release trees that are well formed and have no forks or strong forks. Trees whose crowns are small (usually weak codominants or intermediates) must receive only light crown release (remove adjacent trees whose crowns are within 5 feet) or selection thinning (remove 1 or 2 of the most competitive trees). Codominant or dominant trees of good form and foliage density may receive a heavier release. For the first thinning, release only crop trees — those whose potential for growth and quality is high.

In northern hardwoods, do not reduce the basal area of trees 4.6 inches d.b.h. and over to less than 60 square feet, or leave more than 85 square feet in trees 4.6 inches d.b.h. and over unless basswood or hemlock are present (figs. 6, 7, 8, Appendix). White birch on good sites should be thinned from below primarily, and crown cover of the main stand should be as continuous as possible. White birch probably will not respond to thinning past age 60. Hemlock or basswood pole stands should be thinned from below following even-age stocking levels (figs. 7, 8, Appendix). Unless planned for wildlife purposes, avoid large openings which may result in excessive branching on border trees.

Natural pruning is usually efficient enough to remove nearly all the limbs from the butt log in stands with 60 square feet or more; most live limbs in pole-sized (5 to 9 inches d.b.h.) trees are in the second log.

Do not prune until 3 years after release to reduce epicormic sprouting. Unreleased trees should not be pruned. Trees to be pruned should be in the dominant and codominant crown classes and should be potential crop trees. Discoloration and decay resulting from artificial pruning of northern hardwoods are not important and may even be less than that occurring after natural pruning.

Wound healing time is shortened by pruning limbs close to the bole. (Wound healing is delayed 1 to 3 years for each 1/4 inch of branch stub left.) Wounds heal fastest on rapidly growing trees with good crown development. As a rule of thumb, a radial growth equal to the width of the wound is required to completely heal the wound. White ash and American elm heal the fastest, followed by sugar maple and yellow birch. Basswood is variable. Under current economic conditions, trees under 6 or 7 inches d.b.h. should usually not be pruned since compound interest costs can equal or overtake the returns from pruning trees smaller than this before harvest. It is economically questionable to prune branches in the second log with the equipment currently available since costs are high and pruning is difficult to perform correctly at this height.

Saw Log Stands

First remove culls, trees with weak forks, partially windthrown or leaning trees, those with badly cankered areas, trees with dieback or black bark stemming from sapsucker attack, and trees with other characteristics indicating serious loss of merchantability (table 2, Appendix) or mortality before the next cutting cycle. Remove mature and financially mature trees (generally those with no possibility of attaining veneer or saw log grades 1 or 2) and those not needed for silvicultural purposes. Next remove trees interfering with the growth of those with higher grade potential. Avoid large openings which may reduce quality of border trees.

In northern hardwood stands with less than 20 percent conifers or basswood, the stocking level of the main stand should not be reduced below 80 square feet per acre and should not exceed 120 square feet per acre.

Stands containing appreciable numbers of basswood, or hemlock, or other conifers can be thinned to about 70 percent crown cover or to basal area levels suggested in figures 7 and 8 in the Appendix.

Regenerating Even-Age Stands

Two-Cut Shelterwood For Tolerant Species

1. Select stands that are moderately well stocked with advanced regeneration of desirable species. Stands should average *at least* 8 inches d.b.h. If the stocking of advanced reproduction is sparse, consider the three-cut shelterwood outlined below.

2. Marking *must* be from below. Leave 60 percent crown cover at regular spacing. *All* trees left must be considered part of the residual crown cover.

3. Initial logging should be done only when the ground is snow-covered to minimize seedling loss.

4. Remove the overstory after the reproduction attains a height of 3 to 4 feet. A minimum of 5,000 well-spaced seedlings per acre or 1,000 well-spaced saplings per acre (2- to 4-inch d.b.h. class) are present. Log when the ground is snow-covered, removing all stems. Lopping of slash should be minimized and restricted to recreational or access areas.

5. Space "leave" trees as uniformly as possible. Crown areas and spacing per acre may be calculated by using the crown area per tree (table 3, Appendix).

Modifications to favor yellow birch. (1) Choose cool, moist (hemlock-hardwood) sites for regenerating yellow birch (fig. 3). (2) Discriminate against mature sugar maple in the residual overstory during marking. Leave no more than 70 percent, nor less than 30 percent, crown cover of the most vigorous trees. The lower of the residual crown covers can be used where scarification is done on well-drained soils. Higher basal areas should be used when fire is prescribed or on wetter sites that are not scarified. (3) Scarify 50 percent or more of the surface area after leaf fall but prior to logging. (Scarification in saw log stands often is most easily done before logging debris litters the ground.) Do not scarify soils classed as "sands". Scarification should aim at mixing the humus and mineral soil and destroying advance regeneration. Kill advanced regeneration prior to cutting on sites too difficult to scarify. (4) Make the first cutting during a moderate or better seed year, or direct seed before midwinter at a rate of at least 1/4 pound per acre on the scarified area.

Modifications for converting Aspen-Northern hardwoods to Northern hardwoods.—Follow the shelterwood recommendations for tolerant hardwoods. Allow at least 5 years between the final removal and the first shelterwood cut. The purpose of the overstory is to aid in the establishment of the northern hardwood understory and to suppress aspen sprouts resulting from the first cut.

Figure 3.—*Yellow birch reproduction under a shelterwood overstory.*

Three-Cut Shelterwood

Three-cut shelterwoods may be used where esthetics are a management objective, where advance regeneration is sparse, or where serious grass-brush invasion is probable. Bring the residual stand to 50 percent crown cover in two cuts as follows:

In mature saw log stands of most hardwoods, the first cut from below should leave 90 to 100 square feet of residual basal area in trees over 9.6 inches d.b.h. or about 80 percent crown cover. When the regeneration is about 4 feet in height (5 to 10 years) a second cut to about 50 percent crown cover will partially release the regeneration.

The final removal should be made before regeneration reaches 15 feet in height.

Clearcutting

Clearcutting to provide new even-age stands of most northern hardwood species from seed is generally the least desirable of the regeneration methods in the Upper Great Lakes area. However, clearcutting has application in some situations. Where the, major high-value tolerant species are inherently poorly formed, for example, and the only desirable species are intolerant, clearcutting or clearcutting and planting may be the only feasible alternatives.

Clearcutting by itself is not sufficient to convert stands to more desirable species; other measures must be used in addition to remove maple reproduction. If fire is chosen, burn in the spring during leafout and before cutting. Or, scarify by whatever means available; or use a registered herbicide. (see Pesticide Precautionary Statement, p. 28).

Converting to conifers. If conifers are planted, the size of the clearcut has no stringent silvicultural limitations except that areas which may be reseeded by sugar maple, or where hardwood sprouting occurs, should be weeded during the first 5 years.

Maintaining or converting to white birch.—Clearcutting to regenerate white birch may need to be supplemented by treatment of advance regeneration, depending on the site. First determine the site index of stands to be converted to white birch by using site index curves for old stands (fig. 9, Appendix), soil measurements for young stands, or both. Because sites vary considerably in short distances, manageable units should be outlined, and the most common site index within the unit should be considered to be the site index for the whole unit.

Sites with a site index below 50 generally have poor surface drainage or are on steep slopes, and have silt plus clay percentages less than 10.5. Clearcut paper birch for pulpwood-size products before stands are 60 years old. Regeneration may be primarily by sprouts. Stands older than 60 years will sprout poorly.

Stands with site index 50 to 59 should be managed the same as those below site index 50. Total value yield can be increased by making a light thinning from below when the stand is about 50 years old. If the stand is thinned, the rotation age can be increased to about 70 years. If it is not thinned, treat the same as stands below site index 50.

Stands with a site index of 60 and better have silt plus clay percents greater than 10.5 in the top 6 inches of mineral soil; surface drainage is usually medium to good. Mottling in the upper 4 feet of soil also indicates a good site. Manage stands on these sites for saw logs and veneer. Pure stands can be thinned for pulpwood at age 40 to 50 years. Thinning should primarily be from below. Avoid creating large openings in the crown canopy. Clearcut when the stand is about 80 to 90 years old. Strips should be clearcut about a chain in width or not over tree height at the maximum. Progressive strips are best. Regenerate by scarification. Openings should be less than 300 feet in diameter if regeneration is by natural seeding. If larger clearcuts are necessary, leave seed trees or use supplemental seeding.

Wildlife and Water

Northern hardwood types harbor numerous kinds of birds and animals, both game and nongame. In northern hardwoods as in other forest types, diversity of species and size class leads to a wide representation of animals and birds. Normal forest management can produce sufficient diversity to suit many wildlife species. In some cases, however, a single tree species must be favored because of its special benefit to wildlife.

In areas of deep snow and intense cold, coniferous species provide essential cover for white-tailed deer. In some portions of the Lake States, for example, eastern hemlock provides a significant amount of cover and browse so that the regeneration and maintenance of this species is an important part of management. Hemlock is a long-lived, very tolerant species that requires mineral soil seedbeds for regeneration. The same general procedures used for regeneration of yellow birch can be used for hemlock, except that hemlock should be seeded. It is necessary to seed this species in the fall or stratify seed artificially for 90 days before spring seeding. Because of the long life of hemlock, long rotations and small annual cutting areas are possible.

Where tolerant northern hardwoods border conifer swamp deer yarding areas, the amount of browse can be increased by increasing the frequency of cut and reducing residual stocking levels. Where even-age management is used, a three-cut shelterwood can be employed to increase the length of time that browse is available.

Some rules of thumb for management of browse for wildlife are: selection cutting produces small amounts of browse per acre (fig. 4) and few plant species; clearcutting produces a large amount of browse per acre over a short period of time and relatively many plant species, but the requirements for producing good timber are frequently not met; shelterwood produces as much browse as clearcutting and meets timber production requirements but encourages fewer plant species.

A forest manager need not always modify practices in northern hardwoods to increase wildlife browse or shelter if other forest types that border or are interspersed with the northern hardwoods can provide these wildlife requirements.

Extensive heavy cutting in the past has resulted in large, unbroken areas of pole-size northern hardwoods whose understories are barren and poor habitat for birds and animals. Although small openings usually revegetate quickly and lose value for wildlife, their life can be extended to 20 or 30 years by: (1) cutting them in stands 50 years old or less where there is little or no advanced reproduction; (2) cutting them on either excessively well drained or poorly drained soils, or on soils that are shallow or in frost pockets. Openings should be at least an acre in size, not more than 10, and irregularly shaped.

Northern hardwoods frequently border streams and lakes where they may influence water quality, water temperatures, and fish populations. Silvicultural practices to enhance or preserve these features probably do not vary from those used in other forest types.

Figure 4.—*Unmanaged old growth northern hardwood forest makes poor habitat for deer.*

Recreation and Esthetics

Big trees near campgrounds, roads, trails, and other areas of greater than average visibility, are often esthetically pleasing to recreationists. To manage for them, the normal selection techniques in tolerant hardwoods may be modified by increasing maximum tree size and reducing the q factor (see p. 19, Appendix). The same objective may be obtained by increasing the residual stocking to 90 square feet of basal area per acre and reducing the q factor to 1.1. The first case (increasing tree size) may require frequent removal of cull trees and timber loss through rots, stains, and mortality. In the second case (increasing density) the trees would be relatively rot free and would provide a reasonable timber harvest. In both cases cutting cycles should be reduced to 5 to 8 years from the 10 to 15 years normally used. Both methods will produce large diameter timber stands relatively free of undergrowth.

Denser stands are generally more pleasing to the eye than open ones. For this reason, under even-age management, the rotation should be lengthened to increase tree size. Three or more cuts may be used to accomplish regeneration by shelterwood, instead of two.

The fall colors of northern hardwoods are desirable. The most colorful species is red maple. This species is most easily regenerated by coppicing. Younger trees are the most vigorous sprouters; very old trees are not likely to reproduce well. American beech has the least colorful foliage of the species and might be discriminated against if foliar color is the primary objective. On the other hand, the light grey trunks are pleasing to some people.

White birch is obviously a beautiful tree for many forest visitors. It can be most easily regenerated by coppicing before age 60.

Planting of northern species in campgrounds and other recreational areas should follow shade tree practice. Eastern hemlock seems to be the species most sensitive to compaction, fires, and wounding. Hardwoods are generally less sensitive to damage common to these areas.

DAMAGING AGENTS

Logging

Logging damage to the stems and roots of residual trees increases with the size of the skidding equipment and the length of the load. Rot following damage progresses fastest in yellow birch and slowest in sugar maple. In both species, rot from wounds less than 50 square inches and less than 10 years old will not cause serious loss. Experience shows that logging damage can be held to acceptable levels by good supervision and training of loggers.

Follow these guides to minimize loss from damage to roots and stems.

1. Apply log grading rules to the standing damaged trees and determine which trees will decrease in grade within 10 years. Harvest these trees.

2. In the first cut after wounding (usually about 10 years), harvest all trees with stem wounds larger than 50 square inches if possible.

3. Also in the first cut after wounding, harvest if possible all yellow birch (but not sugar maple) with root wounds that are larger than 50 square inches, within 4 feet of the stem, and in contact with the soil.

4. In subsequent cuts continue to remove the wounded trees still remaining, concentrating on those with the oldest and largest unhealed wounds.

5. When thinning cuts are made with large equipment (such as mechanical fellers) in young stands, clearcut access strips wide enough for equipment to maneuver without bumping trees. The width of strips should not exceed the average crown diameter of the main stand by more than 2 feet or so.

Markers and loggers should try to avoid damaging the crowns and stems of uncut poles and small saw logs. Damage to more than a quarter of the crown may reduce growth, stimulate epicormic branching, and promote both rot and stain.

Although damage to seedlings and saplings in all-age practice often seems extensive, it has no silvicultural significance. In even-age practice, make preparatory cuts in winter before final harvest. Damage to reproduction during winter logging is less than in summer when reproduction may be uprooted. Although slash lopping is often desirable to improve the appearance of a cut-over stand, it tends to inhibit development of regeneration.

Animals and Birds

Damage to reproduction by white-tailed deer and snowshoe hare is not usually significant in managed stands. The changes in form that do result from browsing are corrected in a short time in managed stands. Care should be taken to avoid browsing by farm animals, however. They can cause substantial damage.

Sapsucker feeding in yellow birch crowns reduces growth and may cause top breakage or mortality. Sapsucker feeding on sugar maple stems results in discoloration of the wood and causes a quality degrade if severe. To avoid having sapsuckers transfer feeding to another — perhaps more valuable — tree, leave poor quality trees that they have been feeding on. However, feeding trees that contain high quality logs should be removed promptly to prevent degrade. Sugar maple feeding trees can be distinguished at a distance by patches of black bark discolored by the dark fungi that develop on the sap from sapsucker wounds.

Weather

Wind and ice glaze sometimes permanently bend small trees in even-aged stands. Pole stands, especially ones that have been heavily released, are sometimes damaged when wind and glaze break forks from the trees (fig. 5). In marking to release, favor trees that have strong forks or no forks at all, especially in areas prone to high winds and frequent glaze storms.

Sunscald is sporadic and infrequent in northern hardwoods. Young yellow birch and sugar maple, especially in even-age stands, are most prone to damage. Frost cracking can be a serious cause of degrade and cull in sugar maple in areas such as northern Minnesota. Prolonged drought sometimes results in the death of eastern hemlock.

Figure 5.—*Heavily released forked poles are liable to break at the fork under heavy glaze loads or high winds.*

Insects and Diseases

Most important northern hardwood species are not significantly affected by insect attack. Occasionally an attack coupled with stress caused by unusual climatic conditions can cause serious losses in small areas.

The maple borer may cause degrade or indirectly cause breakage; trees with extensive borer galleries should be marked for cutting. Various bud miners cause forking of young sugar maple, but in dense stands the resulting forks will correct themselves.

The Dutch elm disease is a serious cause of mortality among elm species. Once established, the disease moves rapidly along drainage ways — more slowly in the uplands where elm occurs as scattered individuals. To avoid loss of volume and value, discriminate against elm; remove the higher valued stems first. In bottomlands and drainages where elm is a major species, it is not worthwhile to attempt holding a partial overstory to develop a stand of advance reproduction because the disease moves too rapidly.

A number of canker diseases affect northern hardwoods. Yellow birch stems that become infected by Nectria canker should be removed. Diaporthe canker is a fatal disease of slowly growing yellow birch seedlings. Eutypella cankers on sugar maple weaken the stem and reduce merchantability. Sugar maple stems with large cankers should be removed. Trees with small cankers will survive for many decades and put on much usable wood despite the canker.

Organisms that cause rot and stain, and sapstreak, a wilt disease of sugar maple, gain entry through damaged roots, stems, and branches. Reduce losses from these agents by removing high risk trees, keeping rotations less than 120 years, and avoiding logging damage.

Diebacks have not normally affected growth or merchantability of hardwoods. A large number of causal agents apparently can be involved. Climatic conditions, such as prolonged drought or severe growing season frosts, animals, such as porcupines or sapsuckers, and occasionally insects, may be locally important, however.

Fire

Serious wildfires are rare in the northern hardwood types. Spring ground fires can kill most reproduction-sized trees while reproduction damaged in fall ground fires resprouts the following spring. Repeated ground fires kill larger saplings and poles while hot slash fires kill saw log-sized trees.

APPENDIX

Table 1.—*Desirable stocking per acre for good continuous growth*

D.b.h.	Desirable stand after cutting: Trees	Desirable stand after cutting: Basal area
Inches	*Number*	*Square feet*
2	118	2.6
3	53	2.6
4	31	2.7
Subtotal	202	8
5	21	2.9
6	15	2.9
7	12	3.2
8	9	3.1
9	8	3.5
Subtotal	65	16
10	7	3.8
11	6	4.0
12	5	3.9
13	5	4.6
14	5	5.3
Subtotal	28	22
15	4	4.9
16	4	5.6
17	3	4.7
18	3	5.3
19	3	5.9
Subtotal	17	26
20	2	4.4
21	2	4.8
22	2	5.3
23	1	2.9
24	1	3.1
Subtotal	8	20
TOTAL	320	92

Sample Calculation of All-Age Size Class Distribution

The stand objective is 85 square feet of basal area in trees 5 inches d.b.h. and over; the maximum tree size is 24 inches d.b.h.; the data is needed in 2-inch size classes and the ratio between classes (q factor) is 1.3.

D.B.H.	*Ratio* q^n	×	*Tree Basal area*	=	*Coefficient (k)*	*Number of trees*
24	—		3.14		3.14	2.5
22	1.3		2.64		3.43	3.3
20	1.69		2.18		3.68	4.1
18	2.2		1.77		3.89	5.3
16	2.85		1.40		3.99	6.9
14	3.71		0.07		3.96	9.0
12	4.82		0.79		3.80	11.7
10	6.27		0.55		3.44	.15.2
8	8.15		0.35		2.85	19.8
6	10.6		0.20		2.12	25.7
			Σk	=	34.30	

34.3n = 85 square feet
n = 2.5 trees in the 24-inch class
(2.5) (1.3) = 3.29 trees in the 22-inch class
(3.29) (1.3) = 4.1 trees in the 20-inch class

For other classes, other ratios must be used, i.e., for 5-inch classes 1.9 is about equivalent to 1.3 for 2-inch classes. Coefficients (Σk) for different size class distribution and maximum tree size of 24 inches d.b.h. are: q = 1.1 is 18.5; q = 1.2 is 24.8; q = 1.3 is 34.3; q = 1.4 is 48.09; q = 1.5 is 68.2.

These coefficients divided into any basal area equal the number of trees in the 24-inch class.

Stocking Levels for Even-Age Practice

There have been few tests of the effect of growing stock levels on growth in even-age northern hardwoods in the Lake States. The levels illustrated (figs. 6, 7, 8) were primarily calculated from average growing space requirements. Consequently, the levels are reasonable for good growth and quality, but may not be optimal.

Northern Hardwood (fig. 6)

This curve was developed from sugar maple, white ash, and yellow birch data which seem to represent average conditions for hardwood species other than basswood. The average stocking shown may be conservative for the larger size classes and exceptionally even-sized stands. To preserve individual tree quality, reductions in residual stocking cannot fall below 80 percent of the average. For the same reason, stands containing conifers or small-crowned hardwoods such as basswood should have higher residual stocking.

Northern Hardwood-Basswood (fig. 7)

Basswood trees generally have narrow crowns in relation to stem diameter and stands containing appreciable amounts of this species can hold high basal area stocking compared to other hardwood species.

Stands with less than 20 percent basswood should be treated as other northern hardwood species. Stands with 20 to 49 percent basswood should have higher residual basal area levels — the effect of differing growing space requirements. Stands containing 50 percent or more of basswood can be stocked at higher levels, but residual stocking over 120 probably will not add to net growth very rapidly.

Hemlock-Hardwoods (fig. 8)

The growing space requirements of hemlock and other conifers found in northern hardwood stands are less than basswood, so that residual stocking can be high, although high levels will probably not permit optimum growth. In hemlock stands the economic value of knot-free lumber is somewhat less than in hardwood stands, so a greater range of stocking levels is possible. Residual stocking may be held high for short cutting cycles to prevent unwanted hardwood encroachment and to enhance esthetics, or stands may be cut more heavily to stimulate growth.

Stands of high value hardwoods containing substantial amounts of hemlock should be marked to reflect the effect the hemlock has on the higher value hardwoods, i.e., stands containing more than 20 percent hemlock or other conifers should be marked in proportion to the amount of hemlock to be left.

Because of the great variation in age, soils, cull, and composition of hemlock stands, foresters should make use of local observations, if possible, in prescribing treatments.

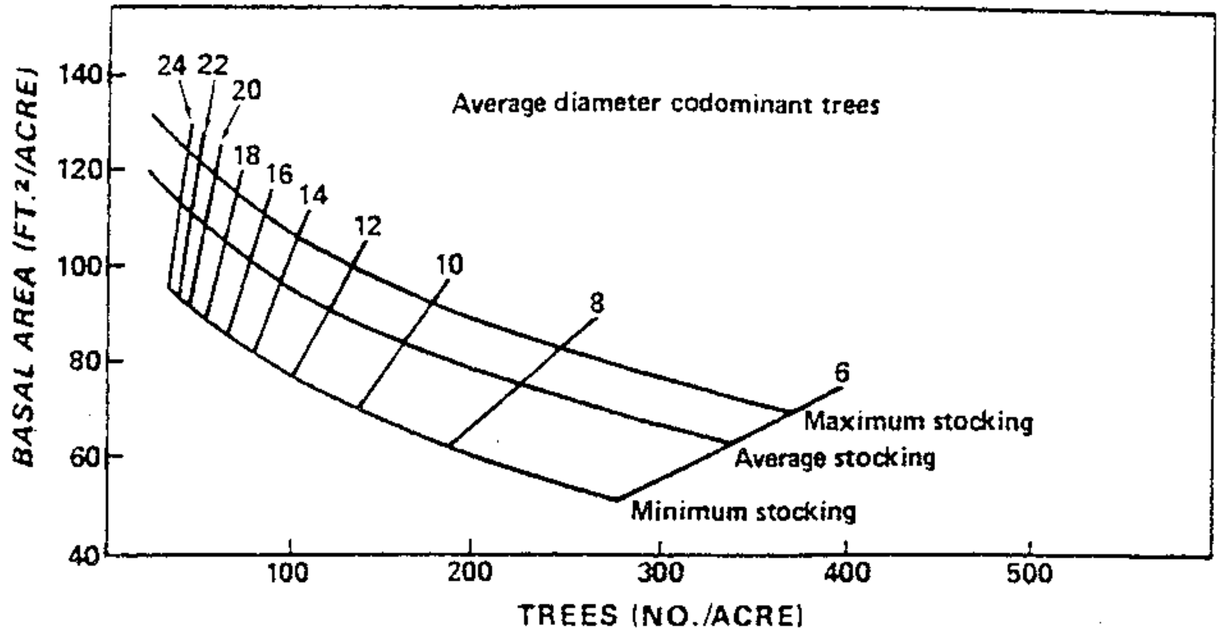

Figure 6.—*Stocking levels for northern hardwood stands containing less than 20 percent conifers or basswood by basal area, and number of trees per acre for specified diameter classes.*

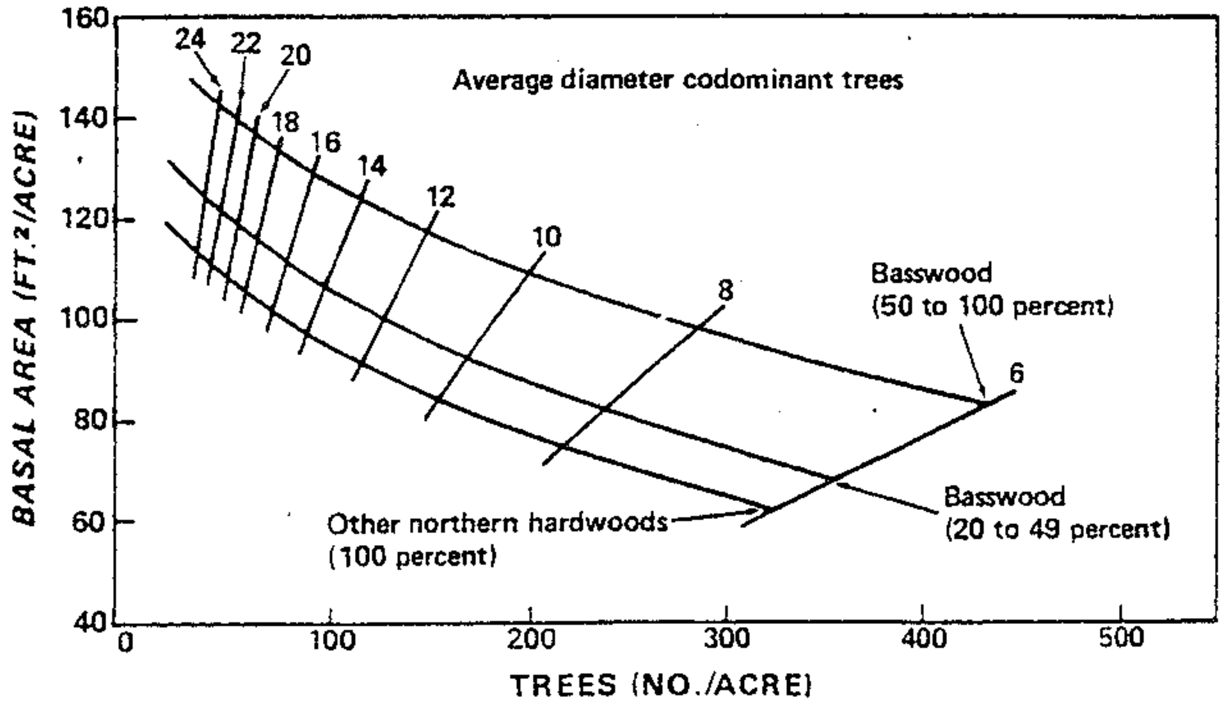

Figure 7.—*Stocking levels for even-age northern hardwood basswood stands in the Lake States by basal area and number of trees per acre for specified diameter classes and certain percentages of basswood and other northern hardwoods.*

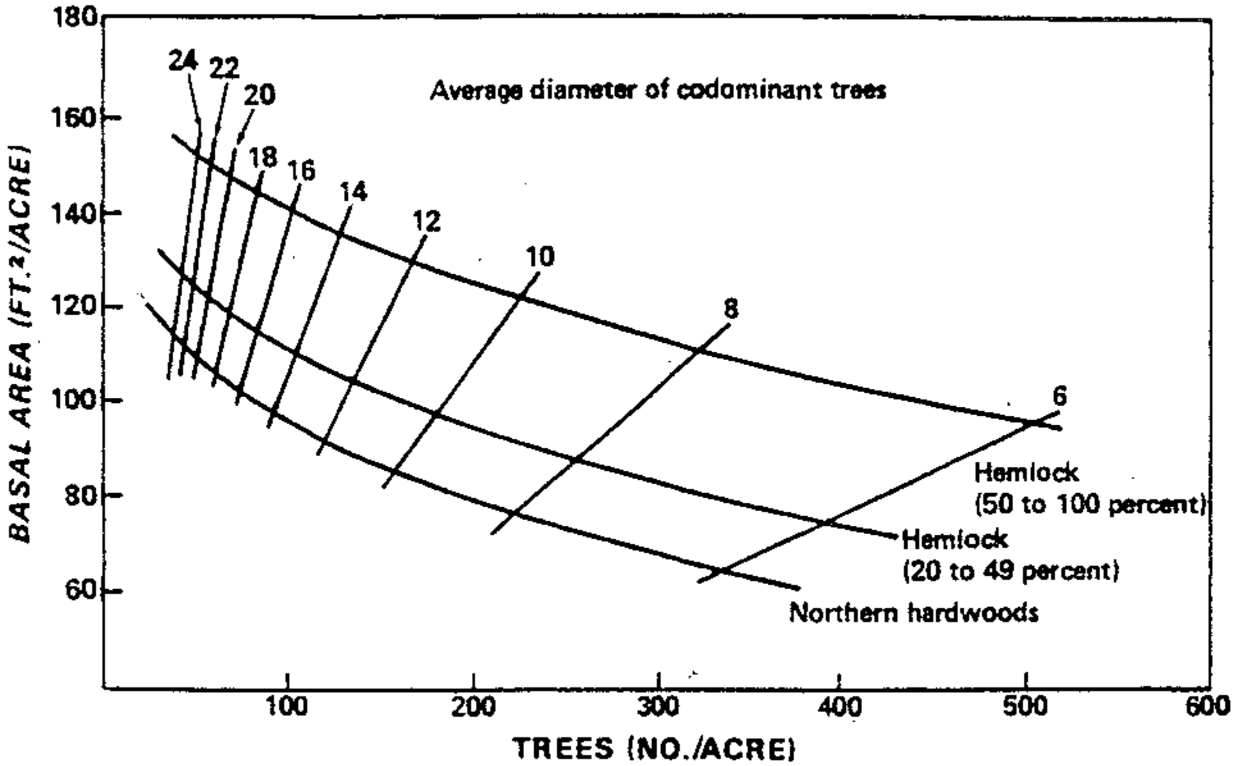

Figure 8.—*Stocking levels for even-age hemlock-hardwood stands in the Lake States by basal area and numbers of trees for specified diameter classes and certain percentages of hemlock and hardwoods.*

Table 2.—*Defects and cull percents caused by them*

Defect	Position within merchantable length of tree	Condition or degree	Class	Cull percent[1]				
				1-log tree	2-log tree	2½-log tree	3-log tree	4-log tree
Broken or dead limb								
(At least 6 inches in diameter)	Anywhere	Large	3	20	17	14	13	11
(Less than 6 inches in diameter)	Anywhere	Small	1	5	4	4	3	3
Broken or dead top (Broken or rotten close enough to top limit of merchantability to indicate loss in scale.)	—	—	3	20	17	14	13	11
Butt rot (At least 1/3 of log lost. If not visible, detectable by blow.)	First log	Advanced	5	39	35	28	25	22
Canker	First log	Advanced	6	56	50	41	36	32
	Above first log	Advanced	4	26	24	20	17	15
Hidden rot (Cannot be detected in standing tree.)	Anywhere	—	2	9	8	6	6	5
Conk	First log	Active	5	39	35	28	25	22
	Above first log	Active	4	26	24	20	17	15
	Anywhere	Sterile	1	5	4	4	3	3
Crack								
(Open. At least 1/3 of log lost.)	First log	Large	5	39	35	28	25	22
(Open. At least 1/3 of log lost.)	Above first log	Large	3	20	17	14	13	11
(Open. Less than 1/3 of log lost.)	Anywhere	Small	2	9	8	6	6	5
Crook or sweep								
(More than 2/3 volume lost.)	First log	Excessive	5	39	35	28	25	22
(1/3 to and including 2/3 volume lost.)	First log	Moderate	4	26	24	20	17	15
(Less than 1/3 volume lost.)	First log	Slight	2	9	8	6	6	5
(More than 2/3 volume lost.)	Intermediate log	Excessive	4	26	24	20	17	15
(To and including 2/3 volume lost.)	Intermediate log	Slight to moderate	2	9	8	6	6	5
(More than 2/3 volume lost.)	Top log	Excessive	3	20	17	14	13	11
(To and including 2/3 volume lost.)	Top log	Slight to moderate	2	9	8	6	6	5
Hole								
(Cavity. At least 1/3 of log lost.)	First log	Large	5	39	35	28	28	22
(Cavity. At least 1/3 of log lost.)	Above first log	Large	4	26	24	20	17	15
(Cavity. Less than 1/3 of log lost.)	Anywhere	Small	2	9	8	6	6	5
Ingrown bark								
(Bark folded into right cylinder.)	First log	—	1	5	4	4	3	3
Rotten burl								
(At least 1/4 of log affected.)	Anywhere	Large	4	26	24	20	17	15
(Less than 1/4 of log affected.)	Anywhere	Small	1	5	4	4	3	3
Scar								
(At least 1/4 of log affected.)	Anywhere	Large	4	26	24	20	17	15
(Less than 1/4 of log affected.)	Anywhere	Small	2	9	8	6	6	5
Seam (Open or tight.)	Anywhere	Spiral	6	56	50	41	36	32
(Tight. At least 6 feet long.)	Anywhere	Large, straight	3	20	17	14	13	11
(Tight. Less than 6 feet long.)	Anywhere	Small, straight	2	9	8	6	6	5

[1] Class averages.

How to Mark Individual Northern Hardwood Trees

After decisions are made concerning residual stocking and structure (table 1), the next step focuses attention on individual trees. Much of the decision to cut or leave is based on the potential of a tree to supply high quality saw logs or veneer. Part depends on the rate at which the tree grows and part depends on its influence on surrounding trees.

The following factors should be weighed in deciding which trees to cut or leave. To upgrade stand quality, minimize loss from cull and mortality, and enhance the potential for the future production, consider these items in the order given:

1. Risk: remove any tree that, in your judgment, will not live and grow until the next cut.

2. Cull: remove cull and highly defective trees that will not increase in value during the cutting cycle. (See Appendix, table 2, for a detailed summary.)

3. Form, crown, and branching habits: remove crooked or leaning trees, those with an acute angle between limbs and bole, and those with short clear length or large limb diameter.

4. Species: low-quality timber has about the same value regardless of species, and high-quality logs of any of the major species are usually salable. Nevertheless, determine local preferences for species.

5. Crown position: in addition to the above items consider the position of a tree in relation to the other trees to be left in a stand. Mark for removal trees that are interfering with the full development of other trees of higher potential quality, thus providing the better trees freedom for crown development in all directions.

6. Size: finally, consider tree diameter. Generally, most tree species within the northern hardwood type become economically mature when they reach 20 to 24 inches d.b.h. Trees that have reached, or grown beyond, economic maturity do not pay their way in comparison to smaller trees.

   More detailed information is provided in the following sections to aid in the decision of what constitutes serious cull, trees of good quality potential, and how to judge the importance of crown position.

This information is based both on formal study and long-term observation and should be used as a flexible guide to be modified according to local conditions.

How to Decide What Trees to Leave

Especially in all-age forestry, trees are of mixed sizes and of varying degrees of importance to the surrounding stand. Decisions regarding the trees to leave should be guided by the following tree classification and modified by the crown classification after that.

Tree Categories

Tree class 1: good growing stock.—The tree must be straight, dominant or codominant, free from crook or lean, and with less than 10 percent cull (class 1 or better). An average of at least 50 percent of the total height of the tree must be clear length. (Consider each tree to have four faces on its main stem. Each face will include one-quarter of the circumference of the tree. The average of the clear length on these four faces will be the average clear length of the tree.) In trees 9 inches or less in diameter at breast height, limbs and knots under 1 inch in diameter may be permitted in clear length. The crown should be full and the vigor good.

Tree class 2: satisfactory growing stock.—Trees of intermediate crown class or better are permitted in this class. The trees may have no defect or crook or internal decay involving over 20 percent cull (class 2). Trees must not have acute forks or multiple crowns; however, U-shaped forks are permitted above 35 feet. An average of at least one-third of the total height must be in clear length. In trees 9 inches or less in diameter at breast height, limbs and knots under 1 inch diameter are permitted in clear length.

Tree class 3: poor growing stock.—Trees that otherwise meet the specifications for tree class 2 but are competing with class 1 trees for growing space and trees merchantable for saw logs or potentially merchantable that do not meet the specifications for the first two classes are included in this class.

Tree class 4: nongrowing stock.—Cull trees and trees with no potential merchantability other than for chemical wood or pulpwood are included in this class.

Crown Categories

Dominant crown class.—These trees are the largest; their crowns and merchantable height are set and cultural practices no longer will have a measurable effect on tree characteristics. The major value of these trees is their approach to final yield and influence on the surrounding stand. Silviculturally, these trees are mature and should be removed when they no longer have a beneficial effect on the surrounding trees, i.e., when their influence on clear length of neighboring trees is minimal or when they are noticeably suppressing understory and neighboring codominants. Trees in the dominant size class, even though they may rate as cull class 2 or worse, may be left if they have a beneficial effect on either regeneration or neighboring trees.

Codominant.—In saw log stands these will often be small saw logs (14 to 19 inches d.b.h.). Select trees to leave on the basis of: (1) potential for increasing grade and merchantable height; (2) least cull (cull class 2 or better); and (3) beneficial influence on the intermediates and other codominants. These trees should provide side shade for well formed intermediate.

Weak codominants.—In saw log stands the weak codominants are the 10- to 14-inch class. These crown classes continue to have an important effect on lesser classes but the most important job is to select those which will make the most rapid increase in value. The least desirable trees in this class have permanent merchantable height stoppers such as low forks with large diameter fork members, other serious cull and low grade improvement potential. Correctable forks have a partly or wholly suppressed fork member less than one-third of the tree diameter at the point of the fork. The best trees should be potential grade 2 or better, have crowns of at least medium density and crown widths average for the d.b.h. class.

In the pole class (5 to 9 inches), a combination of side shade and within-crown competition, controls lower branch mortality and subsequent merchantable length. Trees left in this class should have good form, be free of serious defect and have a good crown of average width and medium or better density. Too heavy a release of trees in this class with crowns of less than average width and density will result in losses of merchantability and quality. Especially in previously unmanaged stands, many poles will have good stem form and clean boles coupled with small crowns. The object of release should be to develop denser crowns without reducing clear length.

Table 3.—*Crown area by diameter classes and theoretical stocking for shelterwood cover (Godman and Tubbs 1973)*

D.b.h.	60 Percent crown cover											
	Northern hardwoods				Basswood				Hemlock-conifers			
	Trees	Basal area	Spacing	Crown area per tree	Trees	Basal area	Spacing	Crown area per tree	Trees	Basal area	Spacing	Crown area per tree
Inches	*Numbers*	*Square feet*	*Feet*	*Square feet*	*Numbers*	*Square feet*	*Feet*	*Square feet*	*Numbers*	*Square feet*	*Feet*	*Square feet*
10	94	51	22	279	171	93	16	153	224	133	13	107
11	80	53	23	325	144	95	17	181	203	133	15	129
12	70	55	25	373	126	99	19	207	170	133	16	154
13	62	57	26	422	108	100	20	241	144	133	17	181
14	54	58	28	480	95	102	21	274	125	133	19	209
15	49	60	30	536	84	103	23	312	108	133	20	241
16	44	61	32	598	75	105	24	349	95	133	21	274
17	40	62	33	662	67	106	25	388	85	133	23	309
18	36	63	35	728	61	108	27	427	76	133	24	346
19	32	64	37	803	56	110	28	470	68	133	25	386
20	20	65	38	881	50	110	29	518	61	133	27	427
21	27	66	40	952	46	111	31	567	56	133	28	471
22	25	67	42	1,035	43	112	32	614	50	133	29	518
23	23	67	43	1,120	39	113	33	665	46	133	31	563
24	22	68	45	1,207	37	115	35	712	43	133	32	612

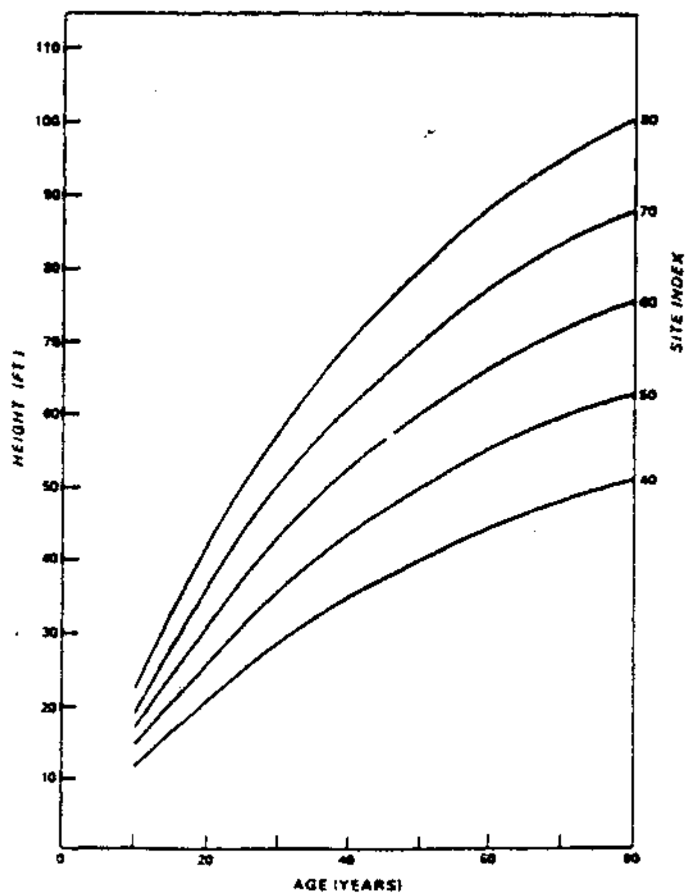

Figure 9.—*Site index graph for paper birch in northern Wisconsin.*

Metric Conversion Factors

To convert	*to*	*Multiply by*
Acres	Hectares	0.405
Board feet[1]	Cubic meters	0.005
Board feet/acre[1]	Cubic meters/hectare	0.012
Chains	Meters	20.117
Cords[1]	Cubic meters	2.605
Cords/acre[1]	Cubic meters/hectare	6.437
Cubic feet	Cubic meters	0.028
Cubic feet/acre	Cubic meters/hectare	0.070
Degrees Fahrenheit	Degrees Celsius	[2]
Feet	Meters	0.305
Gallons	Liters	3.785
Gallons/acre	Liters/hectare	9.353
Inches	Centimeters	2.540
Miles	Kilometers	1.609
Miles/hour	Meters/second	0.447
Number/acre	Number/hectare	2.471
Ounces	Grams	28.350
Ounces/acre	Grams/hectare	70.053
Pounds	Kilograms	0.454
Pounds/acre	Kilograms/hectare	1.121
Pounds/gallon	Kilograms/liter	0.120
Square feet	Square meters	0.093
Square feet/acre	Square meters/hectare	0.230
Tons	Metric tons	0.907
Tons/acre	Metric tons/hectare	2.262

[1]The conversion of board feet and cords to cubic meters can only be approximate; the factors are based on an assumed 5.663 board feet (log scale) per cubic foot and a cord with 92 cubic feet of solid material.

[2]To convert °F to °C, use the formula 5/9 (°F−32) or $\frac{°F-32}{1.8}$.

Common and Scientific Names of Plants and Animals

Plants

Ash, black.	*Fraxinus nigra*
Aspen	*Populus* spp.
Balsam.	*Abies* spp.
Basswood.	*Tilia* spp.
Beech	*Fagus* spp.
Birch, paper.	*Betula papyrifera*
yellow	*Betula alleghaniensis*
Elm	*Ulmus* spp.
Hemlock	*Tsuga* spp.
Maple, red.	*Acer rubrum*
sugar.	*Acer saccharum*
Oak, northern red	*Quercus rubra*
Spruce.	*Picea* spp.
White-cedar, northern . . .	*Thuja occidentalis*

Animals

Deer, white-tailed.	*Dama virginiana*
Hare, snowshoe.	*Lepus americanus*

PESTICIDE PRECAUTIONARY STATEMENT

Pesticides used improperly can be injurious to man, animals, and plants. Follow the directions and heed all precautions on the labels.

Store pesticides in original containers under lock and key — out of the reach of children and animals — and away from food and feed.

Apply pesticides so that they do not endanger humans, livestock, crops, beneficial insects, fish, and wildlife. Do not apply pesticides when there is danger of drift, when honey bees or other pollinating insects are visiting plants, or in ways that may contaminate water or leave illegal residues.

Avoid prolonged inhalation of pesticide sprays or dusts; wear protective clothing and equipment if specified on the container.

If your hands become contaminated with a pesticide, do not eat or drink until you have washed. In case a pesticide is swallowed or gets in the eyes, follow the first-aid treatment given on the label, and get prompt medical attention. If a pesticide is spilled on your skin or clothing, remove clothing immediately and wash skin thoroughly.

Do not clean spray equipment or dump excess spray material near ponds, streams, or wells. Because it is difficult to remove all traces of herbicides from equipment, do not use the same equipment for insecticides or fungicides that you use for herbicides.

Dispose of empty pesticide containers promptly. Have them buried at a sanitary land-fill dump, or crush and bury them in a level, isolated place.

Note: Some States have restrictions on the use of certain pesticides. Check your State and local regulations. Also, because registrations of pesticides are under constant review by the Federal Environmental Protection Agency, consult your county agricultural agent or State extension specialist to be sure the intended use is still registered.

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