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North Central Forest Experiment Station

Northern Hardwood Notes

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NORTHERN HARDWOOD NOTES

Jay G. Hutchinson
Editor

(Cover photo courtesy of Mary Ellen Turchan)

FOREWORD

Northern hardwoods are the main "crop" on 10 million acres of forest land in the Lake States. Most of today's northern hardwoods are "second growth" stands that grew up after the clearcutting and high-grading that took place between 1900 and 1930. These stands are typically even-aged, usually composed of poles 5- to 9-inches in diameter, often poor in quality, and slow growing. Sugar maple is the dominant species; but many other tree species are common—yellow birch, red maple, northern red oak, basswood, black cherry, American elm, white ash, aspen, paper birch, and even conifers such as eastern hemlock and balsam fir. The variety of species, forest types, and site conditions complicates the scientific management of the northern hardwoods.

Still, progress is being made. Forest scientists have been steadily at work learning the complexities of northern hardwood management. At the Argonne and Upper Peninsula Experimental Forests near Rhinelander, Wisconsin, and Marquette, Michigan, as well as other locations in the Lake States, research has been going on for up to 50 years. Much has already been published, and formal documentation of results continues. Equally important, these forests serve as outdoor demonstration areas where visiting foresters can actually see northern hardwood management in action.

For years visiting foresters at the Experimental Forest workshops and field tours have taken home printed handouts aimed at helping them apply the techniques they see demonstrated in the woods. Realizing the practical value of these handouts, we have collected and updated them, filled in gaps, and present them here as a manager's guide. The Notes are written in a concise, straight-forward style, that makes the information easy to understand and easy to apply in the field. They answer such commonly asked questions as: Does the clearcutting silvicultural system work in northern hardwoods? Are there any persistent insect and disease problems? Should we mark all even-aged stands to the same residual basal area? Are the Northeast hardwood guides applicable to the Lake States? What is gained by doing site preparation for regeneration?

The answers to these and other questions represent important concepts that have evolved from northern hardwood research at the North Central Forest Experiment Station. Remember that the Notes abstract the most critical concepts as they apply to the bulk of northern hardwoods in the North Central region. When you apply this general information you should always temper it according to local conditions, practical knowledge, and your specific needs and objectives.

Vague and imprecise terminology has always plagued silviculture. In our Notes, two *methods of management*, even-age (comparable to growing even-sized trees) and uneven-age or all-age (comparable to growing all-sized trees), are recognized. We consider a silviculture system to be a *method of regeneration* used to develop a stand suitable for a given method of management and generally for a given species. The shelterwood system, for example, is a silvicultural system used to achieve immediate regeneration. It is *not* an intermediate cut where regeneration needs are to be met many years later.

These loose-leaf Notes will allow us to make revisions and add new information for you as the technology of northern hardwood management continues to develop. If you would like to receive these additions and revisions in the future, simply complete and send the postcards on the last page of the Notes. We are also interested in your reactions to these Notes. If you find them useful, have ideas about improving existing ones, or have suggestions for additional Notes, please let us know on the postcards.

CONTRIBUTORS

Richard M. Godman, Research Forester (retired), provided the basic information for more than two-thirds of these Notes, much of which first appeared in handouts for the numerous show-me trips on northern hardwood management that he has conducted at the Argonne Experimental Forest over the years.

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Still others contributed to individual notes in the series: Frederick T. Metzger, Silviculturist; H. Michael Rauscher and Carl H. Tubbs, Research Foresters; John E. Phelps, Forest Products Technologist; Forest Stearns, Professor of Botany; and Louis J. Verme, Wildlife Biologist.

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NORTHERN HARDWOOD NOTES

What Are Northern Hardwoods?

The term "northern hardwoods" was used in the early 1900's to separate the hardwoods of the northern region from those growing in the South. With continued usage in the North the term now represents all dense hardwood species both in the Lake States and Northeast. Unfortunately, this has complicated describing and applying silvicultural practices for good northern hardwood management.

Northern hardwoods are very diverse in species composition and stand characteristics. The single characteristic common to all upland "northern hardwood" types is the successional trend toward and predominance of sugar maple.

In the Lake States the SAF recognizes seven (formerly five) major forest cover types as part of the northern hardwood group:

- SAF Type 25-Sugar Maple-Beech-Yellow Birch
- SAF Type 26-Sugar Maple-Basswood
- SAF Type 27-Sugar Maple
- SAF Type 60-Beech-Sugar Maple
- SAF Type 24-Hemlock-Yellow Birch
- SAF Type 23-Hemlock
- SAF Type 108-Red Maple

Types 23 and 24 are usually included because sugar maple is often an important component and/or they occur in association with other predominantly sugar maple types. Type 108 is newly recognized and always intermingles with sugar maple throughout the region. Numerous sub-associations, such as white ash-basswood and sugar maple-basswood-white ash, do occur but are considered variants or transitional types. Type 60 rarely occurs in the Lake States.

A hemlock-yellow birch stand, SAF Type 24.

A mature sugar maple stand. SAF Type 27.

Another hardwood type, SAF 39-Black ash-American elm-red maple, should also be mentioned. Dutch elm disease (see Note 7.03) has reduced the elms in many stands of this lowland hardwood type, resulting in a stand composed mostly of black ash and red maple.

A lowland hardwood forest dominated by black ash, SAF Type 39.

Although many species may occur in northern hardwoods, the principal species nearly always include sugar maple, white ash, yellow birch, basswood, red maple, American elm, beech, and eastern hemlock. Occasionally aspen, paper birch, northern red oak, rock elm, ironwood, black cherry, and balsam fir are important. The northern hardwoods are thus a complex association of cover types and cannot be managed as a single entity like other recognized types.

There are also regional differences in the northern hardwoods relating to species composition, climate, and soil. To best understand and manage the Lake States "northern hardwoods" we should avoid using this all-inclusive term and recognize instead the particular forest cover type on the area in question. How we manage depends greatly on which of the cover types we have. They determine such things as:

1. Whether to use even-age or all-age practices.
2. The optimum residual stocking to work toward.
3. Whether site preparation will be needed to establish some species.
4. What site index to consider (it can vary 5 to 15 feet among species on the same soil).
5. What type of cutting to use to improve bole quality and increase the rate of growth.

These questions will be addressed in the notes to follow.

Reference

Eyre, F. H. (editor). Forest cover types of the United States and Canada. Society of American Foresters; 1980. 148 p.

Richard M. Godman

North Central Forest Experiment Station 1.02

NORTHERN HARDWOOD NOTES

Lake States Management Differs From Northeast

There are "northern hardwoods" in the Lake States and "northern hardwoods" in the Northeast. The term is the same but the forest cover types, stand, and site conditions can be very different. The silvicultural treatments that work in the Northeast may not work at all in the Lake States. And what works in the Lake States will work-but not the best-in the Northeast.

The biggest differences are in regeneration cuttings. Clearcutting works extremely well in the Northeast, but in the Lake States 30 years after clearcutting pioneer tree species or even grass and dense herbaceous cover may still prevail. Strip and small patch cuttings succeed in the Northeast but seldom in the Lake States. Low stocking levels in partial cuttings can be used in the Northeast without losing bole quality; not so in the Lake States.

Climate has the most to do with these regional differences, especially the amount and distribution of precipitation. The Lake States borders on the prairie zone and gets 28-34 inches annually compared with more than 45 inches in the Northeast and more than 60 inches in the Appalachians. Dry periods are more common during the Lake States growing season. Also, most of the northern hardwood area in the Northeast lies at lower latitudes than in the Lake States area so temperatures tend to be higher. The greater warmth and moisture favor more rapid decomposition of litter and better seedbeds so that some tree species can regenerate before competing herbs.

Partly because of climate-the soil depth, drainage, and exposure are more favorable to certain species in the Northeast. Paper birch is of better quality there and thus is a preferred species. Management encourages its production.

The complex of maple-beech-birch species is so varied that it would be better to describe forest cover types according to the SAF standards than use the catch-all phrase "northern hardwoods." This would help in matching cover types to the best silvicultural practices.

Reference

Smith, David M. What's different about northeastern silviculture? In: Future of forest industry in New England and Eastern Canada: papers presented at the 42d Yale Industrial Forestry Seminar; 1976 January 21-22; Amherst, MA; University of Massachusetts; 1976: 79-84.

Richard M. Godman

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Even-age Versus All-age Management

You've got a northern hardwood forest to manage. Which way should you go-the even-age or the all-age method?

From the timber standpoint, the choice should be based mainly on the species you want and the product needed in the future. (If you're considering wildlife habitat needs, esthetics, or soil and water protection, the basis for choosing may be different.) You can change management methods any time. You'll merely prolong the time required to get the right stand structure and species composition.

Different species mixtures have different silvicultural requirements, so identifying each type in a stand is the first step in choosing a management method. Only heavy-seeded species (such as sugar maple and white ash) can be perpetuated by either management method. The light- or small-seeded species can only be regenerated and developed by using the even-age method.

The following tabulation gives some selected differences between even- and all-age management. The characteristics for the all-age method assume a regulated stand.

Even-age Method	All-age Method (regulated stand)
1. Requires a different basal area stocking for every thinning depending on average tree diameter and species composition.	Basal area stocking remains constant for every thinning.
2. Removes many small trees in each thinning.	Removes fewer trees and larger trees at each thinning.
3. Early thinnings are all pulpwood and economically marginal.	Thinnings are mainly saw logs with a small amount of pulpwood.
4. A half to two-thirds of periodic growth can be sold while stocking is building up.	Nearly all the volume growth at each thinning can be sold once the stand is regulated.
5. Merchantable height will usually be less than two 16-foot logs in sugar maple.	Merchantable height can be three 16-foot logs or more due to forking correction.

Even-age Method	All-age Method (regulated stand)
6. Butt rot, resulting from winter sunscald of 1- to 3-inch diameter saplings on exposed sites, can reduce volume and grade in sugar maple and other species.	Sunscald rarely occurs.
7. Provides opportunity for light-or small-seeded hardwood species when combined with seedbed preparation.	Favors shade-tolerant species-especially sugar maple.
8. Provides excellent habitat for wildlife during the first 10 to 15 years of stand development.	Low browse production (See Note 8.02)
9. Ideal for production of fiber.	Produces high-quality logs.

Don't forget to consider other differences between the methods-differences that you are already aware of in road construction and maintenance costs, type of property taxation, persistence of wildlife habitats, esthetic values, the best logging equipment to use, and incidence and control of insects and diseases. Some of these will influence your choice but it will mainly be based on the species you have and the products you want.

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NORTHERN HARDWOOD NOTES

Selecting A Silvicultural System

Sometimes a name creates a problem. The name of a silvicultural system usually refers to the way a stand is cut to get regeneration-"single tree selection"-for example. Trouble is, the name suggests that the regeneration cut will be the *first* treatment applied to the stand. Not so. We are now mostly making "intermediate" cuts in our Lake States stands and bringing them to maturity; then we can make the "regeneration" (or "harvest") cuts to reproduce them.

The regeneration period (i.e., applying a silviculture system) usually lasts less than a tenth of the whole rotation. In the Lake States the regeneration must be established before the overstory can be totally removed for all of the hardwood types. How do we select the right silvicultural system? In general, the kind and size of the present regeneration plus the conditions required to regenerate the desired species determine the silvicultural system. Use the chart on the back page to help in that choice.

Selecting the right silvicultural system to regenerate a species is only part of the battle. The regeneration must be established *before* the overstory can be completely removed. By "established" we mean that the seedlings should be 2 to 4 feet (belt) high. This usually occurs within 3 to 8 years after the initial cut. The root systems of seedlings this high have penetrated mineral soil. The seedlings cannot easily be pulled out and they can withstand an open environment. Regeneration like this was established under large trees in the early 1900's when loggers did the cutting that resulted in today's second-growth stands.

A stand under all-age management using the single tree selection silvicultural system.

Thirty years of research shows that if the overstory is removed in today's second-growth stands *before* regeneration is established, the desired stand *nearly always* fails. Many forms of "one-shot" silvicuitural clearcuts-seed tree, patch, block, group selection, and strip cutting- done in stands without established regeneration, fail consistently. Besides, they entail too much record-keeping for extensive management.

To Regenerate, Select Goal and Use Suggested Silviculture System

FOR:
SAF Type 25-Sugar Maple-Beech-Yellow Birch
SAF Type 26-Sugar Maple-Basswood
SAF Type 27-Sugar Maple
SAF Type 60-Beech-Sugar Maple
SAF Type 108-Red Maple

- Goal: High quality trees, predominantly sugar maple.
  Use: Single tree selection.
  Required: Apply recommended stocking and structure guides but recognize the pole and 3 sawtimber classes.

- Goal: Predominantly sugar maple.
  Use: Two-cut shelterwood.
  Required: Leave 60 percent crown cover (not basal area). Regeneration (any size) of acceptable species must be present. Winter logging in initial cut.

  Or:

  Use: Clearcutting.
  Required: Must have 2 to 3 thinnings before harvest cut to promote advanced regeneration.

- Goal: Mixed species; yellow birch.
  Use: Two-cut shelterwood.
  Required: Site preparation. More than 70 percent crown cover. Eliminate all reproduction present before cutting.

FOR:
SAF Type 23-Hemlock
SAF Type 24-Hemlock-Yellow birch

- Goal: Regenerate yellow birch, hemlock, or other light-seeded species.
  Use: Two-cut shelterwood.
  Required: Site preparation. More than 70 percent crown cover.

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Applying The Shelterwood System

The 2-cut shelterwood silvicultural system is the most reliable method we have for regenerating even-aged hardwoods. Unlike other systems it can be used for all hardwood species, both small- and large-seeded, but will probably be used most often for the small-seeded ones such as yellow birch, paper birch, and hemlock.

In the Lake States the basic requirement for getting reproduction with any even-age method, including shelterwood, is that hardwood regeneration MUST be established BEFORE the overstory is removed. When we cut second growth stands and end up with raspberries, poor stocking, or both, it is usually because this requirement was not met. For hardwood regeneration to be established, seedlings should be 2 to 4 feet high; by then their root systems have penetrated mineral soil.

The kind of shelterwood cut to use in the Lake States depends on the species. Light-seeded ones usually require scarification or fire.

A shelterwood cutting of a sugar maple stand on the Argonne Experimental Forest. This picture was taken three growing seasons after the initial cut. Note the abundance of reproduction in the understory.

How to Select a Shelterwood Type

Use Type 1 shelterwood if: Seedlings, usually sugar maple and where ash, are already present but not established.

Use Type 2 shelterwood if: You want to regenerate a mix of small- or light-seeded species along with maple and ash.

Type 1 shelterwood	Type 2 sheltetwood
1. Cut *from* below to 60 percent *crown cover.*	1. Cut from below to 70 or 80 percent *crown cover;* discriminate against undesirable species.
2. Log in winter.	2. Log in any season, except summer (to avoid sapstreak).
3. Do not scarify site (regeneration will be present).	3. Scarify or burn to remove existing vegetation and prepare a seedbed.
4. Remove overstory completely after regeneration is 2 to 4 feet high, usually within 3 to 8 years. Log in deep snow and/or use forwarder without ground skidding.	*4.* Same as Type 1.

Both types of shelterwoods meet the three requirements for establishing even-aged regeneration in the Lake States by providing:

1. A proper overstory to hold down herbaceous and shrub competition and prevent surface soil drying. (The cover should be uniform even if it means leaving less desirable species or smaller trees.)
2. A proper seedbed of humus and mineral soil shallowly mixed, or 60 percent of the area scarified, or litter removed by fire. (Such seedbeds retain moisture and increase surface soil temperatures for germination of light-seeded species.)
3. A seed source of at least four trees of a preferred species well distributed in each acre, or supplemental seeding. (Shelterwood cuts are ideal for planting.)

Note that marking for both types of shelterwoods should be based on percent *crown cover,* NOT basal area, because basal area is not a good indicator of crown cover from species-to-species or in stands with various diameters. Crown area tables can be used or the percent can be estimated with a little experience.

Summer logging should be avoided because of the possible risk of sapstreak disease resulting from root injury. Certain stem diseases, e.g., Nectria and Eutypella cankers, may be increased by shelterwood cutting if cankered trees have been left in the shelterwood overstory. Be sure to cut cankered trees before or during the first shelterwood cut to remove sources of infection.

Other alternatives are to use the Type 2 method to obtain a diversity of species or limit the Type 1 method to meandering strips not more than 1 chain wide rather than cutting in blocks.

Reference

Godman, R. M.; Tubbs, C. H. Establishing even-age northern hardwood regeneration by the shelterwood method-a preliminary guide. Res. Pap. NC-99. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1973. 9 p.

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A Worksheet For Shelterwood Marking

1. Lay out a 1 /1Oth-acre circular plot (radius of 37.24 feet) in the stand you are marking.
2. Choose the appropriate shelterwood type: type 1 -sugar maple, 60 percent residual crown cover (you'll need to leave 2,600 square feet of residual crown area in co-dominant or better trees); or type 2-light-seeded species, 70 to 80 percent residual crown cover (you'll need to leave up to 3,500 square feet in residual crown area).
3. Tally the diameter and species of residual trees, accumulating total crown areas as you proceed. Make sure that residual trees are well distributed over the plot. Stop marking when the calculated crown area is reached.
4. Use the 1/10th-acre plot you marked as a standard for marking the rest of the stand by eye. From time to time lay out a new l/lOth-acre plot in other parts of the stand to check yourself.

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WORKSHEET FOR SHELTERWOOD MARKING

Area of Plot -----Sq. Ft. Percent Crown Cover Desired ______. Residual Crown Cover Needed-.

DBH	Crown Area — Sq. Ft. N. Hdwds.	Bass-wood	Hemlock B. fir								
5	105	55	25								
6	130	70	40								
7	165	85	50								
8	200	105	70								
9	240	125	85								
10	280	155	105								
11	325	180	130								
12	375	205	155								
13	420	240	180								
14	480	275	210								
15	535	310	240								
16	600	350	275								
17	660	390	310								
18	730	425	345								
19	805	470	385								
20	880	520	425								
21	950	565	470								
22	1,035	615	520								
23	1,120	665	565								
24	1,205	710	610								
25											
26											

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Clearcutting As A Silvicultural System

Clearcutting can be one of the most effective hardwood management systems in the Lake States-if an essential criterion is adhered to. That criterion is: Regeneration must be established-that is, 2 to 4 feet high *before* you clearcut, *before* the overstory can be removed.

This means that the clearcutting silvicultural system is limited to types that are predominately sugar maple. Why? Because only sugar maple germinates at very low temperatures (usually before snow melt) and is shade tolerant enough to develop and become established in the dense shadow of a mature stand overhead. It doesn't become established, though, for many years, so clearcutting should not be done too early. If it is done too early (in a second-growth pole stand, for example), you usually get a heavy cover of herbs and very few sugar maple seedlings. The pioneer species that come in next can dominate for 30 years to come. Even more time may pass before a stand of desirable species develops under the pioneers-all because regeneration was not established *before* clearcutting.

Eventually, a stand becomes large enough (typically more than 10 inches in diameter) to let light filter through to the forest floor, and sugar maple regeneration gets a good start. When the original old-growth stands of the Lake States were cut in the early 1900's, the sugar maple regeneration that was established beneath them turned into the extensive second-growth stands of today.

Periodic thinnings-rather than clearcutting-are usually what's needed in sugar maple pole stands. Not only do they increase tree size more rapidly, they also speed up the development of regeneration on the stand floor. After two thinnings sugar maple regeneration is always established (although the main emphasis continues to be growing the overstory trees to maturity).

Clearcutting is not advisable for other northern hardwood types, particularly the light-seeded species such as eastern hemlock and yellow and paper birch. These species require both site preparation and the overstory conditions provided only by shelterwood cuttings.

Textbooks often leave the mistaken impression that you clearcut first, then worry about regeneration *later.* This works well in aspen stands (which are often used to illustrate the clearcutting silvicultural system) because aspen suckers easily form an extensive root system. But among northern hardwoods, only the sugar maple types can reproduce well under clearcutting, provided regeneration is already established.

Richard M. Godman

NORTHERN HARDWOOD NOTES

A Case History Of Ail-age Management

Single-tree selection “works” in sugar maple stands in the Lake States. This system of all-age management has been used for 31 years on the Argonne Experimental Forest. In 1953, researchers found that cutting according to basal area guides is both a convenient and effective way to regulate a stand. Later experience showed that achieving good stand structure could be speeded by using a separate basal area guide for each of three sawtimber size classes, instead of lumping them into one sawtimber class.

Regulating an even-aged stand consists of gradually reducing the basal area of the pole-and small saw log-size trees, while increasing the basal area of the medium and large saw log-size trees, until the desired balance is reached.

By cutting to specified basal areas every 10 years in the four diameter size-classes, managers can easily regulate second-growth sugar maple stands. The following table shows how regulation in the Argonne Forest stand progressed between 1947 and 1978 after 3 cuttings. Note the rapid change between 1973 and 1978. (Basis: seven 1/5-acre plots).

	Diameter classes (inches)				
	5-9	10-14	15-19	20-24	**Total**
	------ Sq ft ------				
1947 Initial stand	30	38	14	0	82
After 1st cut	27	33	13	0	73
1962-63 After 2nd cut	17	27	26	5	76
1973 After 3rd cut	15	26	31	9	82
1978 Stand	15	27	32	18	93
Basal area goal	16	22	26	20	84

By regulating a stand, managers assure that growth is well distributed. When the basal areas in the foregoing table are converted to volumes by local tables, you can see that the stand is developing favorably.

	Diameter class (inches)			
	10-14	**15-19**	20-24	**Total**
	------- Bd ft -----			
Board foot goal	1,709	3,314	3,150	8,173
1978 stand volume	2,210	4,075	2,785	9,070

The 1978 stand volume exceeds the goals in all but the large saw log category. By the fall of 1983, at the 4th cut, the stand was fully regulated for both board foot and basal area goals. Most of the area will have growth exceeding 350 board feet per acre per year.

Regulation will pay off in quality. Every bit of growth will be salable; in the last harvest only 77 percent was removed for sale because the 20-to 24-inch trees had not yet reached volume goal for their age class.

Quality is on the rise in other ways, too. Merchantable heights are increasing as developing trees overtop trees that“crowned out” earlier. Also, sugar maple is slowly making up more and more of the stand.

Could development have been more rapid? Yes, if present basal area guides had been applied in the first two cuts, which were heavier than currently recommended. Drought also reduced growth rates by nearly half from 1974 to 1977.

Richard M. Godman and *Gilbert A. Mattson*

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A Case History Of Even-age Management

Here is evidence from an actual hardwood stand on the Argonne Experimental Forest in northeastern Wisconsin that even-age management works.

Four intermediate cuttings (thinnings) over 26 years have changed the stand structure (number and size of trees) so that the final objective of quality saw logs is being met. The thinnings were made at about 7-year intervals beginning when the stand was 51 years old. Note how the proportion of basal area in sawtimber-sized trees has increased:

Thinning	Stand age	Date	Percent of basal area in sawtimber trees
	Years		
1 st	51	1956	31
2nd	59	1964	39
3rd	66	1971	49
4th	74	1979	74
Current stand	77	1982	81

How fast structure changes depends both on the method of thinning and how fast **a** species grows. The stand illustrated is predominantly sugar maple-a slower grower-so the stand would be expected to change more slowly than other species managed under the even-age method.

The changes above show that current management guides work, and work rapidly. For instance, the annual growth of saw logs increased from 205 board feet after the first thinning to 429 board feet per acre over the 3 years after the fourth thinning. (Extended drought from late 1974 into 1977, and mortality from Dutch elm disease, seriously reduced growth between the third and fourth thinnings). Current board foot volume is 6,305 (in trees 9.6 inches and up).

Look at how tree quality has improved over a recent lo-year period:

Year	Percent of saw log trees in tree grades		
	1	2	3
1971	5	18	77
1981	28	35	37

You can see that the periodic thinnings generally have removed the low-grade, and high-risk trees. Currently, most of the trees in grade 3 are there because of small diameter only.

At final harvest this stand will yield large volumes of high-grade products. Characteristically though, merchantable heights will mostly be less than two 16-foot logs compared with more than three logs in all-age management. We estimate that fewer than a tenth of the trees will reach two logs, although the butt log should be grade 2 or better.

When the stand reaches economic maturity, all trees will be removed to release the sugar maple regeneration below. Clearcutting can be used in this stand because regeneration became established after the second thinning and should persist until the stand matures. When the entire overstory is removed in a single cut (following periodic thinnings), the new stand will respond to increased light without danger of losing the site to herbs and brushy pioneer species, as would occur if no thinnings were made.

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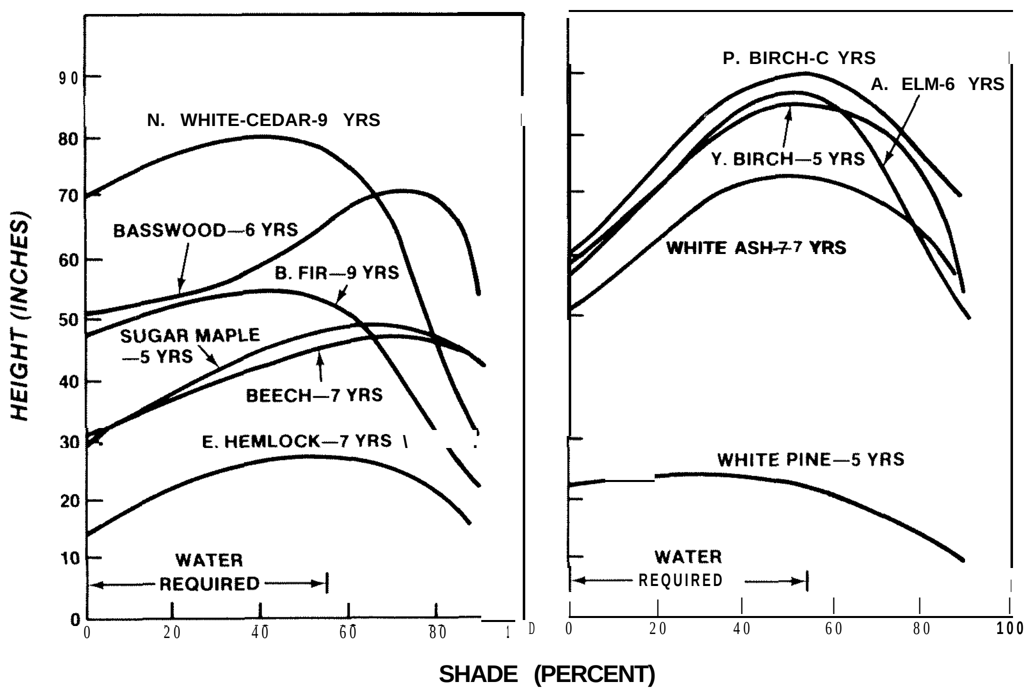
NORTHERN HARDWOOD NOTES

Relative Tolerance Of Hardwood And Associated Conifer Seedlings

"Tolerance" is an expression of the light requirements of a tree species.

The tolerance ratings most quoted today were compiled by F. S. Baker from a questionnaire sent to foresters in the mid-1940's. A weakness of these ratings is that they are a personal opinion based mostly on experience with large trees, and they lack a strong consensus. The most comprehensive study of light requirements of seedlings for the first few years after germination are those of K. T. Logan.[1] The graphs below (adapted from Logan), show what percent of lath shade different species grow tallest under, when grown from seed for several years. "Tolerant" species are on the left, "less tolerant" (Baker's groupings) on the right.



[1]At the Petawawa Forest Experiment Station in central Ontario.

Note that almost all species "tolerant" and "less tolerant" grew tallest in 40-80 percent shade. Even "tolerants" require some light for survival. The Lake States have frequent, hot, dry periods during which seedlings need some shade; supplemental watering was also essential for up to 55 percent shade in Logan's study. Sugar maple is always present-more because of its low germination temperature requirements (**34°** F) than because of its tolerance (see Optimum *Germination Temperatures for Northern Hardwoods* Note 3.03).

Richard M. Godman

NORTHERN HARDWOOD NOTES

Seed Crop Frequency In Northeastern Wisconsin

Knowing the frequency of good seed crops is important in regenerating northern hardwood species, particularly those that require site preparation and special cutting methods. It is also desirable to know the maximum time that might be expected between poor crops to help schedule silvicultural treatment or supplemental seeding. Based on up to 35 years of observation the following frequencies and maximum number of successive years of good and bad crops can be expected in northern Wisconsin:

	Number of years observed	Seed crop[1] frequency		Maximum number of successive years of	
		Good	Poor	Good crops	Poor crops
Spring-maturing species		*Percent of years*			
Quaking aspen	33	67	24	6	2
Bigtooth aspen	32	62	22	6	2
Red maple	30	60	23	8	5
American elm	29	41	41	3	5
Fall-maturing species					
Hardwoods					
Sugar maple	35	40	43	4	2
Yellow birch	35	40	34	4	3
Paper birch	33	27	39	2	5
Basswood	35	63	23	4	2
White ash	35	43	51	3	4
Black ash	34	32	62	2	7
Northern red oak	30	47	40	6	2
Conifers					
Eastern hemlock	34	59	23	5	2
Balsam fir	34	38	56	3	8
Northern white-cedar	34	73	15	15	2
Eastern white pine	35	40	43	2	3
Red pine	34	23	50	2	2
White spruce	34	38	35	3	3
Black spruce	34	44	29	6	4
Jack pine	35	57	17	16	2

[1]"Good" means 61 percent or more of full crop and "poor" means 35 percent or less of full crop.

Here's how this information might be used. Site preparation necessary to regenerate paper birch and possibly red maple normally remains effective for 3 years. This is less time than the succession of poor years shown in the above table; so the odds of a good seedfall while the site is still conducive to regeneration are poor for these two species.

To complicate things further, a good seed crop doesn't necessarily mean the seeds are viable. In white ash, for example, flowering and seed production were observed for 9 years. A "good" seed crop developed during 3 of these years, but seeds were viable during only 1 of these "good" years. (Frost and hard rain killed *all* male flowers during 2 of the 3 years, and most of them the third year, but pollination was still sufficient the third year to get viable seeds.) So, really viable seed crops in white ash, and probably other species, may occur at long intervals.

Richard M. Godman and *Gilbert A. Mattson*

NORTHERN HARDWOOD NOTES

Optimum Germination Temperatures

Why is sugar maple abundant under nearly all stand conditions, and why do hemlock and yellow birch, although differing in tolerance, occur together as a type? At least part of the answer may have to do with the optimum germinating temperatures for their seeds.

Sugar maple seeds get the jump on the other common northern hardwood species by germinating as soon as the snow melts, at 34° F. If a sudden warm spell shoots temperatures higher, few seeds will germinate. This happened in the spring of 1978 when the bumper seed crop failed to germinate except in snowbanks along roads.

Both hemlock and yellow birch germinate best from 59 to 61° F and so get started together.

Unfortunately, research on optimum temperatures for germination is spotty due to lack of seed and low viability (at least 40 percent germination is necessary for evaluating optimum temperatures if the percent of filled seed is not predetermined). The following tables sum up what is known. Table 1 includes some typical northern species, both hardwood and conifer; table 2 is for conifers common in the region.

Table 1. — *Percent germination at different temperatures over 30 days for typical northern hardwood species*

	Degrees fahrenheit						
Species	**34**	**44**	**54**	**64**	**74**	**84**	**94**
Sugar maple	87	*[1]	*	*	—[2]	—	—
Northern red oak	90	*	*	*	0	—	—
White ash	52	50	*	56	*	74	—
Balsam fir[3]	0	*	66	85	86	92	—
Eastern hemlock[4]	—	—	67	64	*	*	—
Yellow birch	0	0	*	62	70	60	—
Northern white-cedar	—	*	*	52	48	80[5]	—
ALL TEMPERATURES							
Quaking aspen[6]	92	93	94	94	92	90	75

[1]Less than 40 percent germinations.
[2] — Not tested.
[3]Fraser 1970.
[4]Olson, Sterns and Nienstaedt 1959.
[5]Other tests showed extremely high germination at 86° F.
[6]McDonough 1979.

Table 2. — *Percent germination at different temperatures for conifers common in northern hardwood reaion*

	Degrees fahrenheit						
Species	34	44	54	64	74	84	94
Black spruce[1]	0	24	72	81	78	71	35
White pine[2]	0	0	26	81	80	61	34
Jack pine[3]	0	0	61	80	83	81	78
Jack pine (Argonne Expt. Forest, WI)	0	*3	50	68	86	94	—[4]
Red pine[2]	0	0	49	95	95	96	92

[1] Fraser 1970c.
[2] Fraser 19706.
[3] *Less than 40 percent germinations.
[4] —Not tested.

We can make a few generalizations:

- The commonest hardwoods generally germinate at low temperatures (table 1);
- Conifers germinate best at high temperatures (table 2).
- Aspen, a pioneer species, seems to do well at all temperatures.
- White ash, like aspen, also does well over a wide range of temperatures. (It is usually the second most abundant species in northern hardwood stands.)

The fact that hemlock and yellow birch germinate best around 60 degrees might explain why seedlings are commonly found on old logs where temperatures are higher than on the forest floor. Somewhat surprising are the high temperature requirements for northern white-cedar, a northern bog species (table 1). Some of the pines germinate at higher temperatures than cedar (table 2).

Achieving the temperatures necessary for germination is crucial for successful regeneration. By knowing these temperatures you can devise the best cutting practices to favor regeneration of one species over another.

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Richard M. Godman and *Gilbert A. Mattson*

NORTHERN HARDWOOD NOTES

Regenerating Yellow Birch In The Lake States

The future of the yellow birch supply in the Lake States is uncertain. Growing-stock volume has declined more than one third since 1963, prompting the search for better ways to handle the difficult job of regenerating the species.

Through research and experience, we have developed enough information about the tree's special needs to make the following recommendations. Yellow birch regenerates best under a shelterwood system and needs:

- a suitable seedbed
- a uniformly spaced overstory
- an adequate seed supply.

To Prepare a Suitable Seedbed

The seedbed should provide a warm, moist site for germination and growth. The optimum germination temperature is about 60° F. Suitable seedbeds can be prepared by scarifying or burning after leaf fall and before cutting to expose 50-75 percent of the area. Scarification should be shallow with good mixing of humus and "A" layer of mineral soil. Areas under dense stands of hemlock require slightly deeper scarification and greater surface mixing. Exposure of the "B" layer, however, should be avoided.

Burning works best immediately after understory leafout and before cutting in the spring. If conifer tops are not a major part of the slash or are removed from the trunk areas, you may burn after cutting, preferably in the spring. Burn in the fall if regeneration of other species is sparse or absent. Burning or scarification increases soil surface temperature to near optimum for germination early in the season when moisture conditions are most favorable.

Scarifying or burning will normally eliminate seedlings already present. But if the regeneration is already 2 to 4 feet high, this understory should be killed with chemicals before scarifying or burning.

To Provide a Uniformly Spaced Overstory

A partial overstory is necessary to prevent surface soil drying and seedling exposure, hold down herbaceous competition, and permit higher soil temperatures.

Cut from below to leave 70-80 percent of the crown cover (NOT basal area) in a high, uniformly distributed canopy. Discriminate against sugar maple but don't create large openings in the canopy even if it means leaving maple or undesirable trees. This overstory shade helps seedlings to survive and to grow more rapidly during the establishment period.

To Obtain an Adequate Seed Supply

Retain at least four well-distributed seed trees per acre. Expect a good or better seed crop about 1 year in 3. A suitable seedbed, ample seed supply, and an adequate overstory enable the regeneration to become established 3-8 years after the initial cut. When the seedlings are about belt high, remove the rest of the overstory.

Do this only during periods of deep snow to minimize ground skidding and protect the seedlings' root systems.

Yellow birch seedlings.

Modification for Direct Seeding

You can direct seed yellow birch to introduce it into a stand or to enhance a poor seed crop.

Modify previous instructions by reversing the first two steps. Don't scarify or burn until after understory leafout in the spring.

Apply ½ pound of stratified yellow birch seed per acre about a week after site preparation. After regeneration is established (2-4 feet tall), remove the overstory.

Success of other methods of regenerating yellow birch in the Lake States has been uncertain. Clear-cutting, strip-cutting, and group selection, for example, have been tried with mixed results. Successful regeneration by these methods requires a combination of favorable weather, soil and site conditions, and past management-conditions that seldom exist in this region. Only the shelterwood system, as described, assures consistent, predictable results.

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NORTHERN HARDWOOD NOTES

Regenerating Eastern Hemlock In The Lake States

The eastern hemlock type is declining in area faster than any other. Growing-stock volume, for example, declined 71 percent in only 20 years in Michigan, and has declined similarly in Wisconsin. Many land management agencies have stopped cutting hemlock until satisfactory regeneration can be assured.

Why Hemlock is Hard to Regenerate

1. The thick mat of mor humus that builds up under long-lived species prevents hemlock (and even germinating sugar maple seedlings) from penetrating to mineral soil.
2. Even though hemlock produces cones 3 years out of 5, only about 2 seeds out of a possible 12 are potentially viable.
3. Hemlock seeds take twice as long to germinate as associated species and need higher temperatures (optimum is 59° F) than earlier findings indicated.
4. Hemlock seeds must land on seedbeds that are free of herbs and composed of shallowly mixed humus and mineral soil that retain moisture a long time. This is necessary because of hemlock's low growth vigor and shallow rooting habit.
5. Hemlock seedbeds need shade (70 to 80 percent crown cover) to inhibit competition from herbaceous growth and other tree species, and to prevent seedling dessication.
6. Damping off kills many hemlock seedlings. No natural control measures are known.
7. Hemlock seedlings grow more slowly than associated species, even under optimum conditions, so it takes a long time for hemlock regeneration to dominate the new stand.
8. Seed insects damage 2 to 42 percent of the seeds. Rodents and smothering by litter also take a toll.

Four Treatments to Obtain Hemlock

Despite these problems the following treatments have been successful:

1. Lightly scarify to mix the humus and upper mineral soil on at least 60 percent of the area. This seedbed holds surface soil moisture, raises and extends the temperature required for germination, and provides a good medium for rooting.
2. Cut from below all low-level trees leaving 70 to 80 percent of the canopy.
3. If natural seeding is inadequate, supplement with artificial seeding at the rate of one-third to two-thirds pound per acre.
4. When hemlock regeneration is 2 to 4 feet high, remove the residual overstory during winter.

You should start regeneration cuttings before 10 percent of the hemlock trees have begun to die, otherwise they will likely be replaced by less desirable hardwoods. By extending site preparation beyond the hemlock type boundaries into neighboring hardwood types, you can sometimes enlarge the area of hemlock. At the least you will be reducing the competition of hardwoods on the boundaries.

Prescribed burning is a good substitute for scarification. It is cheaper, may help control seed and cone insects, and increases nutrient levels.

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North Central Forest Experiment Station 3.06

NORTHERN HARDWOOD NOTES

Prescribed Burning For The Birches And Hemlock

To regenerate light-seeded species such as yellow and paper birch and hemlock, you need three essentials-the right amount of overstory, an adequate seed supply, and a proper seedbed.

A proper seedbed consists of a mixture of humus and mineral soil that: (1) can hold moisture for a long period; (2) warms on the surface early in the spring; (3) is free of litter that keeps weak fibrous roots from penetrating; and (4) is free of competition from ashes, maples, woody shrubs and herbs.

You can get a good seedbed by either scarifying or burning. Historically, fire has been given major credit for our existing stands of birch and hemlock, although some have resulted from other catastrophies Without fire, sugar maple and white ash, with their low germination temperatures and taproots, regenerate at the expense of the birches and hemlock. The result is that yellow birch growing stock has declined a third in only 10 years and hemlock growing stock has declined more than two-thirds in 20 years.

A prescribed burn at the Argonne Experimental Forest showed that fire can indeed create a highly favorable seedbed for birch and hemlock. A stand of small sawtimber with a moderate stocking of yellow birch was given a shelterwood cut in the fall. The stand was burned the next May 31 under the following conditions: buildup index of 48, fire spread index of 25, fine fuels index of 32, adjusted fuel moisture of 12 percent, humidity of 24 percent, and 10 days since the last rain.

The burn resulted in an ideal seedbed on 80 percent of the area. It eliminated all existing regeneration and removed the moderate amount of litter. A bumper crop of yellow birch seed came along the next fall. The result 1 year after the burn was 1,800,000 germinants per acre on the severely burned areas and 972,000 per acre on the lightly burned areas. This was 30 times greater than the germinants of sugar maple that comprised a high percentage of the overstory trees.

Richard M. Godman

NORTHERN HARDWOOD NOTES

Hardwood Planting

Hardwood planting used to be most common on private land. Now more and more hardwoods are being planted on public land. Not much hardwood planting research is going on but recent summaries of earlier trials allow us to give you the following guidelines.

Open Field Planting (the most difficult)

1. Match species to the site. Hardwoods require fertile, well-drained soils without a heavy clay layer or bedrock within 2 feet of the surface.
2. Prepare the site thoroughly (usually by disking and follow up by herbiciding for weed control) until the plantation trees average at least 1 foot taller than the most vigorously competing species. Good site preparation tends to reduce frost heaving.
3. Plant tap-rooted species, such as white ash, northern red oak, black cherry, basswood, and butternut, for best results in open fields. If sugar maple is used, plant it as early as soil conditions permit.
4. Don't plant after below-normal rainfall years and after winters with below-normal snowfall. Groundwater recharge will be low. If precipitation was adequate for planting, survival probably will range from 75 to 85 percent.
5. Control weeds to avoid severe rodent damage and mortality. Don't interplant hardwoods among conifers without control. The habitat is favorable for rodents.

Interplanting Poorly Stocked Stands and Under Shelterwoods

1. Plant stock in the most open areas. In a shelterwood where the overstory has been treated to increase light, plant immediately after treatment to get the jump on competing herbaceous vegetation.
2. Make sure that the soil is suitable for hardwoods.
3. Fibrous-rooted species (yellow birch, hemlock, paper birch, and sugar maple) can be interplanted provided that competitors (primarily sugar maple seedlings already on the site) are not taller than the planting stock.

All Planting

1. Plant hardwoods earlier than conifers. Root hairs need time to regenerate and they do this best before bud break.
2. Top pruning (by cutting below the lowest live limb) seems to be highly desirable for yellow birch and northern red oak, especially in dry years and under open stand conditions.
3. Avoid severe root pruning, i.e., to lengths less than 6 to 8 inches, particularly with northern red oak.
4. On prepared sites, try to mix organic with mineral soil before you plant. If you interplant, either disk or make shallow furrows so a mixture of litter and A horizon covers the roots. Never plant in low spots that collect water, or deep in the B horizon.
5. Plant single species rather than mixtures. This avoids difference in growth rate, dominance, quality, and difference in tolerance to type of herbicide (if required) and rate of application.

Don't plant until stock has a minimum root collar diameter of a quarter inch and a top at least 12 inches long.

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NORTHERN HARDWOOD NOTES

Direct Seeding

At present, direct seeding of hardwoods in the Lake States is more of a supplemental than a *primary* means of artificial regeneration. Direct seeding may be used to augment a poor seed crop or increase the proportion of a preferred species. In the future, it will no doubt play a bigger role-in anticipation of this we need to collect and store the amounts of seed needed. With direct seeding, stand treatments would not have to be scheduled around good seed crops, species composition could be carefully controlled, and genetically superior seed could be sown. "Immediate" regeneration would be possible.

To direct-seed successfully, favorable germination temperatures must be achieved and maintained early in the season when moisture conditions are best. Predation by rodents must be reduced too. The following steps will encourage success:

1. Prepare the site by shallowly mixing organic and mineral soil; this also eliminates any existing regeneration.
2. Leave an overstory of 70 to 80 percent crown cover until the regeneration is 2 to 4 feet high. This reduces competition from herbs and prevents the surface soil and seedlings from drying out. Seeding open fields or clearcut areas will not work.
3. Make sure you use enough seed.

Special Requirements

Sugar Maple-No site preparation is required. Sugar maple germinates at temperatures just above freezing in greater numbers than desired. To reduce its numbers, prepare sites in late spring after soil temperature rises. Most other hardwoods will outgrow maple if they are regenerated before or at the same time maple germinates. Sow 3 to 9 pounds per acre.

White Ash-This species does not require scarification and it germinates at both low and high temperatures. Probably only 1 in 3 of the fall seed "crops" contain viable seed because of male flower abortion. Rodents do not seem to eat ash seed. Sow 2 to 7 pounds per acre.

Yellow and Paper Birch-The birches are very demanding as to seedbed, surface moisture, and amount of competition, but they are easy to regenerate if requirements are met. Sow 1/8 to 1/3 pound per acre.

Hemlock-Hemlock is similar to yellow birch in needs but requires much supplemental seeding because the relatively few cones generally contain only about two viable seeds each. The seedlings are highly susceptible to damping off. Sow 1/3 to 2/3 pound per acre.

Basswood-Most basswood seeds are eaten by rodents; probably less than 2 percent escape destruction. Scarify or burn in early fall to avoid seed predation; or sow stratified seed late in the spring. The few years that new seedlings appear seem to coincide with low rodent populations. Sow 4 to 10 pounds per acre.

Northern Red Oak-Combine scarification or burning with early spring sowing of pregerminated acorns. Scarification minimizes seed predation and extends the period of low temperature favorable for germination. Sow 500 to 1,500 acorns per acre.

See also: Crop Frequency, Optimum Germination Temperature, Yellow Birch-Special Problems, Hemlock-Special Problems, and Prescribed Burning for Site Preparation.

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NORTHERN HARDWOOD NOTES

Sowing Pregerminated Northern Red Oak Acorns

Northern red oak is extremely difficult to regenerate, although it has produced good acorn crops nearly half of the last 32 years in northern Wisconsin. Field trials have shown that for successful seeding, you must protect acorns from predation by wildlife and sow them when temperatures are most favorable for germination.

How do you achieve these conditions? By scarifying the sowing site, and sowing in early spring. Scarification destroys the habitat and cover favorable to acorn-consuming wildlife. And on a scarified surface the temperature stays near 34” F (the optimum germination temperature) longer than it does on litter. Germination drops sharply as temperature climbs beyond 50° F.

To Get The Best Germination

1. Collect acorns either before they fall, or pick them up right after fall.
2. Stratify over winter according to accepted practices.
3. Pregerminate acorns by raising the temperature slightly to 34° F for 12 to 14 days.
4. Sow on scarified, litter-and vegetation-free sites in early spring before the soil surface warms appreciably.

Six weeks after field trails, all acorns sowed this way had germinated and were growing without losses. In contrast, acorns sowed on undisturbed litter (both on the surface and buried) were all eaten by predators. Sowing after temperature is too high also results in failure-even if acorns are protected from wildlife.

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NORTHERN HARDWOOD NOTES

Rodent Influence On Regeneration

Rodents play a large but often ignored role in northern hardwood regeneration. They exert a major influence on seed supply and seedling survival.

Rodents love basswood seeds. Although basswood is the most consistent and heaviest seed producer among the hardwoods, rodents ate more than 98 percent of the basswood seeds lying on the litter in a Wisconsin study. Many of those not eaten had worm holes; seeds under the litter were generally rotten.

Rodents are partial to acorns too, but will not risk exposure to predators to collect them. Pregerminated acorns on a small scarified area in Wisconsin were not touched by rodents, while all acorns were destroyed on adjacent undisturbed litter. Both areas were under a shelterwood overstory.

White ash seed is apparently not on the list of rodent favorites. Rodents consumed all treated sugar maple and basswood seed in a direct seeding study, but left white ash seed on the same area. Earlier studies bore out this preference.

Rodents eat the seeds of most conifers in northern hardwood stands. Feeding studies showed heavy consumption of white pine, red pine, white spruce, and hemlock seeds. It is rare to see any red pine seeds on the litter surface except in cone caches and among destroyed cones under red pine stands. Balsam fir, on the other hand. showed few losses to rodents.

Rodent populations are generally more than ample to destroy most tree seeds. In British Columbia only five mice per hectare consumed 85 percent of the Douglas-fir seed within 15 days; in another study 95 percent was lost to mice in 3 days. Poison-baiting studies and observations from pothole blasting show how high rodent populations are. A Missouri study found that a single pair of white-footed mice could have 900 offspring in one year. In view of these hordes of seed eaters, what can the forest manager do to ensure regeneration?

Scarification or prescribed burning removes the cover that is essential for rodents, and the bigger the area treated, the better. (Small areas are too rapidly reinvaded by rodents for treatment to have a long-lasting effect.)

Until we develop better rodent repellents- or habitats more favorable for the predators of rodents-scarification and prescribed burning will provide the best benefits. Failing that, another way to minimize exposure to predation is to sow pregerminated seed at the beginning of the period when temperature is most favorable for germination. Forest managers, who often need several years of advance planning, haven't the luxury of waiting for good seed years and a downturn in the rodent populations.

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NORTHERN HARDWOOD NOTES

Thinning Sprout Clumps

How do you deal with stump sprouts in second-growth hardwood stands? Although thinning them takes special effort to avoid causing decay, stump sprouts are the only way to regenerate certain species such as basswood. Generally, you should thin them early and preferably when potential crop stems are 3 inches d.b.h. or less. But if you delay thinning until they are pole-size, leave those with vigorous co-dominant crowns, and those joined to the stump at the lowest point.

Basswood

Even though basswood produces the heaviest and most frequent seed crops among the hardwoods, trees rarely originate from seedlings under natural conditions. So in managing basswood you have to depend almost entirely on stump sprouts. Fortunately, basswood is the most prolific stump sprouter among the hardwoods. Basswood sprouts from dormant buds on stumps of all sizes but more abundantly from stumps of saw log-size trees. Few sprouts on suppressed trees develop fully.

Leave two or at most three sprouts to a clump, as widely spaced as possible, to assure good growth and form. You can thin basswood at any age without decay being transmitted, provided that the union is no higher than "normal" stump height for a tree of that diameter.

In thinning clumps, if you have to choose between a saw log-size tree and a pulpwood-size tree with good growth potential, remove the larger tree. Few mills now accept basswood for pulpwood, so let the pulpwood-size tree grow (see figures on next page).

Forty-three-year development of a basswood sprout clump

1939
A basswood sprout clump, age 12 years, with three numbered trees. (Tree 184 is just behind the tree to the right of 183).
D.b.h.
Tree 183-3.5 inches
Tree 184-3.2 inches
Tree 185-2.9 inches

1977
The same clump at age 50. Note two rotten stumps left from trees showing in top photo.
D.b.h.
Tree 183-l 0.8 inches
Tree 184-9.2 inches
Tree 185-l 0.9 inches

1982
The same clump at age 55 showing no decay in tree 185 (left) or 183 (right) and sprouts already showing from the cutting of tree 184 in 1980.
D.b.h.
Tree 183-l 1.8 inches
Tree 185-l 2.1 inches.

Red Maple

Red maple stumps about 10 inches in diameter and stumps of formerly fast-growing trees sprout the most prolifically. Most sprouts have decay, which originates more from dead limbs than from old stumps. Thin red maple early during the sapling or small-pole stage. Leave only one or two sprouts, making sure that they originate at or below the root collar.

Sugar Maple

Sprouting in sugar maple declines rapidly as stump diameter increases, and there are far fewer sprouts per stump than in red maple. Sprouting originates from the root collar so there is little decay. Thin the same as red maple.

White Ash

White ash produces some sprouts. It grows fast but is easily suppressed as a sapling or a pole. Thin sprouts to two or three stems.

Yellow Birch

Yellow birch rarely sprouts, regardless of stump size.

Red Oak

Sprout clumps of red oak are good choices for precommercial thinning because the sprouts grow rapidly after thinning and are potentially long-lived. Thin as early as 4 years and leave just one sprout. Experience shows that stems thinned this early grow faster than stems in unthinned clumps.

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NORTHERN HARDWOOD NOTES

Growth And Development Of Browsed Seedlings

For long it was assumed that deer browsing on the terminal shoot of sugar maple was detrimental to height growth, stem form, and vigor. Does browsing permanently damage sugar maple in northern hardwood stands?

The answer is no, as long as the seedlings are growing vigorously.

A 5-year study in northern Wisconsin showed that height growth and seedling density were not significantly affected by winter browsing. Also, the forking caused by browsing tended to correct naturally.

Why aren't growth and development of sugar maple adversely affected by severe browsing? For one thing, losing the apical bud and part of the terminal leader doesn't hurt height growth. Also, a sugar maple can be browsed repeatedly before it is killed. The reason in both these cases is that a lateral branch usually takes over and becomes apically dominant. Forking, whether or not caused by browsing, is corrected as one leader becomes dominant and grows radially to eliminate "crook" and "sweep." The potential for leader elongation is determined by the conditions in the prior growing season and is not altered much by damage.

Other northern hardwood species may also be able to take heavy browsing without much damage as long as they too are growing vigorously.

If conditions allow these sugar maple seedlings to grow vigorously, they will not be damaged permanently by the heavy deer browsing.

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North Central Forest Experiment Station 4.01

NORTHERN HARDWOOD NOTES

Determining Site Index Accurately In Even-aged Stands

Good site index estimates are necessary for intensive forest management. To get tree age used in determining site index, increment cores are commonly used. The diffuse-porous rings of northern hardwoods, though, are difficult to count in cores, so many site index estimates are imprecise. Also, measuring the height of standing trees is more difficult and less accurate than measuring the height of felled ones.

A more precise way for foresters to determine site index is to fell, measure heights, and take a section for counting rings from representative trees. Site index can then be obtained from polymorphic curves.

Method for Counting Rings

1. Select a stand to measure that is:
   - Even-aged with less than a lo-year age difference among the overstory trees, excluding residuals.
   - Fully stocked with a closed canopy.
   - Mostly free of trees killed by wind, insects, or disease.
   - Not disturbed by fire, grazing, or heavy thinning from above since establishment.
   - At least 20 years old and preferably more than 50 years old at ground line. (Site index estimates in younger stands are not as valid because tree heights and growth rates vary so much).
   - Composed of sugar or red maple, or other hardwoods. (The maples are widely distributed and therefore can be used for comparisons among hardwood species. When suitable maples are not present, reliable estimates can be obtained with other species.)
   - Representative of a large area.
2. Select at least 5 sample trees if they are from stands more than 30 years old; at least 10 if the stand is less than 30 years old. Sample trees must be:
   - Dominants or strong codominants.
   - Above the average diameter for the stand (considering all trees over 5 inches d.b.h.).
   - Single-stemmed, not from a sprout clump.
   - Without serious insect, disease, or fire injuries; (don't use trees with rotten cores unless all rings are evident).
   - At least a stand height away from residual trees.
   - Straight and without pronounced lean.
   - Free of most surface defects, epicormics, bumps, and dead branch stubs.
   - Full-crowned, without dead tops and large forks. Small (l-inch diameter) correcting forks are permissible.
3. Fell each sample tree carefully to avoid breaking or loosing the tip.
4. Measure the total height to the nearest foot.
5. Cut a l-to 2-inch-thick cross sectional disk from the tree at breast height and label it.

6. Count the number of rings on each disk taken at d.b.h. and add 4 years to get the tree's total age at ground line.
   - Smooth the disk with an electric planer or belt sander to help distinguish annual rings. Usually rings can be more readily distinguished a few days after planing; magnification, ample lighting, and staining (phloroglucinol in hydrochloric acid and Bismark brown stains) can be used to bring out growth rings on difficult disks.
   - Be careful to count every ring in periods of slow growth where rings are closer together and avoid counting false (incomplete) rings.
   - Use Carmean's (1978) polymorphic site index curves to determine site index for each tree. Then calculate an average site index for the stand.
   - Use Carmean's (1979) site index comparisons for estimating site indices of other species. (See also Note 4.02).
   - Developing growth curves and relating them to soil and site characteristics which can be used on a variety of sites would make the felling and measurement of a number of trees more worthwhile.

References

Carmean, W. H. Site index curves for northern hardwoods in northern Wisconsin and Upper Michigan. Res. Pap. NC-160. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1978. 16 p.

Carmean, W. H. Site index comparisons among northern hardwoods in northern Wisconsin and Upper Michigan. Res Pap. NC-169. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1979. 17 p.

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NORTHERN HARDWOOD NOTES

Site Index Comparisons Among Hardwoods

Site index is one of the more easily measured indicators of the productive capacity of an area for a given species. In mixed stands, the site index of one species can be used to predict the site index of another. Site index also illustrates growth differences among species.

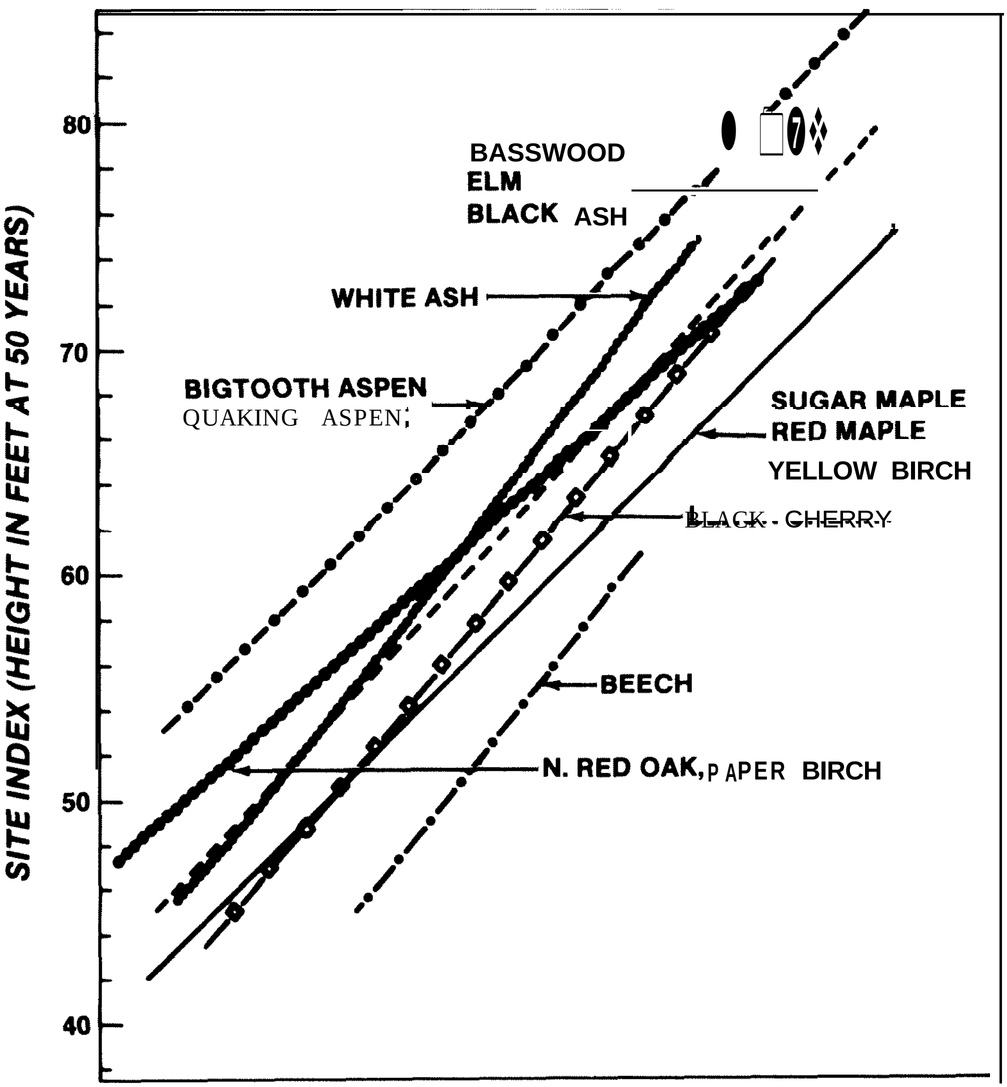
Recently, reliable curves for the major hardwood species have been developed that have made comparisons in the Upper Great Lakes region possible. The curves below compare site index for 13 species found in northern Wisconsin and Upper Michigan.

How to Use the Curves

Simply read directly above or below the known value to the curve of the desired species. For example, if you know the site index for aspen to be 72, find that number on the aspen curve. Then read directly downward to the white ash curve to find the corresponding site index for that species (68.5).

Note: A common sugar maple site index range on the Argonne and Upper Peninsula Experimental Forests in Wisconsin and Michigan, respectively, is 62 to 65.

(Reproduced from Carmean, W. H. Site index comparisons among northern hardwoods in northern Wisconsin and Upper Michigan. Res. Pap. NC-169. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1979. 17 p.)



Annotated References

Carmean, W. H. Site index curves for northern hardwoods in northern Wisconsin and Upper Michigan. Res. Pap. NC-160. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experimental Station; 1978. 16 p.

Describes the construction of site index curves for 13 species and comments on the forms of the curves by species and differences in site quality.

Carmean, W. H. A comparison of site index curves for northern hardwood species. Res. Pap. NC-167. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1979. 12 p.

Reviews and comments on the several previously developed site index curves for northern hardwood species in the eastern United States.

Carmean, W. H. Site index comparisons among northern hardwoods in northern Wisconsin and Upper Michigan. Res. Pap. NC-169. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1979. 17 p.

Illustrates differences in site index between species and changes over the range of site indices.

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NORTHERN HARDWOOD NOTES

Residual Stocking Levels

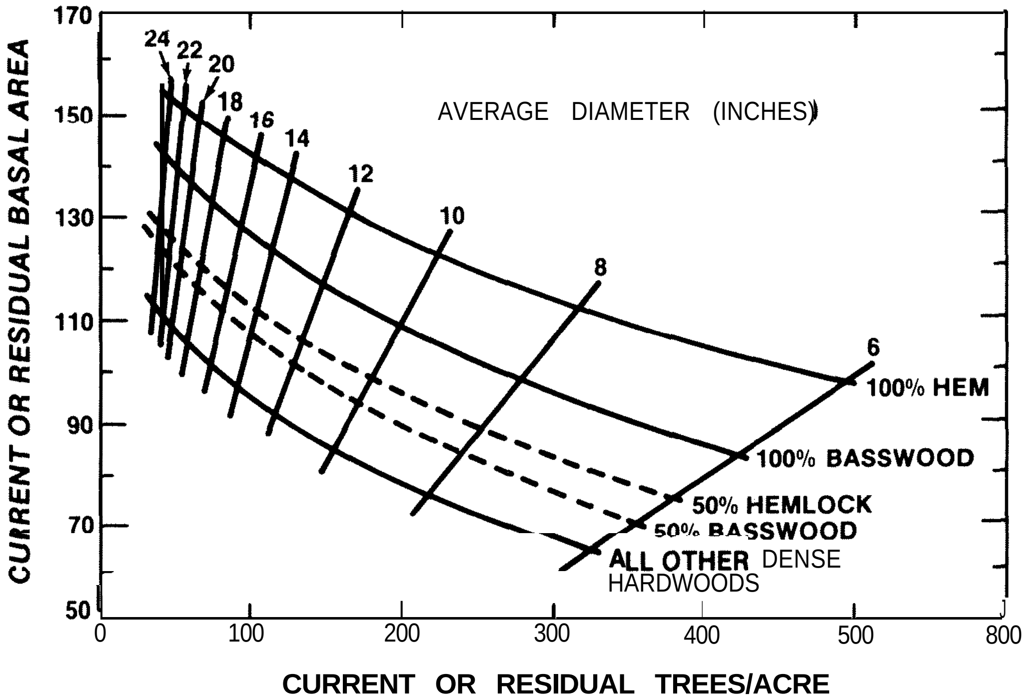
When you "thin" an even-aged stand, or "restructure" an all-aged stand by thinning out certain size classes (both are sometimes called "improvement cuttings"), how much basal area should you leave?

It depends on average tree diameter, the predominant species, and whether you are managing by the even-age or all-age method. (See worksheets for marking, Notes 4.04 and 4.05).

The graph (for even-age management) and tabulation (for all-age management) given below, show how much basal area you should leave. Remember that the residual basal areas include only trees 4.6 inches in diameter and larger.

Even-Age Management Guide

1. On the vertical axis of the graph, find the current basal area per acre of your stand; on the horizontal axis, find the number of trees per acre.
2. Extend a line horizontally from the basal area and vertically from the number of trees per acre. Where these lines meet is the average tree diameter.
3. Extend a line paralleling the average diameter lines to the appropriate species curve. Use the solid-line hemlock and basswood curves (those reading 100 percent) only if the stand you are thinning is *at* /east 80 percent stocked with that particular species. Use the dashed curves for stands that are about 50 percent stocked.
4. Go horizontally from the intersection of the average diameter and species curve to read the *residual* basal area on the vertical axis. The indicated basal area will leave about 80 percent crown cover. Stands will grow 2.6 to 3.0 square feet of basal area per year. This will help you set the desired cutting cycle.



In theory at least, no two stands would ever be cut to the same residual basal area because no two stands have the same average diameter and species composition. The practical message is to watch for changes in stand diameter and composition, and change the residual stocking levels accordingly as you mark for thinning.

All-Age Management Guide

1. Determine the stocking by diameter distribution.
2. Cut trees in each of the size classes to approximately match the suggested residual basal areas in the guide below. Trees 25 inches in diameter are considered economically mature. For trees larger than this the rate of return drops drastically.
3. Leave an occasional cull or poor quality tree as appropriate to discourage epicormic sprouting or forking on smaller but potentially better trees until their crowns develop.

D.b.h.	Residual	
	Trees	**Basal area**
Inches	*Number*	*Square feet*
5	21	2.9
6	15	2.9
7	12	3.2
6	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	118	84

The residual basal areas suggested should give the best overall volume and value growth for a commercial cut every 10 years. If you want larger trees (for esthetic or landscaping purposes, for example) you can establish a new size class. You then have to change the distribution of stocking among size classes. (See the use of the "q" factor in the reference).

Reference

Tubbs, Carl; Oberg, Robert. How to calculate size-class distribution for all-age forests. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1978. 5 p.

Richard M. Godman

NORTHERN HARDWOOD NOTES

A Worksheet For Marking AH-Aged Stands

1. Determine basal area per acre of trees 5 inches and larger in diameter, using a IO-factor prism, from at least 3 points in the stand.
2. Tally the size class for each tree in the appropriate column when you take basal area at each point.
3. Average the basal areas for each size class and enter on "Present B.A." line. Then subtract "B.A. Goal" from "Present B.A." to get the amount to cut by size-class and in total.
4. On a sample plot of known area tally tree basal areas (from table on left side) in the proper column until the amount to cut is reached for each size class.
5. Use the sample plot you marked as a standard for marking the rest of the stand. Train your eye to find where most basal area should be removed to reach a good size distribution.

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WORKSHEET FOR ALL-AGE MARKING

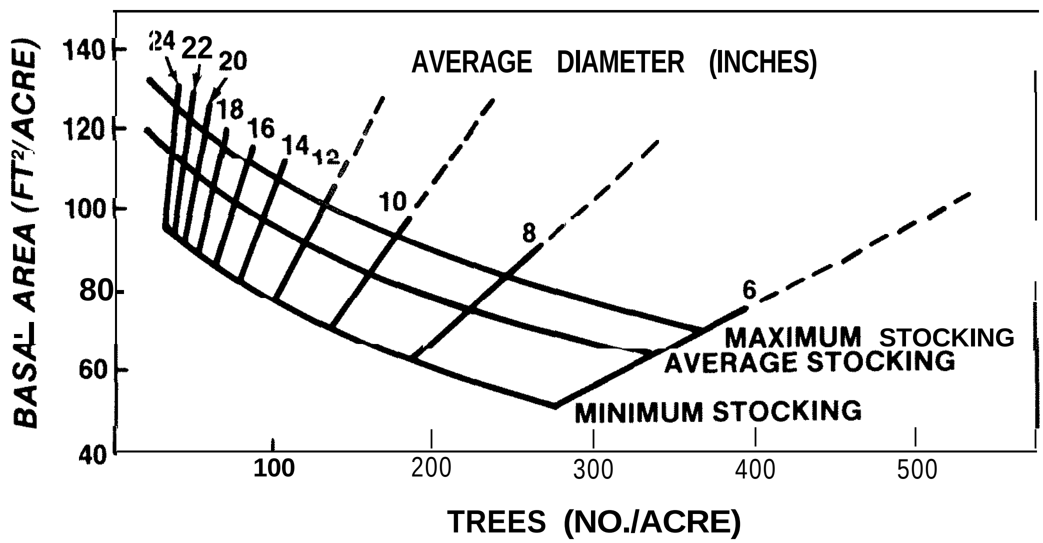
	Size Classes				Total
Present B.A.					
B.A. Goal					
Cut (Present B.A. minus B.A. Goal)					

D.B.H.	*B.A.*				
5	0.1				
6	.2				
7	.3				
8	.3				
9	.4				
10	.5				
11	.7				
12	.8				
13	.9				
14	1.1				
15	1.2				
16	1.4				
17	1.6				
19	2.0				
20	2.2				
21	2.4				
22	2.6				
23	2.9				
24	3.1				
25	3.4				
26	3.7				

NORTHERN HARDWOOD NOTES

A Worksheet For Marking Even-Aged Stands

1. With a lo-factor prism, determine basal area per acre of trees 5 inches and larger in diameter, from at least three points in the stand. (Basal area .)
2. Count the trees on at least two 1/20th-acre circular plots, (radius = 26.33 ft) and multiply by 20 to determine trees per acre (No. of trees). Using trees per acre and the basal area from step 1, find the average diameter on the following graph. (Average diameter .)



3. Find residual basal area (or what should be left after cutting) directly below the average tree diameter shown here:

Average Tree Diameter (inches)	6	8	10	12	14	16	18	20
Residual Basal Area (square feet)	63	75	84	92	96	100	105	109

4. Calculate basal area to be cut (actual - residual = basal area to be cut) and record on worksheet.
5. Stand in the middle of an area of uniform tree diameters and determine which trees should be marked for cutting to achieve an evenly spaced stand.
6. Tally basal areas of marked trees on worksheet (use table on left side) and cumulatively sum basal areas until they equal the basal area that should be cut.
7. Take prism counts of residual trees in areas where you put plots to check on correct residual basal area.

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WORKSHEET FOR ALL EVEN-AGED MARKING

Basal Area to be Cut ________

D.B.H.	B.A.	Tree B.A	Cumul Total								
5	0.1										
6	.2										
7	.3										
8	.3										
9	.4										
10	.5										
11	.7										
12	.8										
13	.9										
14	1.1										
15	1.2										
16	1.4										
17	1.6										
19	1.8										
19	2.0										
20	2.2										
21	2.4										
22	2.6										
23	2.9										
24	3.1										
25	3.4										
26	3.7										

NORTHERN HARDWOOD NOTES

Stocking Level, Stand Structure, Cutting Cycle, And Growth Rates

Stocking, structure, and cutting cycle-how do they affect growth rates? To understand the interrelations we need first to understand the terms.

Stocking-Tells how well the site is being occupied and is expressed in basal area per unit area. When we refer to stocking it will be in terms of beginning basal area or residual basal area after a cut.

Stand structure-How many trees of each size there are-can be characterized by size-class distribution. In an uneven-aged forest this follows a simple geometric progression. The many small trees and relatively few large ones produce an inverted "J"-shaped distribution of tree size. The main reason we manage uneven-aged stands using structural goals is to provide a balanced diameter distribution that will support periodic harvest of nearly equal volumes.

Cutting cycle-The time between harvest cuts.

Also, here are some definitions for the various components of growth:

Survivor growth-Growth on trees present at both the beginning and end of a measurement period within a given size class.

Ingrowth-Growth on trees that grow into the 4.6-inch d.b.h. class during a measurement period (new growing stock) or growth on trees that grew into the 9.6-inch d.b.h. class (new saw log trees).

Mortality-Volume or basal area of all trees that died during a measurement period.

Gross growth-Survivor growth plus ingrowth.

Net growth-Gross growth minus mortality.

Stocking levels strongly affect growth in all forest stands. To show this for a sugar maple forest, we plotted various kinds of growth (in square feet) against beginning basal area (fig. 1A). Note that ingrowth declines with increasing basal area, while survivor growth increases rapidly at low stocking levels and then declines slightly. Mortality doesn't change across a wide range of stocking levels, but increases rapidly above 100 square feet per acre of beginning basal area. The combined effects of these relations produces a rapid increase in basal area growth as initial stocking increases at the low range to a maximum growth rate at 45 square feet, followed by a gradual decline between 50 and 120 square feet per acre and a rapid decline above 120 square feet per acre.

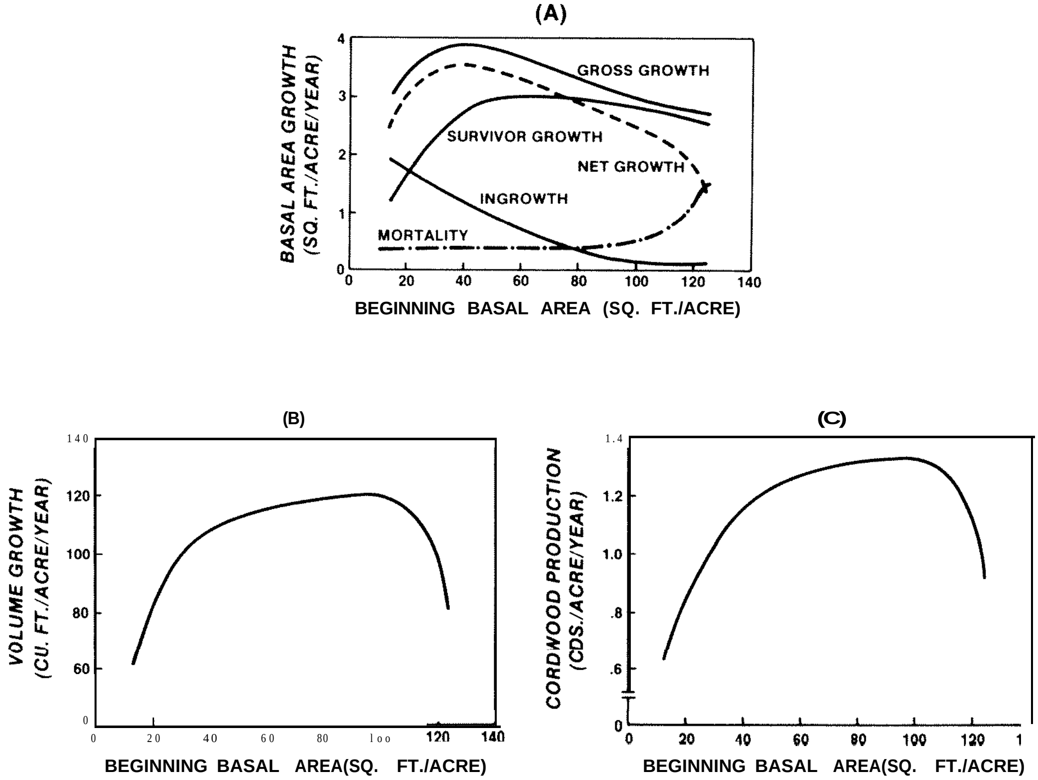

Figure 1 .-Relation of basal area growth (A), volume growth (B), and cordwood production (C), to beginning basal area. (All trees 4.6 inches d.b.h. and larger; site index 65 at age 50 for sugar maple. Values based on 15-year measurements in second-growth hardwoods dominated by sugar maple.)

Cubic foot volume growth (fig. 1 B) and cordwood volume growth (fig. 1 C) show the same basic trends when related to beginning basal area. Both increase sharply at low basal areas, continue to increase at a reduced rate until 100 square feet, then decline sharply at higher stocking levels because of increasing mortality.

Board foot growth parallels growth in other units (table 1), except that optimum stocking is more obvious when you deal with saw logs. Maximum net growth in board feet occurs at 70 square feet of residual basal area. At 30 and 50 square feet of residual stocking, stands are understocked for survivor growth. At 90 square feet, ingrowth declines and mortality increases; both result in lower net growth.

Stand structure is generally said to be important in maintaining sustained yield in uneven-aged stands, but not important in affecting growth rates. However, we can show that the distribution of beginning stand basal area in saw log-size and pole-size classes is a good indicator of future volume growth-both for uneven-age and even-age management.

Table 1 .-*Average annual growth in board feet per acre (Scribner rule) for trees 9.6 inches d.b.h. and larger (values based on 20-year study in mature stands dominated by sugar maple)*

Residual[1] basal area	Survivor growth	Ingrowth	Gross growth	Mortality	Net growth
30	179	18	197	20	177
50	201	18	219	15	204
70	243	14	257	22	235
90	235	10	245	32	213

‘Residual basal area for saw log size class.

To show this, we developed a model of beginning stocking in poles and saw logs with their corresponding board-foot yields (fig. 2). The same comparison in cubic-foot volume is in figure 3. The stands used in constructing these models were young and increasing rapidly in merchantable height, so we don’t expect the high growth rates to be sustained. However, the trends for different combinations of stocking are meaningful for net volume growth.

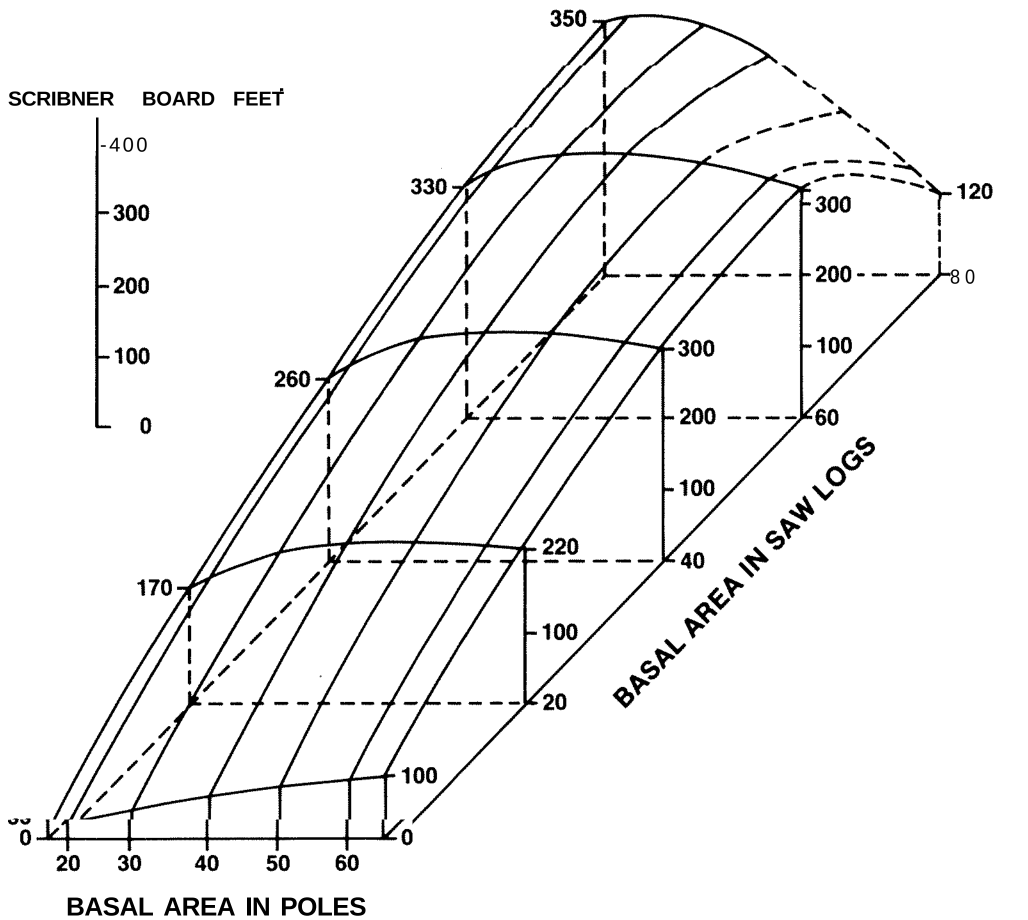

Figure P.-Relation of annual Scribner net board-foot growth to beginning basal area of poles (4.6 to 9.5 in. d.b.h.) and of saw log sized trees (9.6 in. d.b.h. and larger).

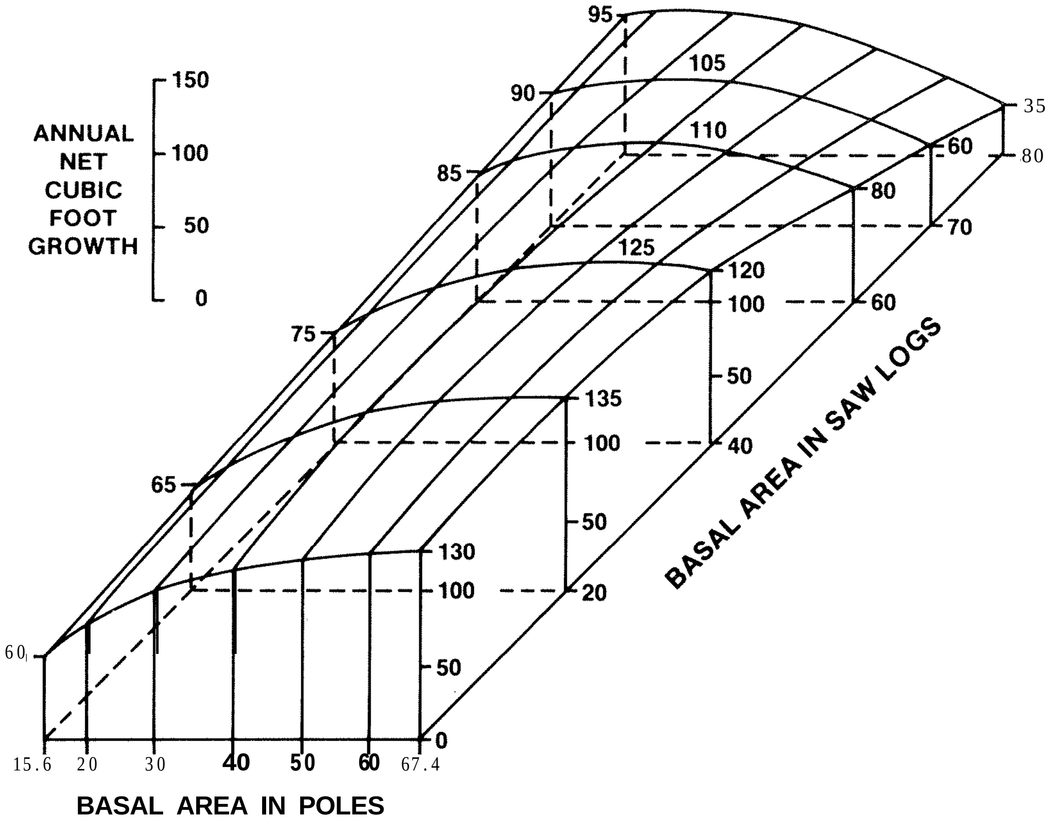

Figure 3.-Relation of annual net cubic foot growth to beginning basal area of poles (4.6 to 9.5 in. d.b.h.) and saw log-sized trees (9.6 in. d.b.h. and larger).

Growth rates vary with length of cutting cycle, although the differences are small and probably not significant within the range of cutting cycles recommended-5 to 15 years. In general, survival growth increases and mortality decreases as the length of the cutting cycle decreases. Cutting a stand more frequently reduces competition and allows high risk trees to be removed that might otherwise die. Extremely short cycles are not economical in most cases. On the other hand, growing stock should not be allowed to increase to a point where growth stagnates. A balance is generally reached with a 10 to 12-year cutting cycle.

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NORTHERN HARDWOOD NOTES

Diameter Limit Cutting

Advantages

Diameter-limit cuts have been widely applied in northern hardwood forests, mainly because they are easy to apply in the field and they result in maximum financial returns.

Choosing trees to cut based on a diameter limit has the virtue of leaving smaller trees to reach fuller economic potential for future cuts. Based on observations and measurements in an array of diameter-limit cuts on the Argonne and Upper Peninsula Experimental Forests, reproduction and growth rates following limit cuts are generally good. Annual growth of board foot volume, however, was lower than other cutting methods because the trees were so small. *Diameter limit cutting is an even-age management option if the production of fiber is the sole objective.*

Disadvantage

The major disadvantage of this type of harvest cutting is that it does not provide for improving the quality of the future stand. If a strict diameter limit is followed, stand quality and growth rates may decline because small, low-quality and defective trees are not removed. Following heavy cutting, such as an 8-or 12-inch diameter limit cut, tree quality and merchantable lengths decrease with a lowering of crowns due to development of large branches following epicormic sprouting. *If developing high quality is an important management goal, diameter-limit cutting is not recommended.*

Other Considerations

When setting diameter limits, consider residual stand stocking, merchantability, quality, and cutting interval. For example, remember that only trees 16 inches d.b.h. and larger produce number 1 logs, and at least 70 square feet of saw log-size trees per acre are necessary to correct canopy forking and produce growth on high-quality stems.

The amount of residual growing stock obviously is affected by the intensity of the cut. A 12-inch-diameter-limit cut removed 90 percent of gross board foot volume in a mature stand on the Upper Peninsula Experimental Forest, while a 22-inch-diameter-limit cut removed only 29 percent. For practical purposes, an 8-inch-diameter-limit cut can be considered a commercial clearcut. Because of the low residual stocking (21 square feet in trees 4.6 inches d.b.h. and larger) in the 8-inch diameter-limit cut on the Argonne Forest, total growth per acre was reduced and the site was not fully utilized by growing stock for at least 6 years after the initial cut. Stocking was sufficient for a second cut (fiber only) approxi'mately 30 years after the initial cut, but the quality potential of the stand was low.

Relating Stump Diameters to D.b.h.

Diameter limits are generally expressed as stump diameters. To convert stump diameter to d.b.h. for several common hardwood species, use the following formula:

D.b.h. = (stump diameter – a)/b where a and b are species values in the tabulation below:

Species	a	b
Sugar maple	-0.2690	1.1041
Basswood	-1.6374	1.2721
Yellow birch	.7618	1.1987
White ash	-.2995	1.1083

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NORTHERN HARDWOOD NOTES

Strip Cutting In Northern Hardwoods

Interest in clearcutting young northern hardwood stands in strips is running high, especially now that mechanical fellers and skidders have been developed to harvest these stands. Strip cutting has several advantages-no overstory to worry about when treating the site, no overstory to remove later, and the economic advantage of cutting the strip only once.

Just how good an even-age management technique is strip cutting? Experience with strip cuttings in second-growth stands since 1951 has been discouraging. The 1 -to 2-chain-wide strips have been poorly and irregularly stocked. Preferred species have not regenerated well and few quality trees have developed.

Why? Two of the three essentials for even-age management have been missing-suitable overstory and seedbed. Regeneration did not become established on the most exposed sites. Hot, dry periods took a heavy toll. Sprouts and wolf trees developed.

But strip cutting still has potential. Mechanized equipment now cuts strips that are less than half-a-tree-height wide. Strips can be cut in any direction to serve as roads for intermediate cuttings. Skidding patterns can be designed to minimize damage to residual trees. This will improve both regeneration and maintain the quality of residual trees. At best, though, strip cuttings will regenerate mostly even-aged sugar maple. Few light-seeded species (birch, hemlock) will regenerate even though they are present in the overstory.

Until we learn more about it, use strip cutting only as a way to get access for the first thinning in sapling and pole stands. Strip cuts will encourage the overstory to develop. Then more uniform thinning can be used later in the rotation.

Reference

Metzger, F. T. Strip clearcutting to regenerate northern hardwoods. Res. Pap. NC-186. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1980. 14 p.

Richard M. Godman

NORTHERN HARDWOOD NOTES

What To Do With Northern Hardwood-Aspen Mixtures

The aspen type covers the most area in the Lake States, followed by northern hardwoods. Both prefer good soil and are easy to regenerate. Because of past cutting practices, though, the types are now mixed over large areas. Usually there is an overstory of fast-growing aspen interspersed with an understory of dense hardwoods.

Choosing the Future Stand

Normally you are better off encouraging a single type than perpetuating a mixture. By first deciding which type you want to favor, you can avoid the half-way measures that lead to low yields, loss of site productivity, and future problems.

Overstory Aspen, Understoty Hardwood

In this mixture, you can easily encourage either type.

To encourage aspen, completely remove the overstory (all stems 1 inch in diameter and larger). Leaving even 15 square feet of basal area can reduce future volume up to 40 percent. Next cut or poison the northern hardwood understory. This stimulates root suckering of aspen by warming the soil. The subsequent rapid growth of suckers allows aspen to dominate the new stand. Take care not to disturb the parent root system. Aspen suckers are completely dependent on this root system at age 6, and still 50 percent dependent at age 30.

To encourage hardwoods, start removing the overstory as described above after the understory hardwoods reach sapling size (1-3 inches d.b.h.). If you start when they are larger than that, the future stand will be more variable in density and thus lower in quality and volume. Leave the understory intact to maintain its dominance and composition. Although some seedlings will be broken when the overstory is removed, these seedling-sprouts will grow faster and tend to maintain a uniform crown cover. The few aspen suckers that develop generally won’t change the composition or dominate the northern hardwoods.

Aspen and Hardwoods of Equal Size

This is a more difficult stand to manage. Wait until volumes are great enough for a merchantable cutting. Otherwise cutting will reduce the site productivity for a few decades.

To encourage aspen, clearcut all species to stimulate suckering. You can also combine clearcutting with burning or shallow scarification if aspen stocking is very low (i.e., less than 20 to 30 square feet of basal area). This will provide a suitable bed for aspen seed. Even if there is no seed available within the stand, prescribed burning or scarification will result in stands both of seedling and sucker origin.

To encourage hardwoods, mark the stand according to the hardwood stocking guides for even-age management. Although some aspen will necessarily be retained through at least one cutting cycle, the increasing density of hardwoods will inhibit aspen suckering. Suckers arising the first 4 years usually die in the increasing shade; after that aspen stops suckering.

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NORTHERN HARDWOOD NOTES

Releasing Yellow Birch Saplings And Poles

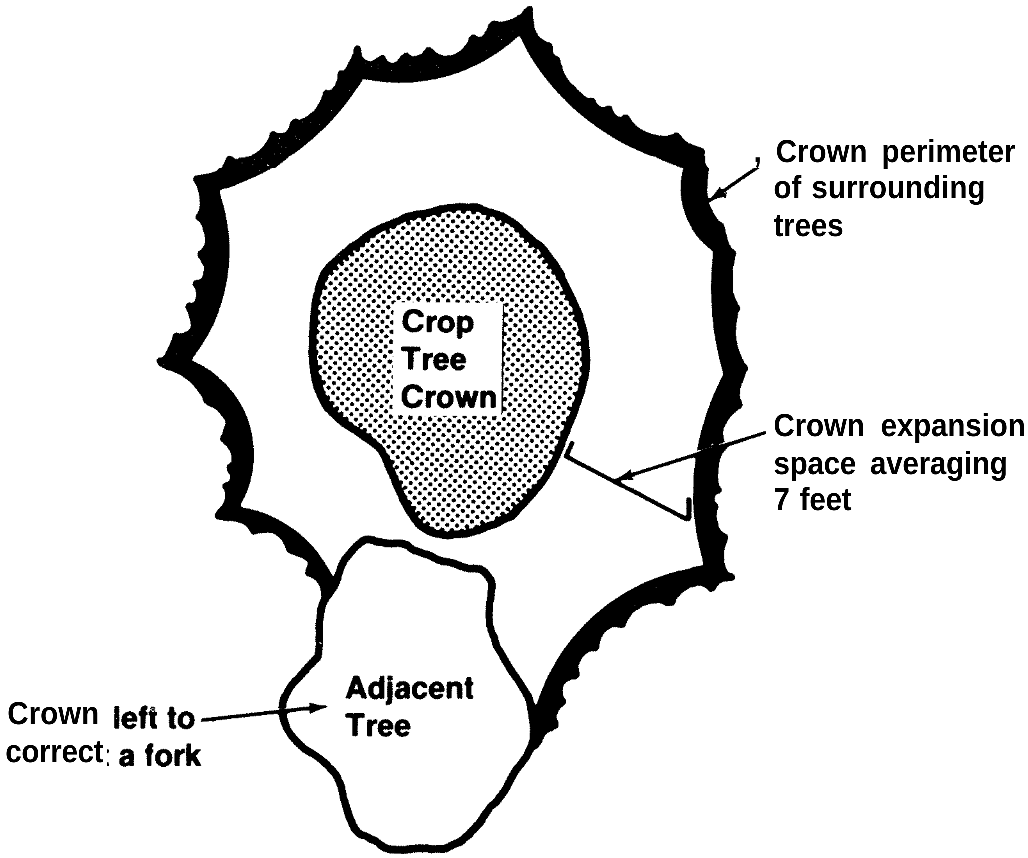
Yellow birch needs moisture, nutrients, overhead light, and enough space for the crown to expand in order to compete successfully with faster-growing northern hardwoods. By releasing crowns early, you can increase the number of future veneer and saw log trees in a stand and double the growth rate, thus cutting rotations in half. If you delay crown release too long, growth response is poor. After 45 years most birch trees in unmanaged stands occupy such poor crown positions that little can be done to improve them.

Saplings respond best to crown release. Diameter growth rates of saplings can be increased up to 3 inches per decade. Pole-size trees respond nearly as well as saplings to crown release. Thinned stands generally grow 2 to 3 square feet in basal area per acre annually. After 10-12 years, adjacent crowns will have met and small lower branches in the live crown will have died.

A reasonable goal is to produce 75 18-inch diameter) final harvest trees per acre on medium to good sites. For yellow birch, this requires releasing 100 crop trees per acre in sapling-and pole-size stands to cover unexpected losses and to keep costs down. Stands are normally ready for commercial cutting when they contain 100 to 120 square feet of basal area per acre and trees are about 6 inches in diameter.

Steps to follow:

1. Determine the number of trees per acre, the basal area, and average tree diameter of the stand. Then see the table for the basal areas to leave after crown release.
2. Select up to 100 dominant and codominant crop trees per acre, spaced about 20 feet apart. Strong intermediates are suitable if dominants and codominants are lacking. Birches with large vigorous crowns and clear boles are preferred for their rapid growth and minimal epicormic sprouting.
3. Release crop trees to provide 7 feet of open space between tree crowns. (see figure). Removing only one or two main canopy trees is not enough. All trees below the main canopy within the prescribed distance can be cut. Cut any subcanopy tree that is rubbing or likely to lean against crop trees to prevent wounds, infections, and decay.
4. Don't create openings larger than 10 feet wide-they won't close before the next thinning.
5. Leave adjacent tree crowns to correct a small fork (less than 2 inches in diameter, see figure).
6. Retain a stem of equal quality nearby to produce a grade 2 butt log if it is the only tree left restricting the crop tree's growth.
7. Don't thin where stocking is already too low.
8. Thin dense pockets of high-quality stems; retain trees with the best developed crowns.



Projection of a crop tree's crown and neighboring crowns after crown release in a pole-size stand.

9. Remove or girdle high-risk, cull, and wolf trees in the overstory.
10. Then cut low-vigor, low-quality, leaning, crooked, forked, and cankered trees from below to reach the prescribed residual basal area.
11. In commercial thinning leave a uniformly thinned stand of thrifty dominants and codominants, with adequate growing space.

Precommercial cuttings can greatly improve the species composition of the final stand. Begin with Step 2, but do not thin unless suitable crop trees are present within the prescribed spacing. Save the trees to make an earlier commercial cut. Then continue from Step 3 through Step 8. Make'firewood salvage sales and remove or girdle high-risk, cull, and wolf trees where feasible.

Suggested stocking for even-aged pole-and saw log-size yellow birch trees on good sites (site index 60 or more)[1]

Average[2] stand d.b.h. (inches)	Trees per acre	Average spacing	Residual basal area per acre
	Number	*Feet*	*Square feet*
4[1]	521-625	9	45-55
5	365-437	10	50-60
6	290-340	12	57-67
7	235-273	13	63-73
8	200-229	14	70-80
9	180-202	15	79-89

[1]Figures are based on measurements of growth and quality development of individual trees in several birch studies in progress.

[2]Average d.b.h. of all trees 4.6 inches and larger except for the 4.0-inch class which includes all trees 0.6 inches and larger.

Gayne G. Erdmann and *Ralph M. Peterson, Jr.*

NORTHERN HARDWOOD NOTES

Epicormic Sprouting

Thin too much the first time and you are likely to get a surge of epicormic sprouts. These small branches that can mar a clean bole and cause serious degrade often develop profusely in pole and small sawtimber before and after initial thinning, particularly under even-age management.

A tree of nearly any size can break out heavily in epicormic sprouts. Epicormics originate from "dormant buds" that form annually in normal bud scales and at the base of branches. Unlike vegetative and flower buds, they are very small or embedded in the bark, and have a "strand" connection to the pith. As the tree increases in diameter, the strands increase in length allowing the bud to survive and sprout whenever conditions are right.

What keeps dormant buds in check are "growth regulators" made by the growing terminal buds in a healthy and vigorous crown. Small-crowned, crowded trees-such as suppressed and intermediate trees in the understory or crowded overstory trees in unmanaged, even-aged stands-don't produce enough regulators, so the buds break dormancy and sprout. (It's not light striking the bud that causes sprouting). Some intermediate and co-dominant trees don't put out epicormic sprouts until right after a stand is first thinned. Then the sprouts receiving the most light often grow rapidly into large limbs that can reduce bole quality.

Tree species such as basswood and white ash that inherently grow tall and have large vigorous crowns, generally sprout less than sugar maple and yellow birch because of their more dominant position.

Controls

Even-aged Stands

1. Follow even-age stocking guides (see Note 4.03). Thin to the proper level, preferably about a third but *never* more than 40 percent of the basal area. This light thinning will allow the crowns to build up in size and release growth regulators while shading out sprouts that develop.
2. In later thinnings when trees are 10 inches d.b.h. and larger, if the crown diameter is 20 times the d.b.h. or more, you can thin more heavily without risk of epicormic sprouts. In shelterwood cuttings, large-crowned trees of all species can be left in open conditions without danger of sprouts developing.

Uneven-aged Stands

If crowns are released gradually by maintaining the proper stand structure, epicormic sprouts are seldom a problem.

Richard M. Godman

NORTHERN HARDWOOD NOTES

Fork Occurrence And Correction

Forking in the opposite-branched sugar maple and white ash can cause trouble. Forks always occur in the large overstory trees that we depend on for the final crop. Quality of the main stem drops on forked trees-along with merchantable volume-and the risk of crown or tree breakage increases in managed stands.

Catastrophies such as ice storms were once thought to cause forking; now we know that the culprit is an insect called a bud miner that overwinters in and kills the terminal bud. The lateral shoots bend upward to take the place of the terminal shoot, creating the fork. In north-central Wisconsin terminal buds are lost to bud miners every 3 to 5 years, so forking occurs repeatedly on a tree from the seedling stage through maturity. Little, if anything, can be done to control the insect, so good silviculture must be practiced to develop the best quality and value.

Fork Correction in All-Aged Stands

Forks are less common in all-aged than even-aged stands. Fork correction is continual in stands with different sized trees because the taller overstory trees shade out part of the fork. For this reason the stem will generally develop 2½ to 4 logs of merchantable height and there is no breakage in the crown.

Fork Correction in Even-Aged Stands

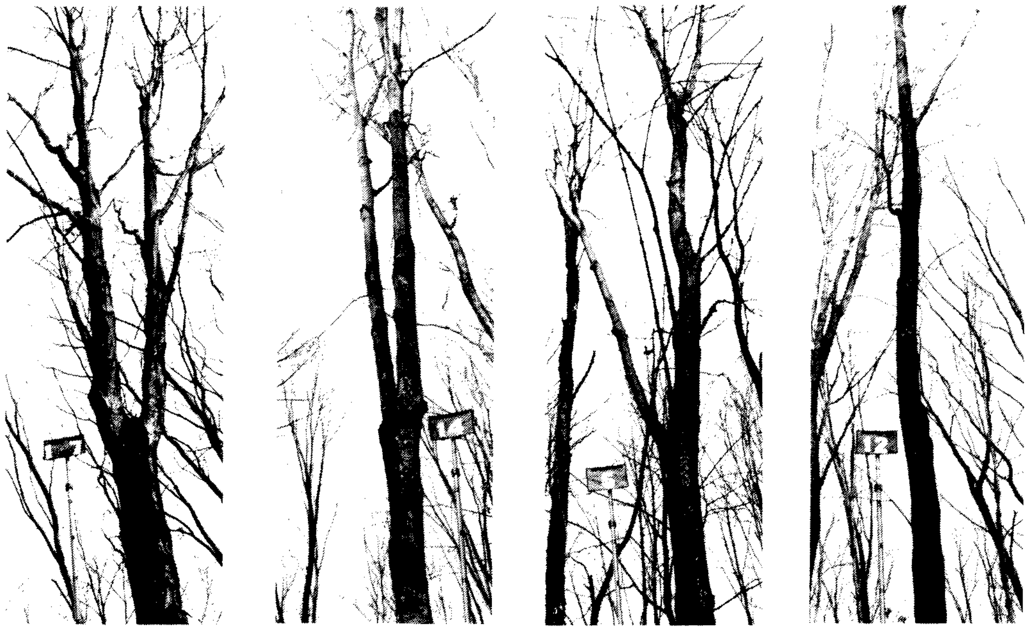
Forking occurs in every overstory sugar maple and most ashes in even-aged stands. These trees seldom produce more than two logs because of forking. Forks in large trees in even-aged stands occur lower and last longer than in all-aged stands and more crowns are lost as the forked branches grow larger and heavier.

To correct forking in even-aged stands you must maintain stand density at or slightly greater than recommended residual levels. Don't thin too early (before the stand averages 6 inches in diameter) or too heavily (more than the stocking curve recommends) in pure sugar maple or forks will increase in size and take longer to correct. On the other hand, don't keep the stand too dense or crown vigor will decline, stimulating epicormic sprouts on the lower bole.

Forks correct themselves when neighboring crowns cause one side of the fork to lose vigor so that the other can take over as a single central stem. Nearly a fifth of the forks on a pole-size, even-aged stand corrected completely after 17 years; ("D" on the following page); three-fifths corrected partially by that time ("A";"B"; "C" on the following page).

Richard M. Godman

Stages in fork correction in an even-aged stand growing at recommended stocking levels.



A B C D

A-No fork correction
B-One fork member gaining dominance over the other
C-One member of original fork degraded to large limb size
D-Complete fork correction; no reduction in stem size above the original fork

NORTHERN HARDWOOD NOTES

Growth And Yield For Managed And Unmanaged Stands

Yield tables were generated using STEMS (Stand and Tree Evaluation and Modeling System) developed by North Central Forest Experiment Station scientists. The data fed into STEMS came from real ¼-acre plots. The plots were selected to characterize 40-year-old stands that averaged 58 percent of basal area in red maple, 23 percent in sugar maple, and the remaining 19 percent in yellow and paper birch, ash, elm, and aspen. One projection was made for unmanaged stands and one for managed stands. The purpose was to compare the gains produced by bringing stands under management.

The management simulated by the STEMS model consisted of reducing each plot to 60 square feet of basal area at age 40 by thinning from below. At ages 55, 70, and 8520 percent of the basal area was removed. At ages 100 and 115 no thinning was simulated.

How Effective Was Management?

1. After one 115-year rotation the managed stands produced 26 percent (poor site), 18 percent (medium site), and 49 percent (good site) more cubic foot volume than the unmanaged ones.
2. The managed stands were larger in average d.b.h. by 5 inches (poor site), 7 inches (medium site), and 10 inches (good site) than the unmanaged stands.
3. The managed stands had 19 percent less basal area and 64 percent fewer stems per acre than the unmanaged stands.
4. The managed stands increased 23 percent in board foot volume on the good site, but only 2 percent on the medium site, and none on the poor site. Why so little volume gain? Partly because so little board foot volume is thinned out of the stands on poor and medium sites. Also, the unmanaged stands would retain many small-diameter trees whose total board foot volume would equal that of managed stands having larger but fewer trees.

Reference

Belcher, David M. The users guide to STEMS: Stand and tree evaluation and modeling system. Gen. Tech. Rep. NC-70. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1981. 49 p.

H. Michael Rauscher

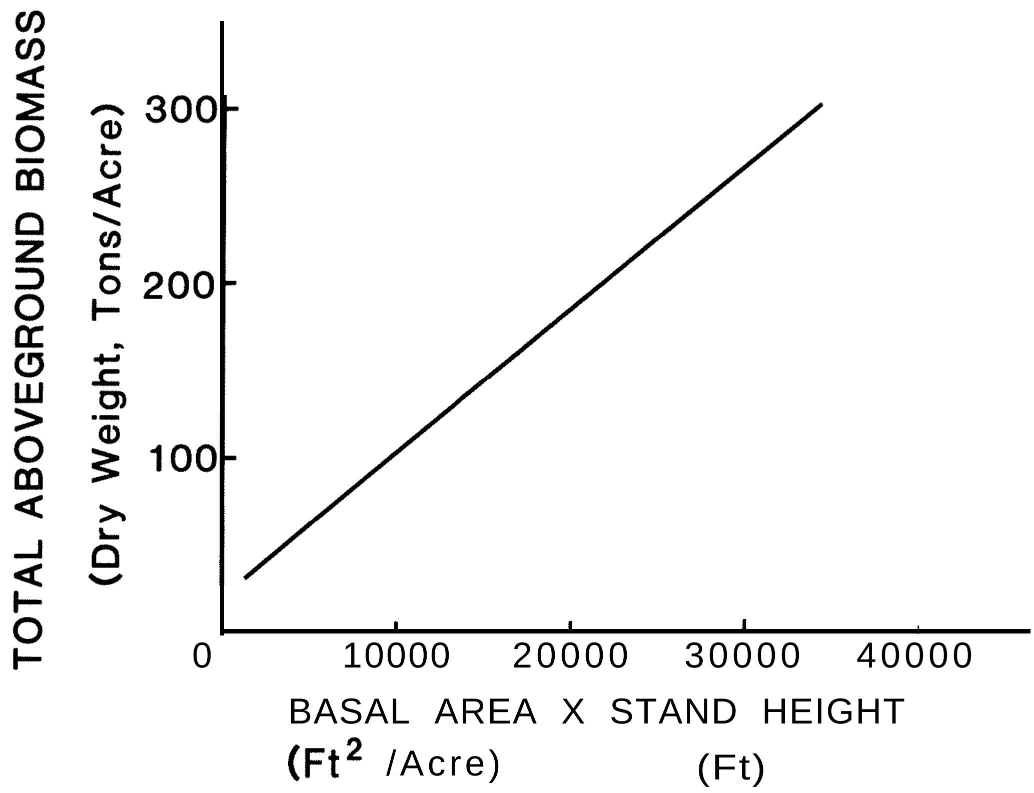
NORTHERN HARDWOOD NOTES

Stand Weights

As the demand for wood products increases, hardwoods will be used in larger amounts and trees more completely utilized. As a result, foresters will have a greater need to predict weight yields of hardwood stands.

We have learned to estimate stand weight very easily from stand height and basal area. This relation seems to be the same regardless of the mixture of hardwood species. Our data come from 52 hardwood stands in the eastern United States (about half of the stands are located in the Lake States). Each has a different composition; included are mixed aspen-maple stands in Wisconsin, red maple dominated stands in Michigan, beech- maple-birch stands in New Hampshire, oak-pine stands in Minnesota, and cove hardwoods in the Appalachians.

You can roughly estimate dry weight of the aboveground stand by using the following figure, or get a more accurate estimate by using the equation below. To use the figure, multiply the total stand basal area (in square feet per acre) by the mean stand height (in feet) and find this amount on the horizontal axis. Project this value vertically to the slanted line and then horizontonally to the vertical axis to get total aboveground dry weight in tons per acre.

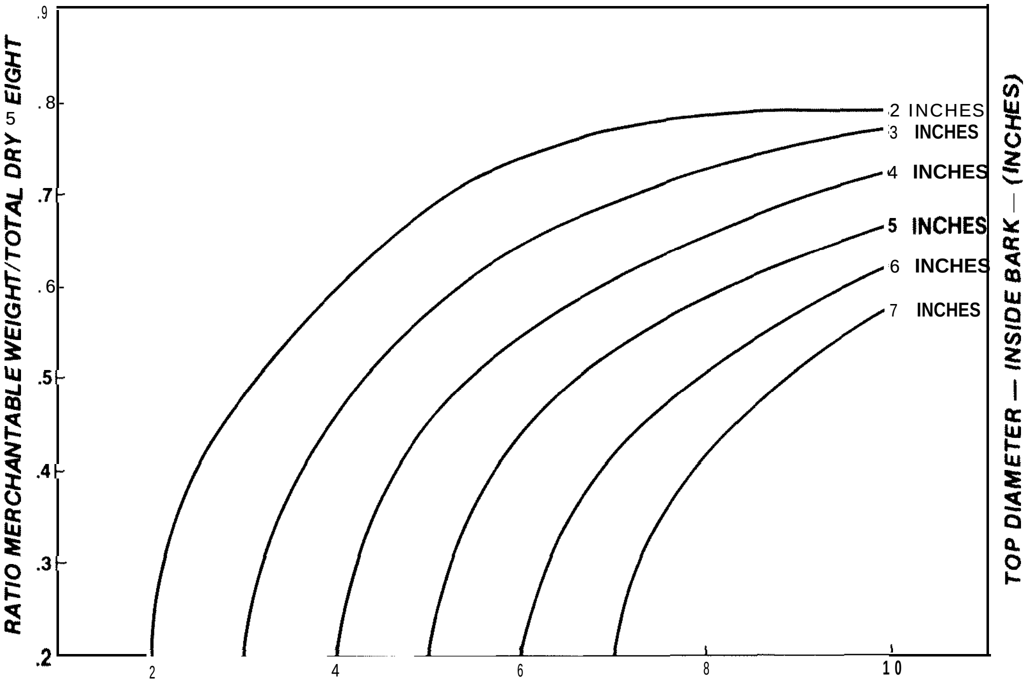


The equation is: Stand weight (tons per acre) = 18.5 + 0.00835 BA (sq. ft. per acre) X Ht. (ft.)

To use the equation, "plug in" the basal area and stand height. For example, a stand with 126 feet per acre of basal area and a mean height of 61 feet has an estimated aboveground stand weight equal to 82.7 tons per acre (or 165,000 pounds): 82.7 = 18.5 + 0.00835 (126 X 61).

This is dry weight and includes all aboveground tree parts including leaves. You can apply this equation to any hardwood or mixed hardwood-conifer stand in the Lake States.

To estimate merchantable stem weight, simply apply the ratios of merchantable weight to total weight shown in the following figure. By using average stand diameter (horizontal axis) and merchantable top diameter (vertical axis on right), you can find merchantable weight (vertical axis on left). For example, given an average stand diameter of 8.5 inches, and a 2-inch top diameter utilization limit, the ratio of merchantable weight to total weight obtained from figure 2 is 0.79. So, 0.79 X 82.7 (the estimated stand weight from above) = 65.3 tons per acre.



Because of seasonal variations in moisture content (see Note 5.03) and differences in moisture content among parts of the tree, it is more difficult to estimate green weight than dry weight. Based on sampling in late summer, we obtained a green-to-dry weight ratio of 1.52. So, by multiplying dry weight estimates by 1.52, you can get a rough estimate of green weight.

Thomas R. Crow

NORTHERN HARDWOOD NOTES

Variation In Seasonal Moisture Content

Several properties of wood are affected by moisture content-weight, fuel value, electrical conductivity, strength, and shrinkage. Differences in these properties are commonly observed in wood in service. For example, a green 2 X 4 weighs more than a kiln-dried 2 X 4, dried wood burns more easily and hotter than green wood, etc.

Furthermore, research has shown that moisture content varies within the tree (pith to bark and stem to crown) and seasonally in aspen and paper birch. (Northern conifers do not seem to vary much seasonally.) Knowing these types of variations could be important if you routinely buy and sell wood by weight.

In paper birch and trembling aspen, water content is highest in the spring just before bud break; it decreases during the summer until leaf fall, and after that increases until December (see graph). During January there is a small decrease but not as much as during summer. Most variations in moisture content were observed in the wood nearest the bark. In aspen, moisture content also generally decreases with height.

In general, the weight of a load of summer-cut (June-July) birch and aspen can be estimated by assuming that half the weight is water. Wood cut in January or February has more moisture and could be 6 or more percent heavier than the same volume cut in summer.

Moisture content will vary from year to year so you should calculate it for individual cases if you wish to be precise. In addition, if you want to compare the weights of winter-cut and summer-cut wood, the samples should include equal proportions of top, middle, and bottom logs because of moisture content variations within the tree.

Calculating Moisture Content

To calculate moisture content of a log:

1. Obtain a representative sample (disk or increment core) from the mid-portion of a log.
2. Weigh the sample green.
3. Oven-dry the sample at 105° C for 16 to 18 hours.
4. Place in a container over a dessicant for 30 minutes and weigh at room temperature.
5. Place in oven again for 2 hours, then put the sample in container over a dessicant and weigh again at room temperature to make sure the weight has stabilized.

6. Use the following formula:

$$\text{Moisture content (percent)} = \frac{\text{Green weight} - \text{ovendry weight}}{\text{Ovendry weight}} \times 100$$

The above formula gives the moisture content on a dry basis and is most commonly used. It could give moisture content in excess of 100 percent because sometimes the weight of water in a sample exceeds the weight of the wood itself.

References

Bendtsen, B. A.; Rees, L. W. Water content variation in the standing aspen tree. For. Prod. J. 12(8): 426-428; 1962.

Gibbs, R. D. Studies of wood. II. On the water content of certain Canadian trees and on changes in the water-gas system during seasoning and floatation. Can. J. Res. 12: 727-760; 1935.

Gibbs, R. D. Studies of tree physiology. I. General introduction. Water contents of certain Canadian trees. Can. J. Res. 17(C): 460-482; 1939.

John E. Phelps

North Central Forest Experiment Station 6.01

NORTHERN HARDWOOD NOTES

Economic Maturity Of Sugar Maple

How large is an economically mature tree?

The answer usually depends on the return demanded by the owner, generally 2 to 6 percent over 10 years. Under this criterion, the optimum tree diameter for sugar maple may range from 15 to more than 30 inches, depending on grade and growth potential. So, each tree needs to be evaluated individually. The table below will help.

For example, a tree with a butt log grade of 2, expected to grow 1.8 inches in diameter and ½ log in height over the next 10 years but not increase in grade, would be “mature” when it reached 20 inches in diameter. That is, if the owner required a 6 percent rate of return. If he or she were willing to accept only 4 percent, the tree would not be economically mature until it reached 26 inches in diameter. Although large high-grade trees are worth more than smaller lower grade trees, the rate of return decreases with increasing tree size even though the expected grade, height, and diameter increment may be identical.

Richard M. Godman

Table 1 .-*Economic maturity diameters of sugar maple for selected growth and grade combinations at given rates of value increase*

(In inches)

Butt log grade	Diameter increase (D.b.h. growth--Inches)			Diameter and 1/2 log height increase (D.b.h. growth--Inches)			Diameter and 1 grade increase (D.b.h. growth--Inches)			Diameter and 1/2 log plus 1 grade increase (D.b.h. growth--Inches)		
	1.4	1.8	2.2	1.4	1.8	2.2	1.4	1.8	2.2	1.4	1.8	2.2
6 PERCENT RATE OF VALUE INCREASE												
3	18	19	21	21	22	24	No grade increase expected?					
2	15	17	19	18	20	22	23	24	25 +[3]	26+	26+	26+
1	1	1	1	15	18	20	No grade increase expected'-					
4 PERCENT RATE OF VALUE INCREASE												
3	22	23	23	27 +	28 +	28 +	No grade increase expected[2]					
2	20	22	24	25	26	28+	28+	28+	28+	28+	28+	
1	16	19	22	24	26	27	No grade increase expected'					
2 PERCENT RATE OF VALUE INCREASE												
3	30 +	30 +	30 +	30+	30+	30 +	No grade Increase expected'					
2	30 +	30+	30 +	30 +	30+	30 +	No grade increase expected[2]					
1	30	30 +	30 +	30 +	30+	30 +	No grade increase expected'					

[1] Maximum rate of value increase for butt log grade 1 trees is 5.6 percent or lower considering only diameter increase.

[2] Because of large diameter.

[3] + indicates that diameter will be higher than indicated but is beyond limitations established for analysis.

[4] Maximum grade considered in present study.

NORTHERN HARDWOOD NOTES

Lumber Value And Rate Of Return For Sugar Maple

In commercial terms, trees change in three ways: by growing in diameter, growing in merchantable height, and changing in grade. So when you are marking a stand for thinning and you have to choose between two trees of the same species, you estimate what the future diameter, height, and tree grade will be for each tree if the other is cut. Then you compare the predicted changes and decide which to cut and which to leave.

It's easier to compare these changes if you can translate them into dollars. That's where the "dollar value" and "rate of return" are useful. The dollar value of lumber is the present value of a tree (of given diameter, log height, and log grade) if milled. The rate of return is simply the percent (compounded annually) at which that dollar value increases as the tree grows or changes in grade over a lo-year period. Together they provide you with numbers that allow you to say with some certainty: " The changes in tree 1 will make it increase $18.54 in value in 10 years if left, while changes in tree 2 will make it increase $21 .12. I'll save tree 2."

The accompanying table shows the IO-year increase in value of various combinations of diameter growth (1.4, 1.8, and 2.2 inches), ½-log height growth, and 1 -grade quality increase. These are the combinations you will most likely need when you are eyeballing two sugar maples and trying to decide which one to leave.

To use the table, simply find in columns l-4 the characteristics that best describe the tree in question. Then read across to the pair of columns that best describes your prediction of what the tree will be like in 10 years. For example, if you are considering a 16-inch, 1½-log, grade 2 tree that you judge will grow 2.2 inches and increase in quality by 1 grade in 10 years, you find that it will have increased in value $8.90 (column 9a) for a rate of return of 11.7 percent (column 9b).

A couple of rules-of-thumb will help:

1. An increase of one grade is worth more than an increase of ½-log in merchantable height (compare columns 6a and 8a). In general, it's also true that a grade increase is worth more than a 1.8-inch increase in diameter. Rule: Leave the tree that is more likely to increase in grade the most in the next 10 years, regardless of potential increase in diameter or merchantable height.
2. Rates of return for small trees are higher than for large trees given the same rate of growth (see any "b" column). It's easy to see why: In a small tree, an inch of growth makes up a larger portion of the total tree's volume than in a large tree.

Table *1 .-Ten-year increase in value and rate of return for various combinations of diameter, merchantable height, and grade increase'*

1	2	3	4	5a	5b	6a	6b	7a	7b	6a	8b	9a	9b	10a	10b
														1/2-log height growth + 1 -grade increase +	
						1/2-log height growth +		1 -grade increase +							
Present size, grade, and value				1.8-inch D.B.H. growth		1.8-inch D.B.H. growth		1.4~inch D.B.H. growth		1.8-inch D.B.H. growth		2.2-inch D.B.H. growth		1.8-inch D.B.H. growth	
D.B.H. (in.)	Height	Grade	Value	Value increase	RR	Value increase	RR	Value increase	RR	Value increase	RR	Value increase	RR	Value increase	RR
	Logs		*Dollars*	*Dollars*	*Percent*	*Dollars*	*Percent*	*Dollars*	*Percent*	*Dollars*	*Percent*	*Dollars*	*Percent*	*Dollars*	*Percent*
14	1/2	3	0.50	1.57	15.2	2.21	18.3	3.97	24.4	4.47	25.7	4.99	27.0	5.32	27.7
		2	2.41	2.57	7.5	3.42	9.2	5.48	12.6	6.14	13.5	6.83	14.4	7.78	15.5
16	1/2	3	1.58	2.28	9.4	3.40	12.2	5.73	16.6	6.41	17.6	7.11	18.6	7.93	19.7
		2	4.40	3.59	6.1	5.11	8.0	7.17	10.2	8.02	10.9	8.90	11.7	10.55	13.0
		1	7.84	4.59	4.7	7.11	6.7	—[2]	—	— —	—	—		—	—
	2	2	5.14	4.36	6.3	5.85	7.9	8.77	10.5	9.81	11.3	10.88	12.0	12.35	13.0
										—		—		—	—
18	1/2	[illegible]	[illegible]	[illegible]	[illegible]	—	—	9.10	8.5	10.16	9.2	11.26	9.8	—	—
		1	11.49	5.90	4.2	—	—	—	—	—	—	—	—	—	—
20	2	2	13.20	7.80	4.8	11.30	6.4	13.86	7.4	15.60	8.1	17.25	8.7	18.51	9.9
22	2	2	19.45	9.54	4.1	—	—	16.53	6.3	18.54	6.9	20.55	7.5	—	—
24	2	2	26.95	10.92	3.5	—	—	19.10	5.5	21.12	6.0	23.16	6.4	—	—
26	2	2	35.15	12.03	3.0	—	—	—	—	—	—	—	—	—	—

'Condensed from "Economic values for growth and grade changes of sugar maple in the Lake States", R.M. Godman and J. J. Mendel, RP-NC-155 North Central Forest Experiment Station; 1978. 16 p. Microfiche copy $4.50. Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22151. Give Accession number PB 287747/AS.

[2]—Change not expected over the next 10 years.

The "best" size tree to grow depends on the rate of return the landowner wants. Of course if harvesting or milling costs go down in the next 10 years (or if the tree were converted into veneer instead of lumber), the net dollar value would be higher for the same size tree than before. That means the landowner could let the tree grow bigger before cutting. Even though the rate of return drops for bigger trees, the added value (because of reduced costs) would keep the rate of return above the landowner's minimum.

Reference

Godman, Richard M.; Mendel, Joseph J. Economic values for growth and grade changes of sugar maple in the Lake States. Res. Pap. NC-155 St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1978. 16 p.

Richard M. Godman

NORTHERN HARDWOOD NOTES

Persistent Insect, Disease, And Climatic Problems

Managed old-growth northern hardwoods have few insect and disease problems Insect damage is only occasional and any major decay from diseases can be eliminated in three cyclic cuts.

Surprisingly, second-growth hardwoods-especially even-age stands-are affected more in the long term by insects, diseases, and climate. Fortunately, these problems can be minimized in even-aged stands by proper thinning and encouraging diverse species.

Insects

Many insects can occasionally become epidemic and cause heavy losses, but a chronic pest is the bud miner in opposite-branched sugar maple. It attacks the terminal bud and can cause forking ‘throughout the life of the tree. Bud miners are continuously present. In stands under even-age management, they affect every tree in or above the main canopy. The forks that miners cause shorten merchantable height and reduce vigor, or provide major entry points for decay and discoloration if the fork splits off. Under proper management, side competition corrects forking over a period of years (see Note 4.12 fork Occurrence *and Correction).*

Diseases

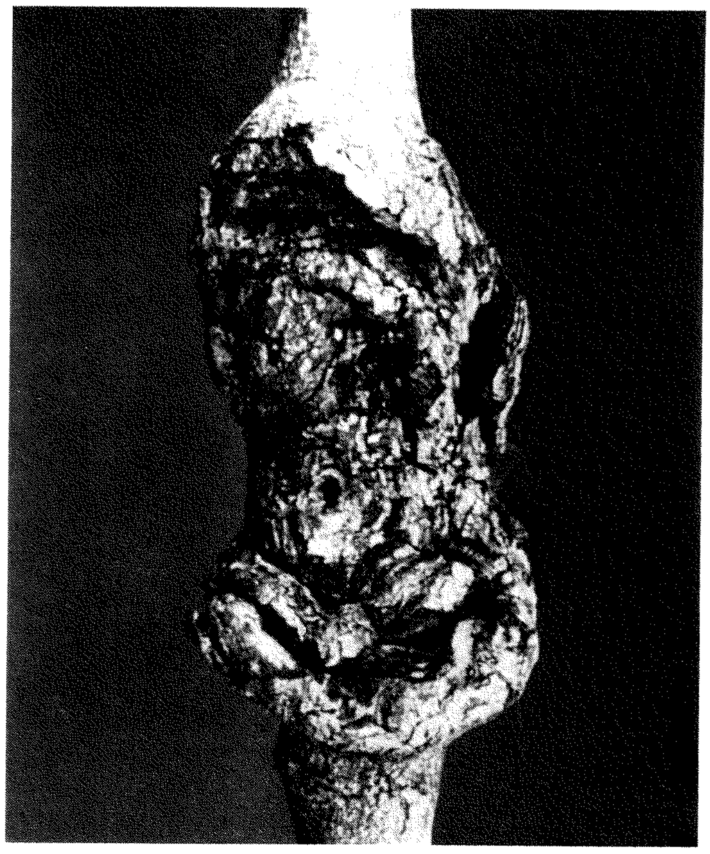
Nectria canker (on all hardwoods) and Eutypella canker (only on maples) are the most serious diseases, especially in even-aged stands. Nectria is more common under the shelterwood system than under other even-age management methods, and Eutypella may be too. In the oldest shelterwood cuttings, nearly all the large trees have serious cankers and many are broken or already dead. Changing the shape of the cut, removing cankered trees from the overstory before the regeneration cut, and encouraging more species during regeneration may help.

Sapstreak disease hits trees whose roots have been damaged by logging in the spring and early summer. Particularly vulnerable are sawtimber-size trees. Restricting time of logging or using wheeled forwarders could keep this disease from becoming a bigger problem under all types of management (see Note 7.04, Sapstreak Disease in Sugar Maple).

Wood-rotting diseases are common in young hardwoods but usually have few long-term effects in managed stands if wounding is kept to a minimum and wounded trees are removed in subsequent thinnings. In some areas, 1- to 3-inch-long cracks form throughout the lower bole of sugar maple. Most heal in a short time but new ones continually develop. The cause of these “annual maple cankers” is unknown but appears to be associated with sharp temperature variations in the bolewood. To help prevent their formation, maintain the recommended stand density and thin periodically.

Nectria canker on a sugar maple. These cankers can vary considerably in appearance; old cankers on sugar maple are frequently almost circular with callous ridges.

Eutypella canker on a sugar maple sapling. These cankers seldom girdle the stem but the enlarged, distorted growth around the canker may structurally weaken the tree. A branch stub was probably the entry point for the fungus.



An old Eutypella canker on a mature sugar maple. Usually there is one canker per tree occurring 2 to 8 feet above the ground.

Climate

Winter sunscald, which leaves large open catfaces on the south and southwest from the snowline several feet up the bole, sometimes causes much cull on trees in certain topographic positions.

Hardest hit are 1- to 3-inch sugar maples in even-aged stands. To reduce losses try to encourage more trees of other species.

All-aged stands are seldom damaged because small trees are shaded by larger ones.

Frost or hard rains frequently destroy male flowers before pollination. Because of this, viable white ash seed crops occur only at long intervals. Management techniques must take sporadic seed crops into account.

Richard M. Godman

A four-foot-long winter sunscald on sugar maple. On bright days with snow cover, the inner bark is warmed enough to become active, and then is killed when temperatures fall sharply at night.

Thin-barked trees such as maple are most susceptible to winter sunscald, especially when they are young.

NORTHERN HARDWOOD NOTES

Recognizing And Preventing Maple Decline

Maple decline (i.e. maple blight, maple dieback) has periodically caused significant losses of sugar maple in northern hardwood forests. The first major outbreak of maple decline was reported in northeastern Wisconsin and upper Michigan in the late 1950's. The disease reappeared in the same general area during the late 1970's and early 1980's.

Maple decline is characterized by branch dieback, discolored or stunted foliage or both, and epicormic sprouting. These symptoms often combine to give affected tree crowns a tufted appearance. Maple decline affects all size trees, but particularly those that are suppressed or overmature and thus low in vigor. Trees die in small scattered pockets, rather than in large continuous blocks. Affected trees normally die over a period of several years, but some may succumb in one season. Others recover entirely. Maple decline can be confused with other diseases such as sapstreak or Verticillium wilt. Both of these diseases result in leaf distortion and branch dieback. Differentiating among maple blight, sapstreak, and Verticillium wilt often requires laboratory isolations.

The tufted appearance of a tree with maple decline.

Maple decline is caused by a complex of insects and diseases working together or in succession. Insect defoliation, caused by leaf rollers and the maple webworm, can trigger the outbreak of maple decline. Such defoliation occurs early enough in the season (July-August) to allow affected trees to reflush, but late enough so they do not harden off before the end of the growing season. Early fall frosts and low soil moisture also increase the severity of maple decline. Singly or combined, these reduce tree vigor and food reserves. As defoliated trees are weakened, Armillaria root rot builds up and eventually kills the tree.

Maple decline is most severe in understocked stands and in stands that have a lot of sugar maple. So, to prevent or reduce potential losses from maple decline maintain well stocked stands and a diversity of species. The more diverse the species the less susceptible stands are to severe insect defoliation.

Reference

Lakes States Forest Experiment Station. The cause of maple blight in the Lake States. Res. Pap. LS-10. St. Paul, MN: U.S. Department of Agriculture, Forest Service, Lakes States Forest Experiment Station; 1964. 15 p.

James W. Walters

NORTHERN HARDWOOD NOTES

Dutch Elm Disease

Since its discovery in the United States in 1930, Dutch elm disease has killed thousands of native elms. The three native elms, American, slippery, and rock, have little or no resistance to Dutch elm disease, but individual trees within each species vary in susceptibility to the disease. The most important of these, American elm, is scattered in upland stands but is more abundant on wetter sites and along river bottoms.

Dutch elm disease continues to spread and intensify. In the past decade, a more aggressive strain of the fungus has appeared in the Midwest, causing additional losses to the remaining elm population. As long as susceptible elms are available, Dutch elm disease will be present in hardwood stands. However, because of the variations in susceptibility, some elms will persist and in future years this disease will become endemic.

Recognizing Dutch elm disease during early to mid-summer is easy. Infected trees have wilted, yellow foliage on one or more branches. At times, an entire crown will wilt all at once. Infected branches develop a brown stain just under the bark. During late summer, Dutch elm disease is more difficult to identify because of color changes associated with natural leaf drop.

Dutch elm disease is spread from infected to healthy trees by root grafts and bark beetles. The most important insect vectors are the native elm bark beetle and the smaller European elm bark beetle. These beetles emerge from infected trees carrying fungus spores that they transmit to healthy trees as they feed. The spores germinate in beetle galleries and the fungus spreads through the tree, eventually plugging the water-conducting system.

Losses to Dutch elm disease in hardwood forests vary in severity. Generally, the more American elms in a stand, and the more concentrated they are, the more severe are losses from the disease. Although elms of all sizes are susceptible to Dutch elm disease, seedlings and saplings are less susceptible than larger trees because they are not attractive to the bark beetles and are less likely to root graft. Control of Dutch elm disease in hardwood stands is generally not feasible, but you should salvage commercial-size American elms if they make up a significant portion of the stand.

Reference

Stipes, R. Jay; Campana, Richard J., ed. Compendium of elm diseases. St. Paul, MN: The American Phytopathological Society; 1981. 96 p.

James W. Walters

NORTHERN HARDWOOD NOTES

Sapstreak Disease Of Sugar Maple

Sapstreak is a fatal disease of sugar maple that usually enters the tree through basal trunk scars or root wounds. The disease most often affects large, wounded trees left after logging. The fungus causing sapstreak readily infects stumps or cut logs during the summer months. So, wounding sugar maples during this time will increase the potential for disease spread. In the Lake States, sapstreak has only been found in a few areas of Michigan and at one location in Wisconsin. Although few trees have been killed by sapstreak, it has the potential to become a serious disease in sugar maple stands.

Symptoms of sapstreak include stunted foliage throughout the crown, gradual branch dieback, and gray stain developing in the lower bole and roots. The radiating, streaked pattern of the stain is characteristic of this disease. Often symptoms go unnoticed until the affected tree dies, normally 3 to 4 years after infection.

Stump of a diseased sugar maple showing radiating pattern of stain.

Sapstreak is spread from tree to tree or stump to tree by insects that carry the sticky spores. Spread of the disease can be reduced or prevented by removing infected trees, avoiding summer logging, and preventing wounding, especially to roots and bases of trunks. Infected trees should be removed as soon as possible to minimize degrade from stain. Early detection and prompt removal of infected trees will prevent sapstreak from becoming a serious threat to sugar maple stands.

Reference

Kessler, K. J., Jr. Sapstreak disease of sugar maple. Forest Pest Leafl. 128. St. Paul, Minnesota: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1972. 4 p.

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NORTHERN HARDWOOD NOTES

Tree Injuries From Mechanized Logging

Small trees in even-aged northern hardwood stands suffer the most mechanical damage when stands are thinned for the first time. From 15 to 35 percent of the trees may be damaged; a quarter of the trees (but usually less than 20 per acre) can be seriously damaged by having at least 50 square inches of the cambium exposed. Bole damage is most common, followed by root and then crown damage.

Although mechanical logging takes its toll of injuries, it makes early thinnings economical, shortens rotations, and speeds volume and quality growth. You can remove damaged stems in later thinnings because initial thirinings commonly leave more than three times the number of trees required at maturity.

What about long-term impact? Most studies show that severe damage to fewer than 30 trees per acre in first thinnings should have little impact if most of the trees are small. Rapid growth on small trees tends to heal injuries quickly.

Skillful operators, of course, and good weather make for less damage. Here are some other ways to minimize damage:

1. Use short equipment, or equipment with boom-mounted heads.
2. Lay out logging patterns to match the equipment.
3. Expect and plan for skidding turns at sharp angles.
4. Look for and then avoid large, high quality trees during logging.
5. Use a large turning radius with all machines, particularly tracked equipment.
6. Encourage reasonable load limitations.
7. Do not log during extremely wet periods.

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NORTHERN HARDWOOD NOTES

Wounding And Hardwood Diseases

Most hardwood diseases are spread by spores that are carried either by wind or insects. The spores enter into the host tree through natural wounds (fire scars, bark splits, sunscald, cankers, and branch stubs) or artificial wounds (bark carving, improper pruning, logging damage). Fresh wounds attract certain insects that can carry spores into the exposed part of the tree. The most common type of wound in managed forests results from logging.

A yellow birch showing stem and root injury from logging. The dark wound face is a good indicator of internal defects. Logging should be carefully done because damage to the butt log can produce considerable loss.

The type of disease that enters the tree depends upon the type of wound and its location. Branch wounds are most likely to become infected with diseases such as Hypoxylon canker, Cytospora canker, or Botryodiplodia canker. Trunk wounds provide entry for many heartrot fungi, oak wilt, Nectria canker, Hypoxylon canker, and Eutypella canker (see Note 7.01). Wounds on the roots or root collar often serve as entry points for butt rots and some root diseases. Root wounds on sugar maple can become infected with sapstreak (see Note 7.04).

The size and age of the wound and season of wounding all influence the amount of defect associated with a wound. Generally, the larger the wound the longer it will take to callus over and, consequently, the longer the exposure time to disease organisms. Wounds less than 10 to 15 years old usually have little decay. Wounding during spring and summer increases the potential for disease spread into the tree. During winter, most disease organisms are inactive and wounds are not as likely to become infected.

Some hardwood diseases, such as Eutypella canker and Nectria canker, continually enlarge, but normally do not kill the host tree. However, the cankers weaken the trunk, making the tree susceptible to wind breakage. In addition, they cause a significant amount of degrade in sawtimber-size trees. Other diseases, such as root and trunk rots, destroy the inside of the tree. This weakening process can result in broken off or blown over trees.

Land managers can minimize tree wounding by carefully planning and administering logging operations, maintaining sufficient stocking to promote rapid self pruning and prevent sunscald, using the proper pruning technique, and controlling wildfire.

James W. Walters

NORTHERN HARDWOOD NOTES

Minimizing Yellow-Bellied Sapsucker Damage

The yellow-bellied sapsucker is a migratory woodpecker that feeds on a wide variety of orchard, shade, and forest trees. Instead of drilling holes to find insects like other woodpeckers, sapsuckers drill holes in living trees to feed on sap and phloem tissues. Yellow and paper birches are their favorite summer food sources on their nesting grounds in Upper Michigan and northern Wisconsin. Hemlock, sugar maple, and other species are favorites in the spring.

During the summer, each pair feeds on selected trees within their lo-acre territory. Nearly all feeding damage occurs within 500 feet of their nests which are excavated in dead trees, stubs, (or trees with decayed centers) over 10 inches in diameter. Sapsuckers cannot excavate more than 1 inch of sound wood, so most nests in second-growth stands are located in overmature aspens and dead stubs of cull trees left over from commercial clearcutting.

Adult sapsuckers drill characteristic ¼-inch square holes through the bark to the cambium. Holes usually are drilled about ½ inch apart in horizontal rows. On heavily damaged trees, rows of holes often extend several feet up the stem and patches of bark between holes flake off.

Heavy sapsucker feeding (50 or more holes in a band or patch) can lower wood quality, reduce growth, and even kill birch trees. Besides discoloration and decay, their feeding injuries cause a localized ring shake. Sapsuckers kill trees and cause top dying by girdling the main stem within and just beneath the live crown. Sapsuckers frequently return to feed on favorite trees in successive breeding seasons until the trees are killed.

These birds feed on trees of all sizes, but most heavily on large saw-log and pole-size trees. They prefer feeding on healthy dominant and codominant trees that have been excessively exposed by heavy thinning, or growing along roads, right-of-ways, and openings. Even in unmanaged stands, they select the largest paper and yellow birches as favorite feeding trees. Sapsuckers are also attracted to old sapsucker wounds and other types of injuries.

Sapsuckers are protected by State and Federal laws and probably could not be controlled by shooting or poisoning because other birds would soon fill vacant territories.

Here are several ways to lessen the impact of sapsucker damage on valuable yellow or white birch.

1. Don't leave valuable saw-log-size birch trees exposed along edges of openings or in shelterwood overstories as seed trees. Adequate seed can be obtained from four well distributed trees per acre or by applying ½ pound of stratified seed from a superior phenotype after site preparation.
2. Don't release birch trees more than 5 to 7 feet beyond their crown perimeters when thinning.
3. Immediately harvest valuable birch trees that are being or have been fed on.
4. Leave low-grade birch trees that sapsuckers are feeding on to slow their movement to more valuable birch trees (they may often kill a residual cull for you).
5. Fell all potential sapsucker nesting trees (large dead, cull, and overmature aspen with decayed centers) within 500 feet of prime birch trees or stands.

Gayne G. Erdmann and *Ralph M. Peterson, Jr.*

NORTHERN HARDWOOD NOTES

Making Wildlife Openings

Most wildlife doesn't prosper in our dense second-growth pole stands. Game animals and birds in particular need openings where various grasses, shrubs, and herbs will flourish away from the dense shade of northern hardwood trees. Here animals, such as deer, bear, and snowshoe rabbit, find the food they need, especially in spring and fall. And birds, such as the ruffed grouse and woodcock, use the openings for nesting and brood rearing.

One rule of thumb is to turn 3 to 5 percent of your total forest area into wildlife openings. You should locate some openings on areas where growing conditions are naturally adverse; this will extend the life of the opening and make it more cost-effective. But there is usually a much larger area of overstocked, good sites that will be improved by the creation of wildlife habitat.

Locating Openings

Locate some openings on poor sites where trees will be slow to reproduce. Some likely areas are:

- Frost pockets,
- Poorly drained sites,
- Very dry sites,
- Sites with shallow soil.

You can, of course, look for such sites on topographic maps, soil maps, aerial photos, and forest type maps. A change in species will often indicate a wet spot-for example, a pocket of black ash, red maple, yellow birch, American elm, black spruce, or hemlock growing in the midst of sugar maple.

On good sites, try to locate openings where the advance reproduction is less than 1 foot tall, no more than 2 feet. This will assure a longer life for the opening. Advance reproduction more than 1 foot tall will most likely sprout after it is cut down.

Try to create openings bordering on a logging trail, another timber type, or a marsh. Game will use the trail for a travel lane; openings that border other types will contain a greater variety of vegetation.

Making the Opening

Make openings 1 to 10 acres in size; several smaller ones are better than one big one. Make openings irregular in shape so that the perimeter will be longer and have more “edge” vegetation. Try to leave large crowned, codominant trees on the edge. Such trees are less likely to develop epicormic sprouts than smaller crowned trees when the stand is opened up. Because existing branches will persist after the opening is made, border trees should have a bole free of branches for a log and a half. (Warning: Don’t leave valuable saw log-size yellow birch along the edge of the openings. Such trees are vulnerable to sapsucker damage. See Note 7.07, Minimizing Yellow-Bellied Sapsucker Damage). If possible, leave clumps of conifer on the border as cover and shelter for wildlife.

If you make openings in stands heavily stocked with good sprouters, such as red maple, basswood, or aspen, cut during summer and spray stumps with a safe herbicide to discourage sprouting.

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North Central Forest Experiment Station 8.02

NORTHERN HARDWOOD NOTES

Woody Browse Production

Sugar maple has great potential as wildlife food, especially as good winter fare for deer in the northern Lake States. Deer will diligently seek out sugar maple browse in the hardwood forests along the edges of a winter yard or in isolated islands of upland forest within a yard.

The amount of available browse produced depends on the species available and the condition of the stand. In upland northern hardwoods, uncut pole stands with 100 to 120 square feet of basal area have very little browse, only about 1 pound per acre (see table). In contrast, open upland stands with vigorous regeneration produce the most. A 7-year-old clearcut strip, for example, can have up to 122 pounds per acre.

Dry weight of buds and twigs cod available browse per acre, and percent sugar maple for different stand conditions

	Dry weight		
Stand condition	**Twigs and buds (total)**	**Available browse**[1]	**Sugar maple**
	---- *Lbs/acre*	----	*Percent*
Northern Hardwoods			
Pole stands 40-60 years old			
1. Uncut (100-l 20 sq ft)	2-5	Up to 1	65
2. Selection (75 sq ft)			
1 year after cut	20-25	5-6	75
3 years after cut	66-120	16-30	89
3. Clear-cut strips			
7 years after cut	**490**	122	
12 years after cut	160	40	55
Mature Stands			
1. Shelterwood (80 sq ft)			
4 years after cut	250	62	81
5 years after cut	375	94	97
Mixed Conifer-Hardwood Swamp			
1. Uncut	38	9	0-1
2. Shelterwood			
4 years after cut	100	25	2-3
3. Clear-cut strips			
4 years after cut	70	17	2-3

[1]About 25 percent of the weight of all buds and twigs are available for browse.

Extremes are not as great in mixed conifer and hardwood swamp forest. Uncut conifer and swamp stands produce more browse than uncut stands of upland hardwoods but clearcut strips produce less than clearcut upland hardwoods.

Try to schedule timber cutting during the winter in areas where deer use is heavy. Tree crowns provide more browse than reproduction and can reduce the feeding pressure on understory vegetation.

Tom Crow and *Forest Stearns*

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