Silvicultural Guide for Northern Hardwoods in the Northeast (second revision)

By

W.B. Leak, M.Yamasaki, R. Holleran 5/26/11, updated 12/1/11 (1/19/12)

Hi Bill,

I have taken a fairly quick look through your document and made a few comments within the text for you to consider. As always, you include a wealth of great information and it is very clear and accessible. You have not lost your touch!

I understand the reasoning for moving away from a strict timber focus as is the case in the current edition. However, this guide still has a heavy timber focus but with add-ons. This is not going to be helpful especially if we continue to rely so heavily on your guide for our Current Use Program.

Please excuse if I overstep here, but how about this approach?

What about giving some background about the evolution of forestry from A strong focus on timber management (Pinchot) to one which focuses more on forest health conservation (Leopold).

Forests provide a wide variety of goods and services. Wood Products include timber..... Non-Wood Forest Products include.... Forest Services include.....

Mention here that "forestland owners should have much more freedom in choosing their objectives and approaches" (Leak personal communication!).

Before managing for forest products and services such as timber production, wildlife habitat, and recreation, it is critically important to focus first on forest health. Leopold told us that healthy land has the capacity for self-renewal.

Indicators of this capacity include water quality, site productivity, native biological diversity, carbon sequestration and storage, and forest vitality.

Look at the status of forest hydrology. Where are the streams, wetlands, vernal pools, seeps, etc.? What is their condition? Are they properly buffered, etc? Look at the status of the soils - are they eroded, compacted, lacking in organic matter, etc,...? And so on......

BOTTOM LINE - Step One is assessing the health of the forest.

The next step is to carefully manage for uses that support the objectives of the landowner, state regulations, tax abatement programs, etc. This can include management for Wood Products (such as high quality timber, biomass, fuelwood,) Non-Wood Forest Products such as maple syrup, mushrooms, etc. and Forest Services (such as watersheds, wildlife habitat, recreation, esthetics...)..

It could be stated that this guide is intended for use in the management of northern hardwood forest communities for high quality timber products. A companion guide is intended for wildlife habitat improvement. Future companion guides will cover other Wood Products, Non-Wood Forest Products, and Forest

Services.

Phew. I did not mean to go on so. But Bill, this is exceptionally important. Your guide will become the Bible and landowners will have to follow it. We must build in more flexibility. We must address the non-timber functions, values, and services of forests.

Thank you again for this opportunity! I hope that I can stay engaged in this exciting opportunity.

David Brynn, Executive Director
Vermont Family Forests

Abstract

This is a revision of the 1987 silvicultural guide (Leak et al 1987). It includes updated silvicultural information on northern hardwoods as well as additional information on wildlife habitat and the management of mixedwood and oak stands. The prescription methodology is simpler. This guide also includes an appendix of tables, graphs and short summaries of management topics that should be useful to practicing field foresters and landowners.

Key Words: northern hardwoods, silvicultural/wildlife prescriptions, silvicultural/wildlife guidelines, northern hardwood management, beech-birch-maple

Purpose and Scope

This is the fourth silvicultural guide for northern hardwoods (beech-birch-maple) in the Northeast. This guide is a revision of the one published in 1987 (Leak et al). This revision provides updated information on approaches and results for a complete range of silvicultural practices for timber management as well as related implications for wildlife habitat development. In addition, appendices include information on control of invasives, exotic insects and diseases, best management practices, carbon, suggested marking codes, and useful forestry tables and graphs. This guide is written with minimal extraneous discussion coupled with supporting data, hopefully providing a useful and easy-to-read reference document.

Regional Conditions

Northern hardwoods and associated mixedwood types occupy at least 20 million acres in New England and New York; similar types occur further west and south. Forest products include wood products, non-wood forest products, and forest services (FAO). Wood products include: veneer, sawlogs, boltwood, pulpwood, fuelwood, smallwood, and biomass. This variety provides unusual opportunities to grow and market wood products with a variety of species and tree qualities, therefore providing for a high level of silvicultural practice. These forests also provide habitat for well over 200 vertebrate wildlife species, excellent summer and winter recreational opportunities, high quality water supplies, and many other forest services.

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Management Objectives

Comment [DJB1]: Would it be good to mention the Triad here – ie. Ecological reserves (self-willed), new forestry (light-on-the-land) , and intensively managed forests (tree farms)?

Landowners in New England and New York have a wide range of reasons for owning northern hardwood forestland. Industrial ownerships manage primarily for commercial forest products, but are constrained by the need to maintain wildlife habitat, visuals, and water quality. Many forest landowners are primarily interested in wildlife habitat, recreation, and esthetics, but need some level of income from forest products to meet the costs of ownership. Also, some state tax abatement programs have traditionally required active timber management, which provides further incentive to manage forestland for various goals. This guide attempts to provide information that will be useful to all.

Since trees grow, forests naturally get crowded. Over-crowding is a natural condition and it does not necessarily have a negative impact on forest health. However, crowding is the single most important factor affecting the health, growth and vigor of most forest trees. Newly regenerating stands might have 10,000 trees per acre, and with natural development, at least 98% of these die by suppression and other natural factors by the time the stand reaches maturity. Silviculture provides methods to guide this development in selecting the trees that make it to maturity to achieve some objective, along with creating desired stand structure. Also, when it is time to promote regeneration, the forester can provide conditions that are favorable to desired species, making re-planting unnecessary.

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Species and Sites

Species and their characteristics are summarized in Table 1. These species occur in recognizable groups or forest types that are closely related to site characteristics and past disturbance (primarily harvesting and agriculture; fire and blowdown to a lesser degree). Forest types and related site characteristics are in Table 2. In developing silvicultural prescriptions, it is very important to be aware of site characteristics and related species successional tendencies. The richest sites supporting sugar maple, ash, and some basswood are found on till soils derived from calcareous bedrock. These areas usually support a rich groundflora. A similar forest type also occurs on enriched soils in areas dominated by granite or other bedrock sources with low to moderate nutrient levels; these soils occur at the base of slopes or terraces, with accumulations of organic matter. However, typical northern hardwoods containing sugar maple, yellow birch, and up to perhaps 50% beech (sometimes more) occur on non-calcareous till soils. Beech-red maple types, often with a softwood component, are common on non-calcareous sandy tills and other lower nutrient sites.

Mixedwood stands often occur following harvesting disturbance on essentially softwood sites: outwash, shallow bedrock, and very shallow (often wet) soils underlain with basal till (hardpan). Sometimes past agricultural use will produce a softwood component due to changes in soil characteristics from grazing, erosion or compaction; oak-pine may be a component on these disturbed sites. Often, pasture regrowth pine will be eventually replaced by hardwoods. Use the white pine silvicultural guide (Lancaster and Leak 1978) while pine is the featured species, then shift to the hardwood guide as hardwoods become more than 50% of the stocking. Mixedwoods can be managed to either favor a greater proportion of softwoods or the hardwood component, providing opportunities for habitat diversity. Mixedwood is referred to at several places in the text as well as under a separate topic before the section on prescriptions. Oak regeneration is addressed in a separate section under the topic of shelterwoods.

Silvicultural Systems

It still seems useful to recognize two classes of silvicultural systems, unevenaged and evenaged, although there are many hybrid approaches.

Unevenaged systems consist of single-tree and group/patch selection approaches. The stands consist of, or develop, at least three age classes. Harvesting occurs at somewhat regular intervals, the cutting cycle, and harvesting entries are regulated so that the stand (or groups of stands) are maintained over time. Generally, there are no separate cultural operations; stand improvement (removal of defective, low-vigor, low-value trees) occurs as part of the harvesting operation. However, there are instances where there could be cultural work within the small evenaged portions created by group/patch selection. Unevenaged systems tend to mimic the wind-dominated natural disturbance regimes that are most common in the self-willed hardwood forests of the northeast.

Evenaged systems consist of regeneration harvests (or pasture abandonment) that create stands with one age class (from clearcuts, patch clearcuts, strip cuts) or two age classes (any of several shelterwood approaches). These harvests occur at the point of stand maturity, the rotation age. There are well recognized (but optional) intermediate operations including noncommercial investments (weeding, release, pruning) as well as one or more commercial thinnings. Stand improvement takes place as part of these operations.

Unevenaged Management: Single-tree Selection

This method is simply the harvesting of single trees, generally separated from one another, so that a continuous crown canopy is maintained coupled with a range of diameter classes. The application of this system requires specification on: 1. stand density and structure, 2. marking guidelines, and 3. cutting cycle (the time interval between entries). The evaluation of single-tree selection approaches involve: 1. regeneration (species composition), 2. growth and yield, and 3. quality development. The chief advantage of single-tree selection is that it is a light touch on the landscape for those concerned about maintaining an unbroken forested appearance. The chief concerns are that it: (1) regenerates primarily tolerant species: beech and mixedwood on mediocre sites, sugar maple on excellent sites; (2) maintains a suite of wildlife species associated only with mature forest (Table 3A and 3B) and (3) may cause more bole/root damage from logging operations than other silvicultural approaches.

Single-tree selection is sometimes used as an excuse for high-grading: removal of the most valuable trees, often the largest ones in the upper crown classes (essentially diameter-limit harvesting). With true single-tree selection, it is important to remove a portion of the unacceptable growing stock on each entry and to maintain a component of vigorous growing stock in the upper crown classes. Since overstory trees are eventually accumulated from the mid and lower canopies, previous suppression can affect their vigor and quality.

Stand Density and Structure:

Results from a study of stand density and structure on the Bartlett Experimental Forest, New Hampshire, are in Table 4. In general, the best growth results occurred with residual basal areas of 60-80 sq.ft./acre (trees > 4.5 inches dbh) with at least 25-30 square feet sawtimber (trees >10.5 inches dbh; however, growth responses are quite variable. This stand was beech-red maple on a sandy till site, so the specifications on residual sawtimber basal area should be considered a minimum. On good/excellent sites, residual sawtimber basal areas of 50-60 square feet with at least 80 square feet total basal area are quite feasible. Within this range, it is important to leave vigorous trees with high potential quality. Earlier guides stressed the importance of following a reverse J-shaped stand structure (number of trees by dbh class). Currently, we believe that specifications on a range in residual basal area and basal area in sawtimber (possibly large vs smaller sawtimber) as outlined above are sufficient – provided that the system produces desirable regeneration.

Maintenance of adequate stocking of acceptable timber growing stock in both unevenaged and evenaged stands ensures good growth per acre as well as adequate quality development since open-grown trees do not naturally prune well, and may epicormic sprout, especially certain species such as yellow birch (see Table 1).

Comment [DJB2]: It is very important to point out that the ultimate product defines the terms of quality.

Marking in poletimber sizes should be restricted to trees with low economic value potential; removal of small trees with quality potential to simply meet a stocking/structure objective will reduce the ingrowth into the sawtimber size class. Removal of defective trees in all sizes will improve the timber quality of the ingrowth.

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Mixedwood stands (stands with 25-65 percent softwoods) support higher basal areas than hardwoods, in the neighborhood of 180 square feet maximum vs. 130 square feet in hardwoods (Fig.1); the greater the softwood proportion, the higher the residual basal area. Residual basal area guidelines as described above should be raised by a factor of up to 50% in stands maintained as mixedwood.

At this point, it is important to point out that wildlife habitat quality should be maintained by leaving some specific wildlife trees. One or two per acre may be sufficient. These are trees with cavities (especially large cavities), evidence of bear feeding, raptor nests, or basket forks with potential for raptor nest sites (see Table 3A). Retention of softwood patches or individual trees (softwood retention) also adds to wildlife diversity, and it is important to maintain a range of wildlife habitat conditions across a property, or several adjacent properties, at the landscape level (Table 3B).

Comment [DJB3]: Perhaps it would be best to stay with timber. There are a host of other forest products and services. Wildlife habitat is just one of them.

Comment [DJB4]: This is not true in many situations!

Marking Guides:

Marking should be directed toward trees that have low timber quality potential (defect or species) or are mature. However, be sure to maintain 1-2 trees per acre with wildlife potential (see Table 3A). Mature trees are those that have reached the peak of timber grade improvement as determined by local market conditions. Commonly, a maximum size for long-lived hardwoods (and largetooth aspen) and hemlock of about 18-20 inches, for trees of acceptable timber growing stock, is sufficient. Spruce is mature at about 14-18 inches; balsam fir, quaking aspen, and paper birch at 12-14 inches. But all these guidelines depend upon crown condition, markets and site, both extremely variable!

Comment [DJB5]: Not enough in many situations.

The term “acceptable timber growing stock” commonly is used to describe trees that have log potential and a reasonable crown; “unacceptable growing stock” denotes trees with no log potential due to defect or unhealthy crown.

Comment [DJB6]: Family forestry has moved away from such a heavy focus on timber. We need a nomenclature that reflects this.

Cutting Cycle:

The general rule on cutting cycles is to wait until there is an optimum operable harvest, prior to a significant reduction in growth due to increased stand density. Landowner concerns over finances, disturbance to the stand, and road access also play a part. Based on growth rates in Table 4, stands approaching 100 sq.ft./basal area/acre are beginning to experience slower growth and increased mortality. Based on net annual growth rates of 1.5-2.0 sq.ft./acre, a stand will change from 60-80 square feet to 100 square feet in 10 to 25 years; a good average figure is about 15 years. ImpactsInsects from insects/diseases and wind storms will, of course, shorten this estimate.

Comment [DJB7]: The damage is to timber. But insects, disease, and wind do not damage forests. They are part of forests.

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Regeneration:

Standard regeneration responses to harvest methods (Table 5) indicate that single-tree selection produces about 92 percent tolerant species. In typical northern hardwoods on granitic till soils, the species composition of saplings (2-4 inches dbh) in twice-harvested stands included 45% beech, 25 % hemlock, 13% percent striped maple, and 10 % sugar maple (Table 6). This species mix is less than desirable for commercial timber management, but quite acceptable as mature wildlife habitat for mast production. However, local results can vary widely with more sugar maple on excellent sites and more striped maple in some locations. Since single tree selection produces limited regeneration in shaded conditions, low levels of deer or moose browse can remove desired species like sugar maple. If browse is a problem, larger groups, or even large clearcuts, may be needed to secure acceptable regeneration.

Growth and Yield:

As referred to earlier (Table 4), net annual growth under single-tree selection in beech-red maple from residual basal areas of 60-80 square feet ranged from 1.5 to 2.0 square feet/acre. This is equivalent to about 40-50 cubic feet or about ½ cord. At 60 or 80 square feet residual with about 25-30 square feet sawtimber, the net growth on sawtimber alone was .6 to .7 sq.ft./acre, equivalent to 15-25 cubic feet, or about 100-125 board feet gross. Over a 15-year cutting cycle, the next cut should yield 7-8 cords per acre including perhaps 1500-2000 bf/acre. Better sites: much better yield!

Quality:

Over a 50-year period after three entries, a typical northern hardwood stand (grantitic fine till) on the Bartlett Forest showed moderate changes in species composition and moderate improvements in timber quality (Tables 7A,7B). Despite heavy marking of the beech component coupled with a heavy infestation from the beech-bark disease, the percentage of cubic volume in beech dropped from 53 to only 49 percent. Grade 1 and 2 butt logs increased from 21 to 30 percent. Sugar maple proportions increased from 18 to 25 percent, and hemlock from 3 to 15 percent. Volumes in grade 1 and 2 butt logs increased from 40 to 65 percent in hardwoods other than beech. So, the moderate volume growth and yield figures mentioned above would be accompanied by moderate improvements in both species composition (tolerant species however) and timber quality under single-tree selection.

Unevenaged Management: Group/Patch Selection

This approach to unevenaged management involves two alternative approaches: (1) the removal of trees in small clearcut patches ranging from ¼-acre or even less up to about 2 acres (or even larger); and (2) removal of trees in small groups (we'll call it group release or group shelterwood) to establish regeneration or release an established understory. The first approach is the more common and most of the following discussion deals with that approach; but there are many opportunities to apply the second approach to release desired species such as softwoods, sugar maple, and oaks. (See the section on oak regeneration under Shelterwoods: Oak Regeneration).

Marking between groups can be accomplished by some level of marking along the access trails. Individual-tree marking throughout the area leads to the problems associated with that system: excess development of a tolerant understory, excess damage to the residual trees, and somewhat uneconomical harvesting. Over time, some of this access-road marking will occur as thinnings in previously initiated groups/patches.

Group/patch selection is especially useful in stands that are patchy, a very common situation, where there are groups of mature /defective trees next to areas of less mature individuals. And it is especially useful where the landowner/manager wishes to practice unevenaged management but desires a much higher component of less tolerant species.

Regeneration:

Numerous studies on the Bartlett Forest have shown the effectiveness of group/patch selection on reducing the tolerant component of the regeneration. Basal area tallies of 50-60-year old groups, averaging about ½-acre in size (Table 8), showed that moderately-well drained sites produced about 31% sugar maple, 34% yellow and paper birch, 11% ash and 16% beech. On the very well-drained sites (so-called beech ridges), the beech composition was 26%, birch 41%, and sugar maple 11%. Comparison of these figures with Tables 5 and 6, show the impact of groups on regeneration as compared to single-tree selection.

Size of group produces variable effects. The larger the group, e.g. 2/3-acre or larger, the more intolerants – aspen, pin cherry, paper birch, Rubus spp. – might be expected. However, the results are somewhat variable. Even very small openings, down to 1/10 acre, produce some increase in less tolerant regeneration. However, these small openings rapidly close in from the side and are difficult to locate over time; so they are not as effective as larger openings. In areas with an established beech understory, larger groups (1-2 acres) with scarification will be effective in improving species composition. Scarification can normally be accomplished through the logging operation, especially with whole-tree harvesting and snow-off conditions.

Group selection does support a small to moderate level of early successional bird species; for this purpose; the larger the group/patch, the better (Table 3A). Normally, cavity trees are not left standing within groups; however, some provision for cavity users should be considered in the surrounding stand.

Where group/patch selection does not produce adequate less-tolerant regeneration, the problem may be excessive browsing from deer or moose that removes all but the tolerant stems of beech or striped maple. To help counteract over-browsing, consider: clearcutting (15 acres plus), larger numbers of groups, leaving large tops or slash barriers, local or statewide herd regulation efforts, or fencing. An excess of invasive plants or ferns may also be traced to overbrowsing. See the Appendix section on invasive plants.

Regulation :

Group/patch selection, using openings of ¼-acre or larger, is generally regulated by rough area control. For example, if the approximate rotation is 100 years, group/patch removals should approximate 1% of the stand area per year. For a 15-year entry period or cutting cycle, about 15% of the stand area should be harvested with group/patches. For initial conversion of even aged or unmanaged stands, larger percentages may be harvested to 'jump-start' the new age classes. (For much smaller openings --true "groups"-- the marking would be controlled as suggested for single-tree selection). Since the regeneration in groups develops more slowly than in clearcuts, a planning rotation of 120-140 years probably is more reasonable. For the system to be most effective, groups should be laid out in patches of mature/defective timber; the size can vary to fit stand conditions. On large industrial properties, the advantages of group/patch selection can be achieved by larger-scale application of these concepts: target multi-acre patches of mature/defective trees, and reserve immature patches. This is well-suited to mechanized harvesting systems.

Comment [DJB8]: How about calling it a conservatioon cycle?

Growth,Yield, Quality:

There are no definitive studies comparing the effects of groups/patches, or evenaged systems, on growth and timber quality with single-tree selection. However, the effects on species composition are very well documented. And experience indicates that dominant/codominant trees growing in competition with one another under evenaged conditions develop the best quality stems. Larger patches will most closely approximate these conditions.

Evenaged Management

There are two basic approaches to regenerating evenaged northern hardwood stands as discussed below: clearcutting and various shelterwood systems including a high-density vs low density regeneration harvest, and standard vs deferred removal harvest. The seed-tree method, leaving a few reserves for seed or esthetics, is used occasionally.

Following the regeneration stage, there are options on precommercial thinning or release as well as commercial thinning (s) discussed below. Rotation ages and yields under evenaged management also are discussed below.

Clearcutting:

As the name implies, clearcutting is the complete removal of mature or defective stands over areas larger than about 5 acres. Proper silvicultural clearcutting removes the smaller suppressed stems down to at least 2” diameter or smaller; whole-tree harvesting is useful for this purpose. Two- to 5- acre clearcuts are sometimes called patch clearcuts. The harvest should remove all trees except for some reserve patches, perhaps ½ acre for every 10 acres of clearcut, that provide for cavity trees, other wildlife trees, seed sources (e.g. yellow birch) and structural diversity. The regeneration will contain a mix of tolerants that were there prior to harvest and less tolerant species that developed anew. A more thorough clearcut with scarification usually is obtained with a whole-tree harvest rather than a standard clearcut; lower percentages of tolerant species are generally obtained with snow-off harvests.

Three examples of clearcut/patch-cut regeneration are in Table 9, showing the dominant stem per milacre including commercial and non commercial species. The shelterwood with 40 square feet residual basal area was a portion of the true clearcut that was feathered into the uncut border; thus, it was the same site and same harvest period as the true clearcut. Note the very high percentage of beech and striped maple. Clearcuts with any component of reserve trees will begin to resemble a shelterwood as described in later sections. The true clearcut may have a high percentage of pin cherry, which drops out of the picture as the stand ages, and can improve the quality of desired species by natural pruning. Note that the larger patch cuts (app. 5 acres) have typical early successional regeneration with high proportions of birch and pin cherry; the smaller patch cuts (app. 3 acres) have much less pin cherry and more beech in a dominant position. A typical species mix of a 25-year-old stand (percent basal area) on a (good) moderately well-drained site is included in Table 9. Even the smaller patch cuts (and group selection harvests) will improve measurably over time.

The heavy harvests and skid-trail activity associated with clearcutting call for particular attention to best management practices (Appendix) to avoid excessive erosion and compaction, as well as stream buffers to minimize impacts on streamwater.

Clearcutting is the ideal system for encouraging early-successional bird species. And evenaged management with clearcutting produces maximum vertebrate wildlife diversity; guidelines suggest that 5-15 percent of an ownership should be in the 0-10-year age class (see Table 3B). In areas with heavy deer browsing pressure, clearcuts (about 15 acres or more) help reduce the damage since deer seldom venture into the center of these larger openings until seedlings are out of reach. However, due partly to heavy browsing around the edges of clearcuts, invasive species and/or ferns may become established. See the Appendix section on invasives.

Aspen-birch stands, especially useful for grouse/woodcock management, are best reproduced by clearcutting where there is an aspen component (10% is more than sufficient)) to provide root suckering capacity. Sandy, granitic tills are suitable sites, but these species can be managed on a wide range of sites.

<u>Shelterwoods (northern hardwoods):</u>

A standard shelterwood in northern hardwoods would consist of a seed cut leaving 50-80 square feet of basal area per acre in fairly mature trees, coupled with a removal cut 5-10 years later. This type of harvest would produce a high percentage of tolerant species. On good sites, those with some calcareous influence or enriched sites, the regeneration should contain a higher proportion of sugar maple and white ash. On less productive sites, the proportions of beech and striped maple would be high, especially with browsing pressure. The removal cut requires careful choices on layout and equipment to avoid excessive damage to the regeneration; snow cover is an asset.

In managed stands that have been previously thinned, a tolerant understory may have developed already. If this is desirable, then the overstory can be removed in one or more cuts – a so-called overstory removal harvest. If an undesirable understory has accumulated, snow-off cutting or scarification or other understory treatment may be needed to shift regeneration species composition.

Low-density shelterwoods leave a residual of perhaps 20-40 square feet basal area in mature trees, including individuals (e.g. yellow birch) desired for a seed source. These provide sufficient sunlight and ground disturbance to allow for the regeneration of a proportion of intermediately tolerant species (e.g. yellow birch), especially if the operation is snow-off and also late-fall after the seed crop is ripe. A standard low-density shelterwood would be followed by a removal cut in 5-10 years. Again, precautions are needed to avoid excess damage, such as operating with snow cover, although the lower amounts of residual timber help in this regard. Low-density shelterwoods leaving less than 20 square feet are approaching a seed-tree harvest where the residual trees primarily serve as a seed source instead of as source of light shade.

Comment [DJB9]: There are many criteria here but wind-firm trees are essential. Also, leaving a mix of high and low timber quality trees will provide opportunities such as girdling…)

Shelterwoods provide cover for maximum numbers of breeding bird species since there is both overhead cover and a brushy understory; these conditions favor upper canopy breeding birds and raptors as well as understory dwellers. Numbers of early successional birds (not species necessarily) are less in shelterwoods than in clearcuts (Table 3A).

Deferred Shelterwood:

Often, a mature hardwood stand contains a significant component of acceptable growing stock that has not reached maturity or maximized their grade potential. This is commonly sugar maple, 10-16” diameter. A standard shelterwood, in most cases, sacrifices many of these trees, in either the establishment or final cut. Also, some landowners do not want to see the final overstory removed in one cut. Deferred shelterwood is when the overstory is retained for more than 20 years for additional growth. In the extreme, it becomes a two-aged system where overstory trees are retained for 40-50 years while the understory has grown to half of its rotation age. Final removal of the overstory creates a new age class, and the “understory” becomes the overstory. In some cases, periodic removal of portions of the overstory will eventually transition the stand into uneven aged condition, especially if there is a patchy arrangement.

This will usually have an irregular arrangement of stocking, as the desirable immature component will be found in groups or erratically located. It is important to reduce the stocking to well below the C-level (20-40 sq. ft./acre) to allow for growth in the overstory, while not shading out the regeneration. It is important that all the leave trees have high quality potential.

Smaller diameter crop trees, especially of mid-tolerant species, are prone to epicormic sprouting. Leaving groups of these trees can reduce this risk, or select trees with larger crowns or better shade tolerance. Sugar maple responds well to this. These deferred shelterwood systems provide a tool for irregular stands that do not fit well into the normal silvicultural prescriptions. Stands that are mature or low quality, but have an immature acceptable component are particularly well suited, including previously high-graded stands. Stands that might otherwise be clearcut have another option to maintain some growing stock. Deferring the removal of the shelterwood overstory can make even aged management more attractive to small woodlot owners. It provides a more continuous forest cover than regular shelterwood, though not as much as uneven aged management. It has better regeneration success in areas of high deer browse pressure, if densities are low enough. It maintains complex stand structure, which provides both overstory and understory wildlife habitats.

An example of the less than ideal regeneration (after 10 years) under a low density, deferred shelterwood (40 sq.ft./acre; granite soils) is in Table 10. Note that beech dominates about 50% of the regeneration. (See also the shelterwood regeneration in Table 9). Residual saplings had to be removed by hand since the residual trees and the time of harvest (winter) resulted in less than optimum ground/understory disturbance. The regeneration no doubt would have been better with a snow-off harvest and a lower residual basal area of 20-30 square feet basal area/acre, providing for a higher level of ground disturbance. Better site conditions, supporting more advanced sugar maple regeneration, would have greatly improved the regeneration.

Shelterwoods (oak regeneration):

The regeneration of oak in northern New England is especially difficult. Oak tends to be more abundant on sandy tills, outwash, and shallow bedrock soils, especially on south to west-facing sites. Many of the better oak stands occur on old fields where the species regenerated under old-field pine, and then was released when the pine was harvested; this phenomenon relates somehow to wildlife interactions. The best opportunities to regenerate oak are on fairly dry, warm sandy till soils. If there is oak regeneration present (perhaps 2 feet tall or more), it should be released by overstory removal, using groups/patches if the regeneration is patchy. If oak regeneration is absent, begin the regeneration process by a light shelterwood removal from below, leaving perhaps 80-100 square feet basal area with well-spaced oak seed trees. Harvested oak will sprout readily, contributing to the regeneration process. This first removal should be done in the fall of a good mast year with sufficient ground disturbance to bury the acorns; acorns on the surface will be almost completely lost to predation. When the regeneration is approximately 2 feet tall, proceed with an overstory removal. Oak is heavily browsed by deer; so early release is advisable. Some stands with a promising overstory oak component have dense understories of beech saplings and other undesirable species. One approach to deal with this problem is a series of intensive cultural treatments, perhaps including fire and chemicals, to minimize the understory competition. Other approaches, not thoroughly tested, include a whole-tree harvest of the understory in the fall of a good acorn crop, coupled with a light overstory harvest. Another possible approach is group/patch selection adjacent to an oak seed source since observation indicates the oak regeneration may develop under an early-successional overstory, but not under a beech canopy.

Precommercial Thinning:

Four precommercial thinning (release) treatments were examined in a 25-year-old stand on the Bartlett Forest:

1. Heavy crop-tree: Removal of all trees touching the crown of selected crop trees (average of 385 per acre).

2. Light crop-tree: Removal of the most severe competitor around each crop tree.

3. Species removal: Removal of all aspen, pin cherry, striped maple and some red maple sprouts.

4. Control.

Results after 5 years showed a dbh growth response on the crop trees of over 50% (Table 11). Over the next 30 years, the crop trees generally showed an increase of about 2 inches more than the controls;

however white ash and yellow birch showed much less response. An economic analysis showed rates of return for the light crop-tree treatment of 3.5% (31 years after treatment) or 2.3% (44 years after treatment); much less for the heavy treatment. If a harvest had been done at about age 45, and if less crop trees (50-100 per acre) had been targeted, the rates would have been better (perhaps doubled).

As a result, it is difficult to make a strong recommendation for large-scale precommercial thinning unless there are over-riding circumstances such as an overtopping overstory of less desirable species resulting from a less-than-complete clearcut, or a minimal stocking of highly valuable species in a matrix of poor quality stems. However, some landowners may wish to personally engage in some limited precommercial crop-tree work.

Commercial Thinning:

The definition of commercial thinning is expanding since there are growing markets for small stems as biomass or specialty products. However, we use the term herein as a commercially viable thinning for conventional products, usually in a stand containing 8-10-inch trees at the very least, usually 45 years old or more. Precommercial thinning is usually not warranted at this stage.

Northern hardwoods are unique in that they often contain a component of short-lived, intolerant species (aspen, paper birch) in mixture with longer-lived species of appreciable value (white ash, red maple, black cherry) plus extremely long-lived species such as sugar maple, yellow birch, and red oak. The intolerants become mature at age roughly 50-70, the middle category at 80-100, while the long-lived species mature at 100-140 years or more. Thinning of the short-lived species, coupled with stand improvement within the long-lived species, creates the opportunity for repeated high-volume commercial thinnings.

A thinning in a 75-year old northern hardwood stand, on an excellent site, on the Bartlett Forest produced about 19 cords per acre. It removed mostly paper birch and aspen, and reduced the basal area down to an average of 70 square feet per acre, ranging from about 50 to 90 square feet per ¼-acre plot, equivalent to the C-line (or well above) on the northern hardwood stocking guide (Fig.1). Diameter growth responses were moderate to adequate, especially for yellow birch and white ash which were growing at only a moderate rate in the unthinned stand (Table 12A). Although the northern hardwood stocking chart provides a reasonable range in stocking levels, stand growth rates were more closely related to the vigor and crown class of individual stems and species than they were to stocking level. A second study in partially harvested northern hardwoods on a moderate site showed similar (only moderate) diameter growth responses (Table 12B). However, an early thinning study (1936) on the Bartlett Forest showed that the larger trees grew at up to .15 inches annually in dbh growth compared to about .10 inches in the unthinned. This stand had not been previously managed, possibly the reason for the somewhat better diameter growth response.

Growth responses in young stands (Table 11) apparently are superior to those in older stands. The older-stand thinnings, however, are very worthwhile in salvaging potential mortality, and especially concentrating growth over time on high-value species with high quality potential.

Commercial thinning in northern hardwoods is useful and almost essential in stands with a component of short-lived species to produce maximum volume yields. In addition, commercial thinning extends the period of increasing mean annual increment up to the end of a normal rotation (next section). But thinning does have its problems. Careful operation is more expensive, and thinning products are generally lower value, so thinning may not be profitable. It is important to keep in mind the goal of increasing the growth and health of the crop trees and not to sacrifice the premium trees to try to make it more economical, unless they are short-lived species. If the desired thinning is deemed to be sub-profitable, it may be best to wait for improved markets and additional growth. Risk of felling and skidding damage is high with repeated thinning, so the contractor needs to be compensated for the careful work required. Laying out straight access trails in initial thinning is important, regardless of crop trees, as these will be used in future entries, and will reduce skidding damage, especially with repeated entries. In very uniform stands, this can almost be treated as a row-thinning. Finally, even mild thinning will provide enough light for tolerant regeneration or invasive species to accumulate. While they do not interfere with the growth of the main canopy, they may make regeneration more difficult at the end of the rotation.

Where the stand is primarily long-lived species, a commercial thinning still is viable, targeting lower-quality stems that have reached their maximum grade potential. A conscious effort also can be made to release the best crop trees on 3 or 4 sides – a so-called crop-tree thinning. It is best to flag selected, well spaced premium crop trees to guide the marking, and reduce the risk of damage during harvesting. Residual stand density can be guided by the stocking guides described below; however, it is more important to mark the stand well, retaining trees with quality potential and good crowns.

The stocking chart for northern hardwoods (Fig. 1) provides very general guidance on both growth and quality. Stands below the B-line will appear understocked, and will begin to develop a dense understory. Some species, such as yellow birch, will begin to epicormic sprout. Windthrow is also more likely below the B line. The C-line represents our best estimate of the bottom line. Stands that contain acceptable growing stock below the C-line may not be worth maintaining over a full rotation. The so-called quality line suggests that fairly high densities should be maintained in young stands to ensure natural pruning of live branches. The mixedwood stocking chart (Fig. 1) for stands containing 25-65% softwoods ranges about 50-60 square feet above the northern hardwood chart; higher stocking can be allowed with higher percentages of softwood.

Growth, Yield, Rotation:

Managed and unmanaged yield tables for evenaged northern hardwoods were developed through simulation procedures and checked by available volume information (Table 13). For the unmanaged (unthinned) stands at site index 60, the maximum mean annual cubic-foot volume peaks at about 50-70 years of age (mean dbh 6.0-8.0) at around 30 cubic feet (1547/49 or1924/67). For the managed stands, mean annual increment peaks at about 95 years of age at around 50 cubic feet (2602 from thinnings plus 2011 standing divided by 95 years). Note that this figure is about the same as the growth estimates for unevenaged management (Table 4 and related discussion), which is consistent with expectations. Mean annual board-foot growth (gross volume) levels at about 150 board feet/year at ages 107-119, which is a reasonable, minimum rotation age for quality sawtimber products; rotations up to 120-140 years are quite within reason for long-lived species. Shorter-lived species, and species with lower quality potential (white birch, red maple, beech) might be managed on shorter rotations such as 80-100 years.

Aspen-birch, useful for woodcock/grouse management, generally is grown on rotations of 40 to 60 years, often in small blocks of about 5 acres in size that vary in age class (table 3). These stands do well on less productive sites such as sandy, granitic till or hardpan.

Mixedwood Stands:

Mixedwood stands (25-65% mixtures of hemlock/spruce/fir/pine with northern hardwoods) are problematical. Some mixedwood stands originated from heavy harvesting of softwood stands, especially on soils that are not strong softwood sites (Table 2). Some mixedwood occurs in areas where the site conditions are very variable, consisting of a mixture of softwood and hardwood sites. Many mixedwood stands result from past history: essentially hardwood sites on abandoned agricultural land which can produce a mixed condition. Old-field pine is a typical example. To deal with mixedwood, first try to evaluate the site capability, hardwood vs softwood, which will help set the long-term goal. Areas with a hardwood objective can be handled through the methods described above, including the section on oak regeneration. Many mixedwood sites support lower value hardwoods such as red maple. However, yellow birch is often readily regenerated and vigorous on mixedwood sites, especially those with abundant moisture.

Areas to be pushed toward softwood are more problematical. If the stand has groups/patches of softwood regeneration, these can be carefully released through overstory removal on a group/patch basis, using equipment and harvesting layout to avoid damage. In a well-stocked stand without any softwood regeneration, approaching the A-line on the mixedwood stocking chart (Fig. 1), light thinning/shelterwood by harvesting from below is a logical choice to begin the process of softwood regeneration; scarification from snow-free logging should be helpful. Then, group/patch selection may be used to release the established softwood regeneration. Small group selection openings (app. 1/10-acre) may also be useful, although the resulting regeneration may have an overstory of early-successional hardwood with a softwood understory.

When stocking is lower and the understory is mostly unwanted hardwood or weed species (and softwood still is the objective), it may be possible to use long strips about a chain wide to thoroughly eliminate the understory and heavy scarification to expose the lower soil horizons. This tends to emulate the well-known phenomena of softwood in old skid trails or on cut road banks.

Thinnings in mixedwood stands with 25-65% softwood should follow the mixedwood stocking chart (Fig. 1), keeping in mind that the condition of the growing stock (vigor and quality potential) are more important than strict adherence to the chart numbers.

Inventory and Prescriptions

Unevenaged/Evenaged Management: Inventory

To develop accurate stand prescriptions for unevenaged or evenaged management, the following minimal procedures should be adequate. These are well-stocked stands ready for some type of harvest. The guide below is intended to: (1) take account of the patchy nature of many stands and incorporate this feature into the prescription, and (2) provide very general guidelines, allowing for substantial on-the-ground flexibility. The prescriptions can/should be adjusted to meet particular landowner objectives or operational concerns.

1. Take up to 30 sample points per stand. In clearly two-aged stands, it may be beneficial to sample only the overstory, or keep the overstory and understory separate. In such stands, the “regeneration” may include the seedlings, saplings and small poles.

Comment [DJB10]: Yes! But how will we pay for this? Bigger stands?

2. At each point, measure/estimate basal area in the following categories and judge the regeneration potential. (Keep in mind the possible separation in two-aged stands of overstory and understory.)

a. Total basal area

b. Basal area of economically mature/overmature/defective trees.

c. Regeneration (or understory): none (minimal), desirable, undesirable.

3. For each point, summarize percent BA in mature/overmature/defective trees (MOD). Presumably, the remaining percent is immature acceptable timber growing stock. Also, calculate MOD for the overall stand.

4. If MOD>50% on 50-100% of the plots:

4A. Regeneration mostly desirable: overstory removal in one or several entries; or low-density shelterwood harvest, especially on a good site.

Comment [DJB11]: This makes total sense if timber is your primary objective. But it should be pointed out that this could severely compromise other values...)

4B. Regeneration mostly undesirable or absent: clearcut in one or several entries.

4. If MOD>50% on 10-50 percent of plots:

4C. Regeneration mostly desirable: group/patch selection, retain regeneration.

4D. Regeneration undesirable or absent: group/patch selection, destroy/replace advance regeneration.

4.If MOD>50% on less than 10 percent of plots.

4E. Average MOD (all plots)> 25 percent or more: consider a light partial harvest such as a light intial shelterwood, thinning or single-tree selection including some groups where feasible.

4F. Average MOD (all plots) less than 25%: defer cutting unless overstocked.

Prescription Details:

Comment [DJB12]: RED FLAG HERE!!!It strikes me that this revision will force people to be much more aggressive than is currently required in the existing NE-603.

4A. This stand is mostly mature, overmature, and defective with desirable advanced regeneration such as sugar maple. Overstory removal is appropriate, in one or more entries, using harvesting guidelines/equipment to protect the regeneration. A low-density shelterwood is another option, retaining 20-40 square feet basal area/acre in thrifty small sawtimber.

4B. Same as above with undesirable regeneration. Clearcutting with sufficient ground disturbance is the best choice, coupled with reserve patches containing seed sources and wildlife trees. A low-density shelterwood may not provide sufficient ground disturbance.

4C. This stand has numerous patches of MOD and is ready for group/patch selection. With desirable advanced regeneration, the harvest/layout/equipment/season should protect the advanced regeneration to the extent possible. For regular returns at a 15-20-year interval, the area in groups/patches should be a somewhat less than 15-20%. Consider marking between groups, especially along skid trails.

4D. Same as 4C except with undesirable regeneration. Harvesting should be designed to provide sufficient ground/understory disturbance. Again, consider marking along skid trails.

4E. This stand has few patches of MOD and a small average proportion of MOD. Consider a partial harvest (light shelterwood or partial overstory removal, stand improvement, thinning, single-tree selection) to harvest material that is ready to go. Consider groups/patches (even small ones) to the extent possible.

4F. This stand has few patches of MOD timber, and a small average proportion of MOD timber. Defer harvesting, or if basal area/acre is more than half way between the A and B lines, consider thinning (possibly crop-tree) or stand improvement. Indications are that overstocked stands (basal area above the A-line on the stocking charts, Fig. 1) may be thinned to B- line or C-line levels without negative long-term effects.

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_Table 1.—Silvical characteristics of the important species.

Species	Shade Tolerance	Early Relative Height Growth	Relative Site Requirements	Natural Pruning	Good Seed Crop Interval	Sprouting Vigor
Sugar maple *Acer saccharum*	Tolerant (moderately)	slow to moderate	high	poor to medium	3-7	moderate-small stumps
American beech *Fagus grandifolia*	Very Tolerant	slow	low	poor	2-5	moderate-small stumps high-root suckers
Yellow birch *Betula alleghaniensis*	Intermediate	moderate	medium to high	medium	2-3	low
Paper birch *B. papyrifera*	Intolerant	fast	low	good	2-3	moderate-small stumps
White ash *Fraxinus americana*	Intermediate (more tolerant as seedling)	moderate	very high	good	2-5	moderate to high
Red maple *A. rubrum*	Intermediate	moderate	low	medium	1	high
Aspen *Populus spp.*	Intolerant	very fast	low	good	4-5	high-root suckers

Northern red oak Quercus rubra	Intermediate	moderate	medium	medium	3-5	high
Black cherry Prunus serotina	Intermediate	fast	low	good	1-5 seeds stay viable	high
Red spruce Picea rubens	tolerant	very slow	low	poor	3-8	none
Eastern hemlock Tsuga canadensis	Very tolerant	very slow	low	poor	2-4	none
Eastern white pine Pinus strobus	intermediate	moderate	low	poor	3-10	none

Table 2.- Forest types and associated site characteristics: bedrock source and soils.

Forest Type	Characteristic Species	Bedrock Type	Soils Descriptions
Sugar Maple/Ash	Sugar maple, white ash, basswood	Calcareous	Well- or moderately well-drained tills
	Sugar maple, white ash,	Granite, schist	Enriched
Northern Hardwood	Beech, sugar maple, yellow birch	Granite, schist	Well- to moderately well-drained tills
Beech-Red Maple	Beech, red maple	Granite, schist	Sandy, loose tills
Mixedwood	Hemlock, red spruce, white pine, yellow birch, red maple	Any	Shallow bedrock; moderately/poorly drained basal till or sediments. Abandoned pasture/cropland.
Oak with mixed pine-hardwood	Northern red oak, white pine.	Any: often with an agricultural history	Sandy tills, outwash especially

Table 3A. Wildlife habitat conditions for classes of vertebrate species. (A first try!!!!!)

Wildlife	Habitat Characteristic
Maximum forest wildlife diversity	Regulated evenaged management w/ clearcutting, full-length rotations; softwood inclusions.
Grouse/woodcock	Aspen/birch; four age classes; 60-year rotations; 2-5 acre stands
Small mammals	Hardwood/mixedwood forest in all age classes. Dependent on mast (beech, oak, others)
Early-successional breeding birds	Clearcuts > 5 acres. Also some impact from large group/patch selection
Late successional breeding birds	Mature forest; single-tree selection.
Early and late successional bird species during the post-fledging period.	Patch clearcuts: 5 acres plus.
Maximum total numbers of bird species (in a single stand)	Low-density shelterwoods
Forest raptors: owls, hawks,	Cavity trees; basket forks.
Snowshoe hare: and related predators	Regenerating mixedwood, 0-10-year age class. Low softwood cover.
etc etc	

Table 3B. Landscape-scale wildlife objectives: percent of acres by stand size-class, cover type, and nonforest (DeGraaf etal 2005).

Habitat Condition	Percent of Acres
Size Class:	
Regeneration	5-15
Sapling-Pole	30-40
Sawtimber	40-50
Large Sawtimber/Old Forest	<10
Cover Type Distribution:	
Deciduous Short Rotation	5-15
Deciduous Long Rotation	20-35
Hard Mast-Oak	1-5
Conifers	35-50
Upland Openings	3-5
Wetlands	1-3

Table 4.—Annual net growth (over 25 years) in basal area of poletimber (4.5-10.5 inches dbh) and sawtimber (10.5 inches plus) of a beech-red maple stand related to residual basal area in poletimber and sawtimber (Leak and Gove 2008; from a study initiated by D.S. Solomon).

Basal Area/acre	Percent Basal Area in Sawtimber	Poletimber Growth	Sawtimber Growth	Total Growth
(sq.ft./acre)		(sq.ft.)	(sq.ft.)	(sq.ft.)
40	30	.82	1.42	2.24
	45	.84	1.37	2.21
	60	1.13	1.18	2.31
60	30	.22	1.59	1.81
	45	.57	1.69	2.26
	60	.46	1.52	1.98
80	30	-0.22	1.82	1.60
	45	.08	1.47	1.55
	60	0.0	1.38	1.38
100	30	-0.13	1.80	1.67
	45	-0.17	1.49	1.32
	60	-0.24	1.44	1.20

Table 5.—Species composition (percent of milacres stocked by the tallest commercial species) by harvest method 10-15 years after cutting.

Species Tolerance Group	Clearcutting	Group/patch	Individual-tree Selection
	(%)	(%)	(%)
Tolerants	43	62	92
Intermediates	19	34	7
Intolerants	38	4	1

Table 6. Numbers per acre and percentages of saplings (2, 3 and 4-inch classes) in compartments cut twice by single-tree selection; granitic well-drained fine till.

Species	Number/acre	Percent
Beech	102	45
Yellow birch	8	3
Sugar maple	22	9
Red maple	1	1
Paper birch	0	0
White ash	1	1
Red spruce	8	3
Hemlock	57	25
Striped maple	30	13
Other	0	0
All	229	100

Table 7A.—Species changes (percent cubic volume, trees 5.0 inches plus) over a 50-year period after three single-tree selection harvests (1952, 1975, 1992).

Species	1952	1976	2000
	(%)	(%)	(%)
Beech	53	53	49
Yellow birch	11	7	6
Sugar maple	18	27	25
Red maple	2	2	3
Paper birch	11	0	0
White ash	1	1	1
Red spruce	1	1	1
Hemlock	3	9	15

Table 7B.— Changes in butt-log grade of beech and other hardwoods over a 50-year period after three selection harvests (1952, 1975, 1992); percent of cubic-foot volume (trees 11.0 inches dbh plus).

Species	Butt-log grade	1952	1976	2000
		(%)	(%)	(%)
Beech	1 and 2	21	21	30
	3	52	36	47
	5	16	41	18
	Cull	11	2	5
Other hardwoods	1 and 2	40	67	65
	3	47	25	31
	5	10	8	3
	Cull	3	0	1

Table 8.—Percent basal area by species in 50-60-year old groups/patches averaging about ½-acre in size by drainage class; trees 3.5 inches dbh plus.

Drainage	Beech	Yellow birch	Sugar maple	Red maple	Paper birch	White ash	Hemlock	Other
	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
Well	26	15	11	14	26	2	5	1
Moderate	16	15	31	5	19	11	2	1

Table 9. Percent composition (10-12 years after harvest) of regeneration (dominant stem per milacre of any species) in a clearcut, patch cuts (3-5 acres), and in a shelterwood (with 40 square-feet residual basal area retained. Also percent composition of basal area in a 25-year-old stand (moderately well drained).

Species	Clearcut (fine till)	Shelterwood w/ 40 sq.ft. residuals (fine till)	Two 5-acre patch cuts (sandy tills)	Two 3-acre patch cuts (sandy tills)	25-year-old clearcut
	(%)	(%)	(%)	(%)	(% Ba)
Beech	4	48	0-3	15-41	11
Yellow birch	9	7	13-45	5-24	10
Sugar maple	3	2	0	0	11
Red maple	1	0	0-3	0-5	5
Paper birch	23	5	3-24	23-25	24
White ash	7	2	0	0	3
Red spruce	0	0	0	0	1
Hemlock	0	0	0	0-6	1
Str. maple	4	31	0	0-6	2
Pin cherry	46	2	24-51	0-10	23
Aspen	0	0	0-30	0-40	9
Other	3	3	0-4	0	--

Table 10.—Percentage of milacres dominated by commercial regeneration species or any species (commercial or noncommercial) 10 years after a low-density shelterwood. Granitic moderately well-drained soils; winter harvest; 40 sq.ft. residual basal area/acre. Over time, the commercials should dominate as the noncommercials subside. (Methodology: the species of the dominant stem per milacre was recorded; if a noncommercial, the tallest commercial species was then recorded).

Species	Commercial species only	Any species
	(%)	(%)
Beech	54	42
Yellow birch	22	17
Sugar maple	5	4
Red maple	10	4
Paper birch	2	2
White ash	5	2
Red spruce	1	1
Hemlock	0	0
Str. maple	--	20
Pin cherry	--	5
Aspen	0	0
Other	1	3

Table 11.—Annual response (over 5 years) of a 25-year-old precommercially thinned northern hardwood stand.

Treatment	Entire Stand: basal area growth	Crop trees: basal area growth	Crop trees : dbh growth
	(sq.ft./acre)	(sq.ft./acre)	(Inches)
Heavy	4.0	3.2	.18
Light	3.3	2.7	.15
Species	4.9	2.7	.15
Control	2.2	2.1	.11

Table 12A.- Annual (7 years) dbh growth rates by species for thinned (to 70 sq.ft. average)and unthinned northern hardwoods at 75 years of age.

Treatment	Beech	Yellow birch	Sugar maple	Red maple	White ash
	(inches)	(inches)	(inches)	(inches)	(inches)
Thinned	.17	.13	.20	.19	.17

Unthinned	.16	.06	.17	.19	.13

Table 12 B. Annual dbh growth of sawtimber-sized trees (25-year period) in young sawtimber/poletimber stands thinned to 60 sq.ft. basal area vs 100 sq.ft. basal area (Leak and Gove 2008).

Residual Basal Area	Beech	Yellow Birch	Paper Birch	Red Maple	Hemlock
(sq.ft./acre)	(inches)	(inches)	(inches)	(inches)	(inches)
60	.14	.05	.10	.12	.20
100	.11	.04	.06	.10	.19

Table 13.—Simulated yields per acre for unthinned and thinned northern hardwoods at S.I. 60. The cumulative thinned volumes include a summation of volumes up to a given age/mean diameter. The standing volume is the after-thinning volume. The bf volumes are total gross volumes based on tree dimensions, trees larger than 11 inches dbh to an 8-inch top.

Mean Dbh (overstory)	Age Unthinned	Standing Cf Volume Unthinned	Standing Bf Volume Unthinned	Age Thinned	Cumulative Thinned Volumes	Cumulative Thinned Volumes	Standing Cf Volume Thinned	Standing Bf Volume Thinned
(inches)	(Years)	(cf)	(bf)	(Years)	(cf)	(bf)	(cf)	(bf)
4.0	30				--	--	--	--
6.0	49	1547		48	269	--	1418	--
8.0	67	1924	3560	61	1243	895	1189	2211
10.0	87	2311	6640	72	1243	895	1912	5471
12.0	114	2700	9783	83	1854	2680	2039	7375
14.0	157	3102	13048	95	2602	5633	2011	8449
16.0	--	--	--	107	2602	5633	2449	10289
18.0	--	--	--	119	3394	8960	2085	8760

Figures:

Fig. 1.—Hardwood and mixedwood stocking guides. (***Note use stocking charts from 1987 guide!!!).

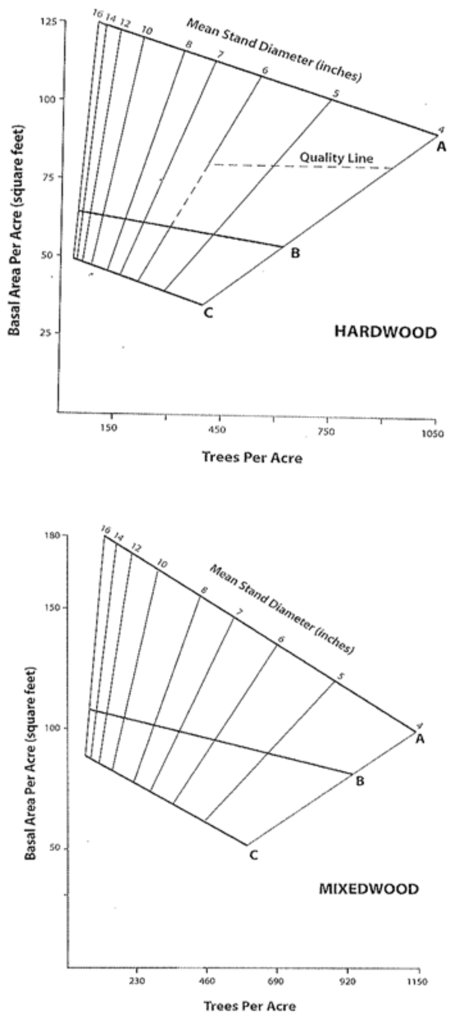

Fig.1.—Hardwood and mixedwood stocking guides.

APPENDIX

1. Invasives

2.Exotic Insects and Diseases

3. BMP's

4. Carbon Management

5. Suggested Marking Codes

6. Useful Tables and Charts (Adapted from Wenger 1984, USDA Forest Service 2008) :

Appendix Table 1. Plot radius factors

Appendix Table 2. Basal area by dbh class, and number of stems/acre for each tree counted by several basal areas factors.

Appendix Table 3. International log rule.

Appendix Table 4.Total volume in board feet (International ¼-inch rule)

Appendix Table 5. Total volume in board feet (Doyle Rule)

Appendix Table 6 .Percent of board-foot volume (International ¼ inch kerf) in 8-foot bolts by tree log height.

Appendix Table 7. Cubic-foot volume (ib) to a variable top diameter.

Appendix Table 8 . Sawlog scale deduction for sweep.

Appendix Table 9. Relation of stump dib to dbh.

Appendix. Table 10.Sugar maple tap hole computation sheet.

Appendix Table 11. Weight table for various species.

Site Index Curves: American beech, Yellow birch, Red maple, White ash, Black cherry, Red spruce,

Sugar maple, Upland oaks, Paper birch, White pine, Red pine

Stocking Charts: White pine, Upland hardwoods

Textural Classification of Soils

Invasive Plants: (by R. Holleran)

Northeastern hardwood forests are affected by dozens of species of exotic invasive plants, particularly on abandoned farm fields. Often these are shrubs that were planted for landscape purposes, wildlife habitat, or 'fenceless fencing' during active agricultural use or adjacent suburban areas. Ironically, many of these species were promoted or provided by government agencies and nurseries. Most of these propagate easily, have seeds that are distributed by birds or other wildlife, and many of them bud out earlier, or lose leaves later than native foliage, giving them an advantage with longer active growth period.

The most offensive of these are shrubs of imported honeysuckles, buckthorn, barberries, bittersweet, multiflora rose, autumn and Russian olive, and Japanese knotweed. There are other species of local importance, along with dozens of herbaceous plants and a few tree species that are also considered invasive. These can form a dense understory in existing forests, and reduce the species diversity of native ground flora.

A reasonable land management strategy starts with prevention, then monitoring/early awareness of a problem, and finally control. Pressure washing equipment is an effective way to reduce the importation of new seed which can be brought to your site on logging equipment. But some sites are prone to invasion by birds and other wildlife from adjacent properties. My detecting initial establishment of these species, control efforts can be directed at limited populations before they become a problem. Mechanical control is often effective if initial populations are detected.

Many areas are obviously infested with these shrubs. From the perspective of this guide, it is not likely that these can be eradicated from any given area, and control is a reasonable goal. These plants can effectively replace or preclude desirable regeneration, and that is where they interfere with the productivity of a site. These are often found on rich soils, in proximity to roads, and under immature forests of recent pasture abandonment. Delaying regeneration treatment by thinning is a reasonable alternative, but any disturbance, such as thinning, will provide conditions for their accumulation. This will give a more serious problem to deal with at rotation age.

If invasive shrubs are already present, light shelterwood, small group and individual tree selection provide perfect conditions for these shrubs to occupy a site. It is important to control these before, or directly after, a harvesting operation, if regeneration is required. Larger groups of an acre or more, clearcuts, and heavy shelterwood cuts with good scarification often have large populations of these in the regeneration strata, but usually have successful regeneration of desirable tree species mixed in. From a timber productivity standpoint, this may be an acceptable option.

Mechanical control with scattered populations can be effective. They can be pulled up with the roots and hung up to dry. They are likely to re-root if left in contact with the ground. Mechanical control can have lower costs in equipment but high labor costs.

Exotic Insects and Diseases (by R. Holleran)

Managers of northern hardwood forests have adapted to exotic diseases and insects which have had significant affects. Well-known examples include Chestnut Blight, Dutch Elm Disease, Beech Nectria complex, and gypsy moth. The trees that host these diseases often lack the natural resistance that would be found in their native lands. The insects arrive without the natural controls that balance their populations. There are many other examples with less drastic impacts. As of this writing (2011) there are several serious forest insects beginning to impact the northern hardwood region, and perhaps more will be found as time continues. Asian Longhorned Beetle (ALB), Emerald Ash Borer (EAB) and Hemlock Wooly Adelgid (HWA) are current species of primary concern.

There is plenty of new and evolving information on these species and it is not the goal of this essay to try to summarize what will soon be out of date. Our goal is to discuss the adaptive nature of forest management, and applying silvicultural principles to the process. Chestnut trees were salvaged until they were essentially gone, making room for oak and other species to occupy their niche. Could we have done something differently to slow or stop the spread of this virulent blight? Perhaps genetically resistant trees were salvaged as a matter of course, but I do not believe we could have stopped the spread. Salvage cutting of host species has slowed the spread of ALB, but if these sites regenerate to host species, then little is gained. Silvicultural principals can be applied to shift species composition, and maintain forest productivity and ecosystem values. EAB and HWA are species specific. Is it prudent to salvage all of these host species? Probably not. Forest management is much more complex. Gypsy moth has caused severe damage to oak forest types, but management has adapted by growing oaks to shorter rotations on moth-prone sites, and encouraging non-oak species, and species diversity.

In the southern part of the range, hemlock has been seriously affected by HWA. In the northern hardwood zone, damage has been more slight, and the insect seems slower to spread. Cold temperatures may have an impact. Maintaining healthy crowns to increase tree vigor may help trees to withstand HWA infestation. Hemlocks are often maintained as dense stands for winter wildlife cover, so thinning conflicts with this tree heath goal. But if the trees will lose their crown density and perhaps die, thinning may be prudent. Application of silvicultural principals can maintain tree health and species diversity, which can minimize environmental damage from this, and other pests.

EAB was discovered in Detroit in 2002, but indications show it was likely there as early as 1996. It has spread rapidly with new infestations found every year, and this will likely continue. It seems to impact, and soon kill, every ash specie and every ash tree it comes in contact with. In Michigan, spread seems most effective in suburban areas, and much slower in extensive forests. It may be many decades before it gets into the "deep woods" of some of the northern hardwoods. By then, there may be natural or introduced predators, parasites, or diseases that provide some level of control, such as with gypsy moth. With this in mind, extensive pre-salvage is not warranted.

The northern hardwood forest is incredibly diverse. That is a strength. Would it be poorer without ash or hemlock? Decidedly so. Would the ecosystem recover? In some new balance, yes. Other exotic insect and disease problems will likely arrive over the next decades. Each one will have characteristics that help define an appropriate response. Hopefully, we can learn from the efforts of so many over the past century in this struggle to maintain our diversity and forest health. New techniques will be developed. Salvaging trees at risk, removing host trees from areas of potential spread, and attempts at eradication will stretch our silvicultural understanding, but the basic principals should still apply.

BMPs (by R. Holleran)

Every state has its laws and rules regarding water quality and Best Management Practices (BMPs). Field Foresters and logging professionals should be intimately acquainted with them in each state they work. Most of these boil down to common sense, keep the mud out of the flowing water. Logging in and around wetlands, vernal pools, and in buffer strips along water courses, steep slopes, and even seeps all have risk of impacting clean water, and are treated differently in each state. Stream crossings are probably the greatest risk. Most state forestry departments have service foresters available to provide technical assistance in applying BMPs. Timber harvesting around water reservoirs, and high quality streams requires the highest level of protection.

Careful planning is the first step to minimizing problems. The time of year for harvesting each site is the first consideration. There are very few lots that are appropriate for spring mud season, and this is a good time for scheduled maintenance, maple sugaring, certification classes, and perhaps a vacation. Planning on higher elevation, north facing slopes for the end of winter can stretch the logging season. Lower elevation locations with sandy or gravelly soils for spring can shorten the forced vacation. Fall mud season is another feature of the calendar. After the leaves come off the trees in October, until the ground freezes in December or January is always wet. This is a good time of year to avoid wet soils, or to achieve scarification on regeneration cuts, on well drained soils. There are some sites which are only appropriate for frozen ground logging, such as glacial hardpan, forested wetlands and other poorly drained areas. It may be difficult to get adequate scarification during winter logging without some extra work. Getting skidder operators to travel different routes, rather than a well-defined trail, in regeneration units can be successful with little added cost. Logging during unfrozen conditions also has to be prepared for severe thunderstorms with high rates of water flow at any time.

Truck roads, especially with stream crossings, are very involved. With the expense of this type of permanent improvement, careful layout and construction is essential to minimize costs, maximize effectiveness, and comply with local regulations. Check your local rules and technical assistance to insure compliance with buffer strips, culvert and bridge sizing, permits, and drainage issues.

Locate landings on firm ground wherever possible, away from running water or wetlands. More latitude is often available for frozen conditions, but protective strips need to be planned in at the beginning. Generous application of geotextile fabric and coarse crushed stone on the traveled portions can save time and money later on. Perimeter drains around the landing can be effective to keep the landing stable, and channel runoff in predictable ways. Silt fence is inexpensive and best applied before there is a problem. Landings should also be planned to minimize stream crossings and uphill pulls, and should be the minimum size needed for the equipment used and amount of wood handled. These are likely to be permanent improvements, and so warrant careful consideration and some expense.

Location of main skid trails is the next step. Minimizing stream crossings, maintaining required buffers and avoiding wet and very steep ground are a priority. Good forestry maps, topographic maps and a handheld GPS can simplify this process, to “connect the dots” between where you must and must not travel. Sometimes pre-existing trails are appropriate, but some trails used in the past are a bad idea and should be ignored. A well planned and built skid trail system will save time and money throughout the operation, and allow for more productive days in wet weather. When wet ground must be crossed in unfrozen conditions, corduroy is a time-tested technique, along with “brushing in” trail sections. A common mistake, especially with cable skidders, is laying tops into a trail parallel with the direction of travel. These are less effective in supporting the equipment, and can impede the flow of water. Laying logs and tops perpendicular to travel is very effective, and relatively easy with a forwarder, grapple skidder, or feller-buncher.

Steep slopes are best approached with bulldozed or excavated grades diagonally at planned grades of 15-25%. Again, check with local rules for allowable slopes, and required drainage devices. Rock outcrops and other features may limit these locations, so planning ahead is important. Planning drainage at the beginning of a project to provide adequate filter strips, and constructing broad-based dips and poled waterbars or culverts that can sustain the logging process will help to keep the equipment productive. Scrambling to “fix things up” at the risk of every thundershower is counterproductive. Erosion is dependent upon the volume and velocity of water flow. Steep trails that accumulate water flow, on fine textured soils are at greatest risk. By diverting water off of steep sections of trail, both the volume and velocity are reduced.

Stream crossing pose the greatest risk for siltation, and warrant careful planning. Finding the best approaches, with stable ground and modest slopes is the first step. Temporary bridges are more available, and probably the best option for any stream crossing. Culverts may be adequate for small streams, if properly sized, and properly installed. Corduroy and brushing-in may be allowed for wet areas, especially during frozen conditions. Approaches should be drained to keep silt and water flow from the trail away from the actual stream. Stream crossings should be inspected and maintained over the course of the operation. At the completion of logging, temporary bridges, culverts and poles or brush should be removed, and the stream channel restored as much as possible. Disturbed soils should be seeded and mulched along streams or where there is risk of erosion..

Buffer strips vary from state to state, by slope, and by the type of water being protected (ponds, lakes, wetlands, and stream sizes). Some protective strips allow for no cutting, and no machine entry. Some allow for a portion of the basal area to be removed, but no machine entry. The purpose is to reduce disturbance along the water, provide a filter strip for any potential siltation, and sometimes to provide shade for cold-water resources. Some states require aesthetic buffers along roads as well. Check with your local rules and technical assistance for details.

Logging in and around wetlands has very particular rules in each state. Check your local BMPs, wetland rules and technical assistance for what is allowed, required and forbidden. Identification of wetland boundaries and category of protection may require professional assistance.

Vernal pools are small depressions in the forest which usually hold water for a month or two in the spring. These can be important breeding areas for amphibians, and are receiving greater attention and protection. When dry, these can be noticed by the presence of matted leaves, changes in vegetation, and sometimes a distinct edge. They generally do not have a pronounced inlet or outlet. They should be avoided, with appropriate buffer strips left as needed.

Rare and Endangered species are a consideration for the logging process. Most states have a Natural Heritage database of known locations or rare communities that should be protected. Some states have a specific review process. These are often unusual habitats such as ledge outcrops, wetlands, ridgetops, or other areas with unique growth features that can be identified and avoided.

Closing out a logging operation may have different requirements, in terms of stabilizing disturbed areas, reducing the risk of erosion from spring runoff or summer thunderstorms, and recreational traffic during the years between active harvesting operations. Restoration of stream crossings, repairing ruts and drainage devices (waterbars and broad-based dips) in trails, seed and mulching of disturbed ground and landing are common practices. Requirements vary by state. In some cases, the best efforts at stabilizing logging trails and stream crossings are negated by recreational traffic. ATV's, Off-road vehicles, mountain bikes, and even horses are capable of cutting ruts through water bars and encouraging erosion. If the risk of this traffic is high, then extra effort is warranted to maintain the investment in a good trail system and clean water, such as profound waterbars, or closing off trails with piles of logs or a gate.

Slash requirements also vary from state to state, and sometimes from hardwood to softwood. Tree tops and branches often have to be pulled out of streams and away from public roads, woods roads and property boundaries for distances of 20-50 feet, and/or lopped to within 2 feet of the ground for up to 100 feet.

Diesel and hydraulic oil spills present another risk to water resources. Logging contractors should maintain spill kits and consult with requirements in each state.

Each logging system had advantages and limitations in protecting water quality and applying BMP's:

	winch ability	steep ground	corduroy	brushing in	waterbars	debris at landing	buffer access
Chainsaw-cable skidder	good	good	poor	poor	good	fair	good
Chainsaw-forwarder	poor	poor	good	good	fair	good	poor
Processor-forwarder	poor	poor	good	good	fair	good	poor

F-B - grapple	poor	fair	fair	good	good	fair	poor

Carbon Management (by R.Holleran)

Managing forests for carbon sequestration is a growing concern. Trees both store and release carbon as they grow, and release this stored carbon as they die and decay. Carbon accounting is complicated, aggregating tree growth, total stocking, mortality, decay, and soil carbon; and various studies have come to different conclusions about management implications. (Lucier 2010, Manomet… 2010, Morris 2008, O'Laughlin 2010, Nunery and Keeton 2010, Strauss 2011) Emerging markets for "carbon credits" may influence forest practices on designated lands. It is the opinion of the authors that "good forest management is good carbon management". Converting forests to non-forest use has the greatest overall effect on forest carbon accounting, and active timber management may be the best incentive to keep forests in forest use while providing a wide range of other benefits, including carbon sequestration.

There are two main considerations for carbon accounting, and they are in conflict. One is the amount of carbon already stored through decades of forest growth. This is maximized with fully stocked stands. The other is the rate at which additional carbon is stored. This is maximized in pole sized stands with B level stocking. Over a landscape scale, you can't maximize either stocking or growth rate on every acre. It is important to have a mix of age classes across the landscape to manage the tradeoffs between the two. Even 'wilderness areas' have a flux of carbon storage as natural mortality varies from site to site.

Forest soils sequester a large amount of carbon, as root biomass, woody debris on the forest floor, and other organic matter in the soil. This will vary greatly with the soil type, stand age, and strategies of management. Since moisture is usually available in northeastern forests, and temperatures are moderate, decomposition rates are relatively high. Soil carbon will also be in flux, with material added by root growth, tree mortality, and logging debris. Decomposition will return this carbon to the air, primarily as carbon dioxide at predictable rates, but methane or NO2 may be produced in oxygen-poor environments. Under a wide range of sustainable management scenarios, even with biomass harvesting under normal operating conditions, moderate amounts of woody debris are left to maintain forest soil carbon levels in a normal range. (Johnson 1992, Johnson et al 2002, Knoepp and Swank 1997, McLaughlin and Phillips. 2006) Maximizing soil carbon, at any given time, is not a practical forest management goal, in itself. Converting to non-forest use loses this aspect of carbon storage almost completely.

Since forest carbon is either “on the stump or in the air”, carbon accounting methods emphasize maximum stocking in the forest. (Nunery and Keeton 2010) This is because most of the harvested wood (80-90%) gets back into the atmosphere within a decade after harvesting, either though decay of tops and branches, or short term use of products such as paper, fuelwood, scraps, or lumber in short term use. Maintaining forest stocking at maximum levels sacrifices tree growth and tree health, and maximizes mortality. (Leak et al 1987) At some point, net growth slows to near zero as mortality begins to equal growth. This has been shown to be about 120 years (Leak 1982) for unmanaged northern hardwoods, though carbon may be further accumulating in mortality, forest floors, or softwood understory over subsequent decades. If managing for maximum stocking, some form of single tree selection can capture mortality, and have some influence on stand structure, species composition, and quality, though 50-year studies have shown forest improvement to be slow and regeneration to be unreliable. Overstory trees are eventually recruited from the lower canopy, and do not have the growth rate or quality of trees that have not been suppressed. Maximizing total forest stocking and carbon sequestration with a “no harvesting approach” sacrifices many of the ecosystem benefits of active management.

On a landscape scale, if harvest rate is close to, but less than total growth, growth rate (sequestering additional carbon) is at a high level. Stocking levels are low to moderate overall. Forest products are being removed at a steady rate. With the decline of pulp markets in the northeast over previous decades, and improvements in markets for biomass fuels, it can be assumed that some fossil fuels are replaced by woody biomass, such as chips or firewood. Even if biomass is burned with lower efficiency than fossil fuels, forest growth more than offsets carbon emission, since less than 100% of the harvest is burned, and growth will equal or exceed harvest. So the fact that some fossil fuels are being replaced is important to the carbon account. Some portion of the wood products is sequestering carbon in durable products (though the actual percent may be small, such as 10-20% of total harvest). And wood products are replacing, in theory, products of other origin that have higher carbon impacts, such as metals or plastic. Also, some short term woody products end up in landfills with very slow decomposition rates (though some of this may be producing methane), so some portion is effectively sequestered. The authors believe that a careful accounting on a landscape scale with these variables will show a net increase in carbon sequestration, and fossil fuel replacement, over the short and long term.

In landscapes with very low harvest rates, forests will continue to sequester carbon over the short term as forests approach maximum stocking. Net growth rates, product sequestration and substitution effects will be less dramatic. As forests reach maturity and net growth slows, additionality of these landscapes to sequester carbon will also slow and only approach the harvest level.

It seems disingenuous to take forest carbon sequestration as "granted" against other carbon emissions, and dis-favor biomass use, as a carbon "source" if it is less than forest growth. Forests have been a source of home and industrial energy for centuries, and these products provide reasonable markets for the products of thinning, improvement cutting, salvage cutting and regeneration cutting required for effective management of higher-value durable timber products. If a forest, on a landscape level, is being harvested at or below the growth rate, then the forest will be functioning as a carbon sink instead of a source.

Overall, a process of forest management that grows a high proportion of durable goods will prove to be good carbon management. With reasonable growth and harvest rates, continual effort to improve overall timber quality, salvage of anticipated mortality and rapid regeneration of harvested sites, northern hardwood forest types can support a significant amount of biomass energy, durable timber products, and a wide range of wildlife habitats and other ecosystem services, while still being a net carbon benefit.

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<u>Suggested Marking Codes</u> (by R. Holleran)

Each forester has developed their own code for marking trees for harvest or retention. This creates a potential communication problem for loggers who work with many foresters. This essay is to suggest a more standard code for colors and markings for use by field foresters.

Property boundaries should be marked with red or orange paint, in a distinct vertical oval or rectangle properly located on line trees and witness trees, with three marks on corner trees. Since blue is commonly used for harvest trees, blue paint should be avoided for boundaries.

Trees for harvest are commonly marked with blue paint. Blue is one of the most visible colors, and completely unnatural in the woods. In some cases, another color for harvest trees is needed. Teal green is also unnatural, but some forest workers have a hard time seeing this color. Yellow is another good choice for harvest trees if another color is needed.

Trees for harvest should be boldly marked on 2 or 3 sides to be clearly visible. Highly visible paint also adds to the value of the wood and saves time for the marker to clearly see what has been already marked. Prospective timber buyers can clearly see what is offered, and logging contractors can see what is expected in terms of harvesting volume per acre and reserve trees. More importantly, it makes it easier for the operator to carry out the instructions of the timber marker. Especially with mechanized felling, bold paint, well above eye level is most helpful. Machine time is much more valuable than marking time, so whatever the field forester can do to facilitate the process will be appreciated.

/ Log trees should be marked with the longest diagonal slash on at least two sides, to be clearly visible from all angles.

* Pulp trees should be marked with a spot, on at least 2 sides.

^ Hazard trees can be marked with a bold arrow pointing up. This cautions a faller to review the hazard and determine the best way to handle or avoid it.

: Optional trees should be marked with a double spot, one on top of the other. This may be helpful at times when the marker is suggesting a felling corridor, or otherwise leaving a preference to the operator.

X Cull or girdle trees can be marked with an X.

1 Skid trails and felling corridors should be marked with a long vertical stripe on two sides, to be clearly visible from either direction of travel.

Harvest trees can be marked on the stump, below expected cut level to assist in verification that the correct trees were harvested. These are best put on the downhill side, between root flares.

Harvest unit boundaries should be marked with “triple stripes”, three diagonal slashes above eye level.

In low-density shelterwoods where more than 50% of the trees are being harvested, and where an individual tree tally is not needed, reserve trees can be marked. A whole different color group should be used for reserve trees so there is no mistake. Orange, yellow, (black and white on certain species groups) are recommended for leave trees. These should be marked in a ring all the way around the circumference, to be clearly visible from every perspective. These can also be stump marked for control. Flagging can also be used to distinguish reserve trees, but with mechanized harvesting there is a risk of pulling off the ribbons with the tops of nearby harvest trees. Finding stumps with ribbon on the ground instead of reserve trees is discouraging.

Appendix Table 1. Plot Radius Factors: Multiply the PRF times the tree dbh to determine the maximum horizontal distance from prism-plot center to tree center.

Basal Area Factor	Plot Radius Factor
5	3.8891
10	2.750
20	1.9445
40	1.3750
80	0.972

Appendix Table 2.-- Basal area by dbh class, and number of stems/acre for each tree counted by several basal area factors (USDA Forest Service NA S&PF, 2008)

DBH	Basal Area	Basal Area Factor				
		5	10	20	40	80
(in.)	(ft.^{2})	(no.)	(no.)	(no.)	(no.)	(no.)
2	.022	229.4	458.7	917.4	1834.9	3669.7
3	.049	101.9	203.7	407.4	814.9	1629.7
4	.087	57.3	114.6	229.2	458.4	916.7
5	.136	36.7	73.3	146.7	293.4	586.7
6	.196	25.5	50.9	101.9	203.7	407.4
7	.267	18.7	37.4	74.8	149.7	299.3
8	.349	14.3	28.6	57.3	114.6	229.2
9	.442	11.3	22.6	45.3	90.5	181.1
10	.545	9.2	18.3	36.7	73.3	146.7
11	.660	7.6	15.2	30.3	60.6	121.2
12	.785	6.4	12.7	25.5	50.9	101.9
13	.922	5.4	10.8	21.7	43.4	86.8
14	1.069	4.7	9.4	18.7	37.4	74.8
16	1.396	3.6	7.2	14.3	28.6	57.3
18	1.767	2.8	5.7	11.3	22.6	45.3
20	2.181	2.3	4.6	9.2	18.3	36.7
22	2.640	1.9	3.8	7.6	15.2	30.3
24	3.142	1.6	3.2	6.4	12.7	25.5
26	3.69	1.4	2.7	5.4	10.8	21.7
28	4.28	1.2	2.3	4.7	9.4	18.7
30	4.91	1.0	2.0	4.1	8.1	16.3
32	5.59	0.9	1.8	3.6	7.2	14.3
34	6.30	0.8	1.6	3.2	6.3	12.7
36	7.07	0.7	1.4	2.8	5.7	11.3

Appendix Table 3.—International Log Rule: Board feet by top diameter and log length (1/4 in saw kerf) (Wenger 1984).

Log Length (ft.) .

.

Top Diameter	8	10	12	14	16	18	20
(in.)	(bf)	(bf)	(bf)	(bf)	(bf)	(bf)	(bf)
4	--	5	5	5	5	5	10
5	5	5	10	10	10	15	15
6	10	10	15	15	20	25	25
7	10	15	20	25	30	35	40
8	15	20	25	35	40	45	50
9	20	30	35	45	50	60	70
10	30	35	45	55	65	75	85
11	35	45	55	70	80	95	105
12	45	55	70	85	95	110	125
13	55	70	85	100	115	135	150
14	65	80	100	115	135	155	175
15	75	95	115	135	160	180	205
16	85	110	130	155	180	205	235
17	95	125	150	180	205	235	265
18	110	140	170	200	230	265	300
19	125	155	190	225	260	300	335
20	135	175	210	250	290	330	370

21	155	195	235	280	320	365	410
22	170	215	260	305	355	405	455
23	185	235	285	335	390	445	495
24	205	255	310	370	425	485	545
25	220	280	340	400	460	525	590
26	240	305	370	435	500	570	640
27	260	330	400	470	540	615	690
28	280	355	430	510	585	665	745
29	305	385	465	545	630	715	800
30	325	410	495	585	675	765	860
31	350	440	530	625	720	820	915
32	375	470	570	670	770	875	980
33	400	500	605	715	820	930	1045
34	425	535	645	760	875	990	1110
35	450	565	685	805	925	1050	1175
36	475	600	725	855	980	1115	1245

Appendix Table 4.—Total volume in board feet (International ¼-inch rule) by dbh and number of 16-foot logs to an 8.0-inch top dib (Wenger 1984).

	Number of 16-foot logs							
Dbh	1/2	1	1 1/2	2	2 1/2	3	3 1/2	4
(in.)	(bf)	(bf)	(bf)	(bf)	(bf)	(bf)	(bf)	(bf)
12	30	57	80	100				
13	36	68	96	118	134			
14	42	79	110	140	163	184		
15	50	92	128	160	188	214	232	
16	59	105	147	180	213	247	274	295
17	66	118	166	208	245	281	314	340
18	74	135	188	235	278	320	360	400
19	83	152	212	265	314	360	405	450
20	92	170	236	295	350	400	450	500
21	102	189	262	328	390	450	505	550
22	112	209	290	362	430	495	555	610
23	122	228	316	396	470	540	610	680
24	133	252	346	430	510	595	670	740
25	145	275	376	470	555	645	730	810
26	158	300	410	510	605	700	790	880
27	172	325	440	550	650	760	850	950

28	187	348	480	595	700	810	920	1020
29	203	378	515	640	760	870	990	1100
30	220	410	550	685	810	930	1060	1180
31	237	440	595	740	870	1000	1140	1260
32	254	470	635	790	930	1070	1210	1350
33	270	500	680	840	990	1140	1290	1440
34	291	530	725	900	1060	1210	1380	1530
35	311	565	770	950	1120	1290	1460	1630
36	333	600	820	1010	1190	1370	1550	1725

Appendix Table 5.—Total volume in board feet (Doyle Log Rule) by dbh and number of 16-foot logs to an 8.0-inch top.

Number of 16-foot logs .

Dbh	1/2	1	1 1/2	2	2 1/2	3	3 1/2	4
12	20	30	40	50	60			
14	30	50	70	80	90	100		
16	40	70	100	120	140	160	180	190
18	60	100	130	160	200	220	240	260
20	80	130	180	220	260	300	320	360
22	100	170	230	280	340	380	420	460
24	130	220	290	360	430	490	540	600
26	160	260	360	440	520	590	660	740
28	190	320	430	520	620	710	800	880
30	230	380	510	630	740	840	940	1040
32	270	440	590	730	860	990	1120	1220
34	300	510	680	850	1000	1140	1300	1440
36	350	580	780	970	1140	1310	1480	1640
38	390	660	880	1100	1290	1480	1680	1860
40	430	740	990	1230	1450	1660	1880	2080
42	470	830	1100	1370	1620	1860	2100	2320

Appendix Table 6.—Percent of board-foot volume (International ¼ inch kerf) in 8-foot bolts by tree log height. Bolts numbered from bottom (#1) to top (#10). (Wenger 1984).

Bolt No.	1	1 1/2	2	2 1/2	3	4	5
1	56	41	33	27	24	20	18
2	44	32	26	23	20	17	15
3		27	22	19	18	16	13
4			19	17	15	13	12
5				14	13	12	11
6					10	9	9
7						8	8
8						5	6
9							5
10							3

Appendix Table 7.—Cubic-foot volume (ib) to a variable top diameter (4 inches dib or more) by dbh and number of 8-foot bolts. (USDA Forest Service NA S&PF, 2008)

	No. of bolts							
Dbh	1	2	3	4	5	6	7	8
(in.)	(cf)	(cf)	(cf)	(cf)	(cf)	(cf)	(cf)	(cf)
6	1.3	2.2	3.2	--	--	--	--	--

8	2.4	3.9	5.4	6.9	8.4	--	--	--
10	3.9	6.5	8.8	10.5	12.6	14.9	--	--
12	5.5	9.6	13.0	15.6	17.8	20.5	23.7	--
14	7.5	13.2	18.0	21.6	24.6	27.9	31.6	37.1
16	9.6	17.4	23.7	29.0	33.2	37.1	41.9	46.6
18	12.2	22.3	30.2	37.1	43.4	47.4	51.3	57.7
20	15.3	27.9	37.9	46.6	53.7	60.0	64.0	70.3
22	19.0	34.8	47.4	57.7	66.4	73.5	79.0	84.5
24	22.8	41.1	56.9	69.5	79.0	88.5	95.6	101.1
26	26.9	49.0	66.4	82.2	94.0	105.1	113.8	119.3
28	30.7	56.9	76.6	94.8	109.0	122.4	131.9	139.0
30	34.0	63.2	86.9	108.2	125.6	134.3	152.5	161.2

Appendix Table 8 .--Sawlog scale deduction for sweep in percent of gross scale for 16-foot logs and 8-foot logs. (USDA Forest Service NA S&PF, 2008)

Absolute sweep (in.) 16-foot logs

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Scaling diameter	3	4	5	6	7	8	9	10
(in.)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
8	12	25	38	50	+50	+50	+50	+50
9	11	22	33	44	56	+50	+50	+50
10	10	20	30	40	50	60	+50	+50
11	9	18	27	36	45	54	64	+50
12	8	17	25	33	42	50	58	+50
13	8	15	23	31	38	46	54	62
14	7	14	21	29	36	43	50	57
15	7	13	20	27	33	40	47	53
16	6	12	19	25	31	38	44	50
17	6	12	18	24	29	35	41	47
18	6	11	17	22	28	33	39	44
19	5	11	16	21	26	32	37	42
20	5	10	15	20	25	30	35	40
22	5	9	14	18	23	27	32	36

Absolute sweep (in.) 8-foot logs

Scaling Diameter	2	3	4	5	6	7	8
(in.)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
8	12	25	38	50	50+	50+	50+
9	11	22	33	44	56	50+	50+
10	10	20	30	40	50	60	50+
11	9	18	27	36	45	54	64
12	8	17	25	33	42	50	58
13	8	15	23	31	38	46	54
14	7	14	21	29	36	43	50
15	7	13	20	27	33	40	47
16	6	12	19	25	31	38	44
17	6	12	18	24	29	35	41
18	6	11	17	22	28	33	39
19	5	11	16	21	26	32	37
20	5	10	15	20	25	30	35
22	5	9	14	18	23	27	32

Appendix Table 9.—Relation of stump dib to dbh: stump height 0.5 ft (stumps 5-10 inches diameter) and 1.0 ft (stumps 11 inches diameter and over) (Wenger 1984).

Stump dib	Beech	Red/sugar maple	Yellow/black birch	Aspen	Red oak	White ash	White pine
(in.)	(in.)	(in.)	(in.)	(in.)	(in.)	(in.)	(in.)
5	4	4	4	5	4	4	4
6	5	5	5	6	5	5	5
7	6	6	5	7	6	6	6
8	6	7	6	8	6	7	7
9	7	8	7	9	7	8	8
10	8	8	8	10	8	9	9
11	10	10	9	11	10	10	10
12	11	11	10	12	10	11	11
13	11	12	11	13	11	12	12
14	12	13	12	14	12	13	12
15	13	14	13	15	13	14	13
16	14	14	13	16	14	15	14
17	15	15	14	--	14	16	15
18	15	16	15		15	17	16
19	16	17	16		16	17	17
20	17	18	17		17	18	18
21	18	19	17		18	19	--

22	19	20	18		18	20	
23	19	20	19		19	21	
24	20	21	20		20	22	
25	21	22	21		21	22	
26	21	23	--		21	23	
21	22	24			22	24	
28	23	--			23	--	
29	24	--			24		

Appendix Table 10.—Sugar maple tap hole computation sheet: point sample method (10 factor).Directions : Take 10-factor prism plots. Cross off tree numbers when tallied by dbh in table below. For multiple taps/tree, count each tap as separate tree. Tally # prism points. Divide total no. trees (last entry in below table) by # prism plots. Use multiple sheets as needed. Prism plot count:_______.

Dbh (inches) .

10	12	14	16	18	20	22	24	26
(no. Trees)	(no. trees)	(no. trees)	(no. trees)	(no. trees)	(no. trees)	(no. trees)	(no. trees)	(no. trees)
18	13	9	14	11	14	11	10	11
37	25	19	29	23	28	23	19	22
55	38	28	43	34	41	34	29	32
73	51	38	58	46	55	46	38	43
92	64	47	72	57	69	57	48	54
110	76	56	86	68	83	68	58	65
128	89	66	101	80	97	80	67	76
146	102	75	115	91	110	91	77	86
165	114	85	130	103	124	103	86	97
183	127	94	144	114	138	114	96	108
201	140	103	158	125	152	125	106	119
220	152	113	173	137	166	137	115	130
238	165	122	187	148	179	148	125	140
256	178	132	202	160	193	160	134	151

<u>Example:</u> 3 plots; five 10's, four 14s, two 20's, one 26. Calculations: 92+38+28+11 = 169/3 = 56 taps/acre.

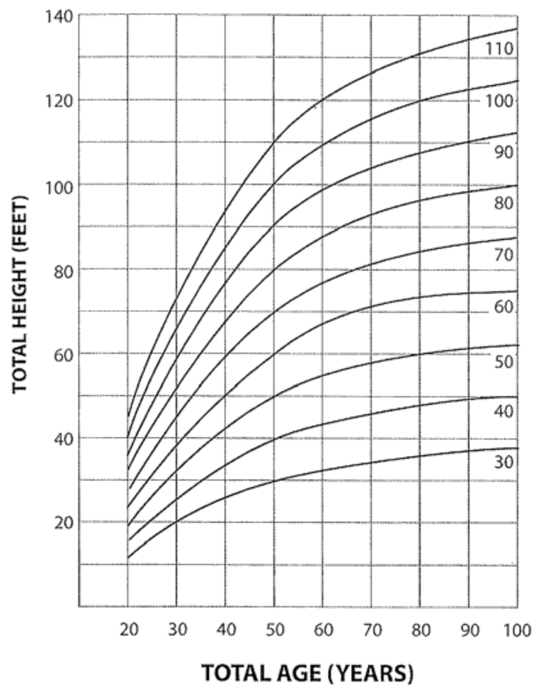
Appendix Table 11.—Weight table for various species.

Species	Green Weight per cord	Green weight per mbf of lumber	Green weight per cubic foot	Air dry weight per cubic foot
	(lbs)	(lbs)	(lbs)	(lbs)
Ash, white	4300	4000	48	41
Aspen	3900	3600	42	27
Basswood	3800	3500	41	26
Beech	4900	4500	55	44
Birch, yellow	5100	4800	58	43
Birch, white	4500	4200	50	39
Cherry, black	4000	3800	46	35
Elm	5000	4600	56	37
Hemlock	4500	4200	49	28
Hickory	5700	5300	64	51
Locust, black	5200	4800	58	49
Maple, hard	5300	4600	56	44
Maple, soft	4300	3900	50	38
Oak, red	5700	5200	63	44
Oak, white	5600	5200	62	48
Pine, red	3800	3500	42	33
Pine, white	3200	3000	36	25

Spruce	3000	2800	34	28

5.27 AMERICAN BEECH

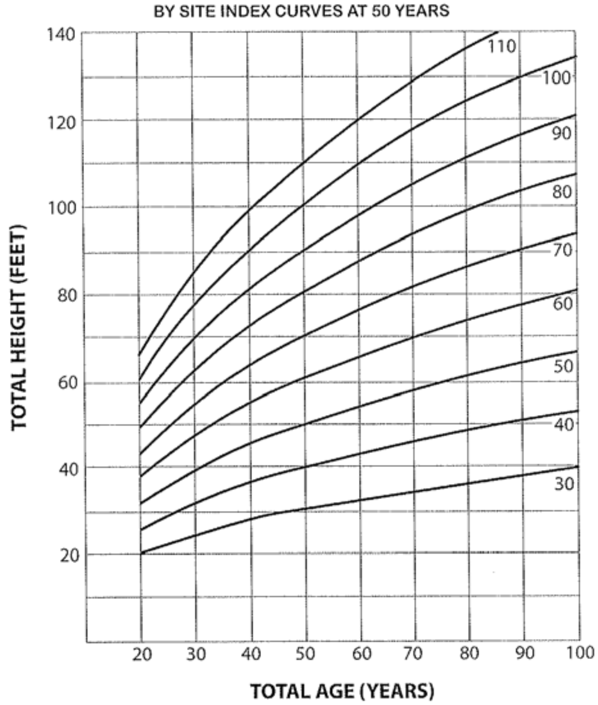
HEIGHT IN FEET OF AVERAGE DOMINANT & CODOMINANT TREES, BY SITE INDEX CURVES AT 50 YEARS



Source: Constructed from Unpublished Data, N.E. Forest Exp. Station, Upper Darby, PA.

5.41 YELLOW BIRCH

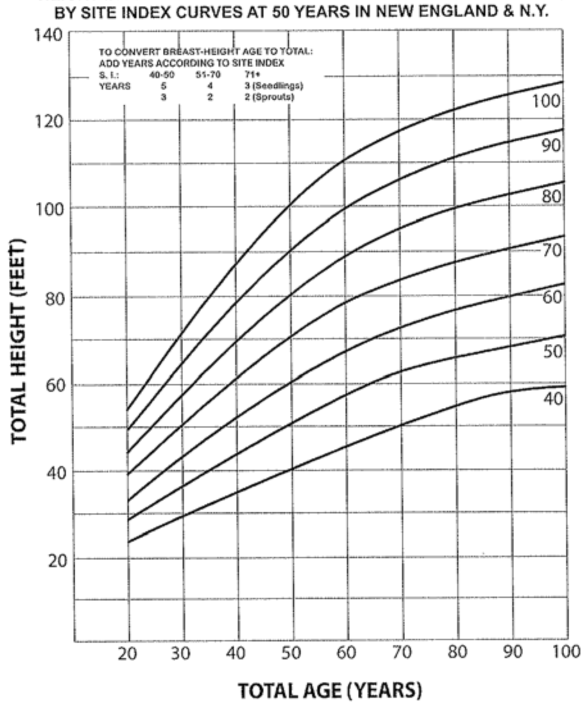
HEIGHT IN FEET OF AVERAGE DOMINANT & CODOMINANT TREES BY SITE INDEX CURVES AT 50 YEARS



Source: Constructed from Formula Developed by R.O. Curtis & B.W. Post, Bull. 629 Agr. Exp. Station, University of Vermont & State Agr. College, August 1962.

5.34 RED MAPLE

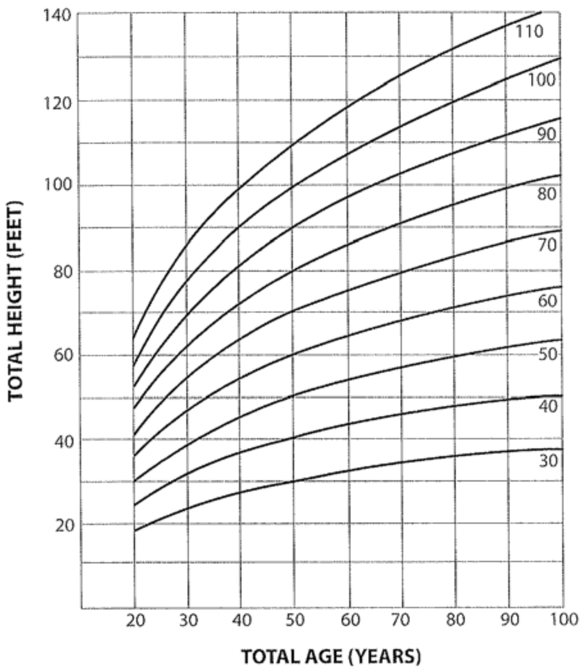
HEIGHT IN FEET OF AVERAGE DOMINANT & CODOMINANT TREES, BY SITE INDEX CURVES AT 50 YEARS IN NEW ENGLAND & N.Y.



Source: Constructed from Data Reported by R.W. Foster, Forest Science, Vol. 5, No. 3, Sept., 1959. (For Trees of Seedling Origin Only)

5.39 WHITE ASH

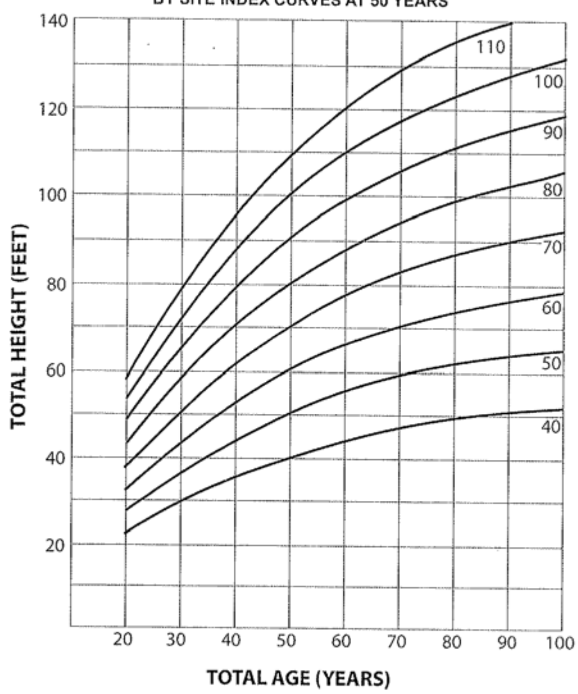
HEIGHT IN FEET OF AVERAGE DOMINANT & CODOMINANT TREES
BY SITE INDEX CURVES AT 50 YEARS



Source: Constructed from Formula Developed by R.O. Curtis & B.W. Post, Bull. 629, Agr. Exp. Station University of Vermont & State Agriculture College, August 1962.

5.29 BLACK CHERRY

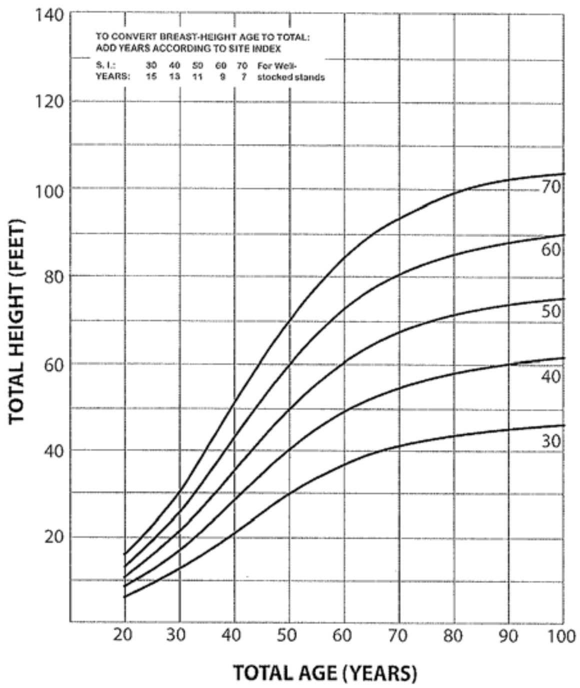
HEIGHT IN FEET OF AVERAGE DOMINANT TREES, BY SITE INDEX CURVES AT 50 YEARS



Source: Prepared from a Thesis for Graduate Degree by S.E. Defler, N.Y. State College of Forestry, 1937.

5.35 RED SPRUCE

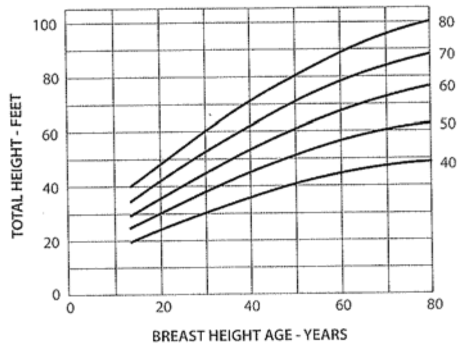
HEIGHT IN FEET OF AVERAGE DOMINANT & CODOMINANT TREES IN EVEN-AGED STANDS BY SITE INDEX CURVES AT 50 YEARS IN NATURAL RANGE



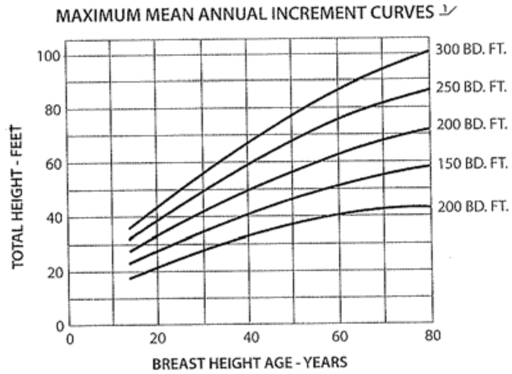
Source: Meyer, W. H., USDA Tech. Bull. No. 142, Nov. 1929. (Revised to 50-Year Age from 65 Years)

5.20 SUGAR MAPLE

SITE INDEX CURVES



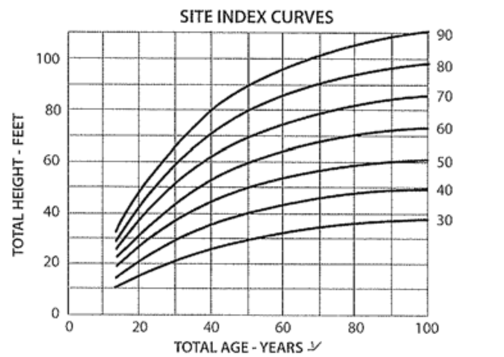
MAXIMUM MEAN ANNUAL INCREMENT CURVES 1/

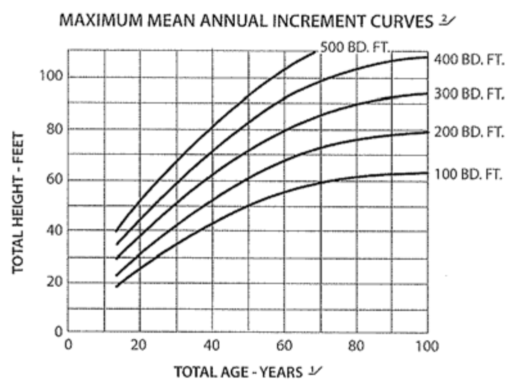


1/ Intensive all-age management of northern hardwoods using sugar maple as site indicator.

Source: Yield tables for important timber species of the Lake States, unpublished, L.S.F.E.S.; and Bulletin 629, Univ. of Vermont Agric. Station.

5.22 UPLAND OAKS

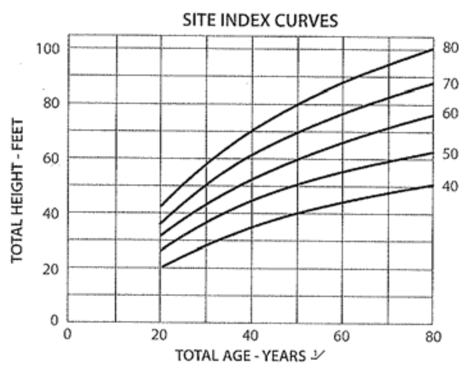


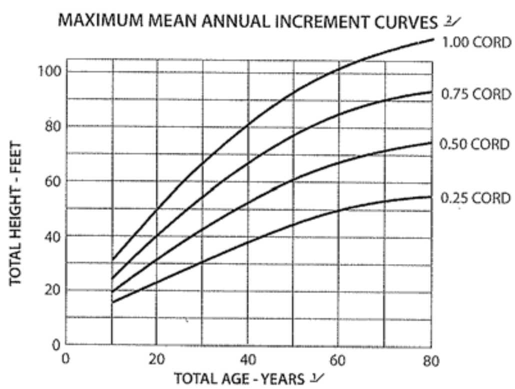


1/ Total age = Breast height age + 2 years

2/ Rotation = 100 years. Managed stands.
Source: Tech. Bull. No. 560, USDA, and Res. Note #125, S.E.F.E.S.

5.18 PAPER BIRCH

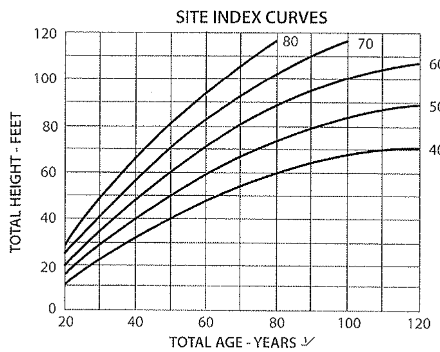


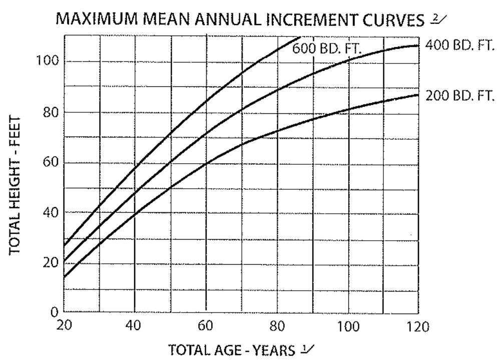


1/ Total age = Breast height age + 2 years

2/ Rotation = 60 years. Unmanaged stands.
Source: L.S.F.E.S. Technical Note No. 541.

5.23 WHITE PINE



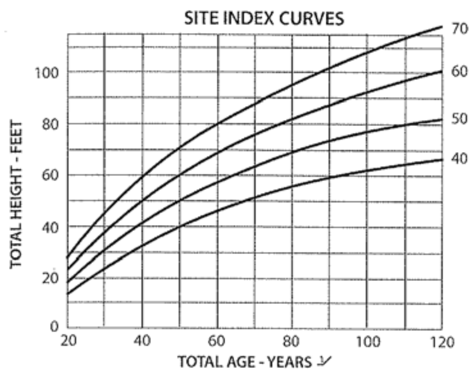


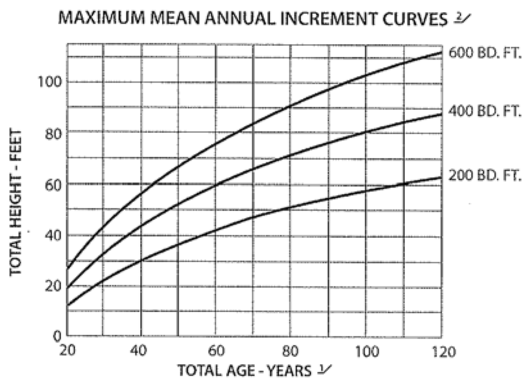
1/ Total age = Breast height age + 10 years

2/ Managed stands. Intermediate yield estimate was based on the assumption that the increase would be proportional to that realized between managed and unmanaged red pine stands. Rotation = 115 years.

Source: Yield tables for important timber species of the Lake States, unpublished, and Tech. Note 483.

5.19 RED PINE


SITE INDEX CURVES
TOTAL HEIGHT - FEET
0
20
40
60
80
100
20
40
60
80
100
120
TOTAL AGE - YEARS 1/
70
60
50
40


MAXIMUM MEAN ANNUAL INCREMENT CURVES 2/
TOTAL HEIGHT - FEET
0
20
40
60
80
100
20
40
60
80
100
120
TOTAL AGE - YEARS 1/
600 BD. FT.
400 BD. FT.
200 BD. FT.

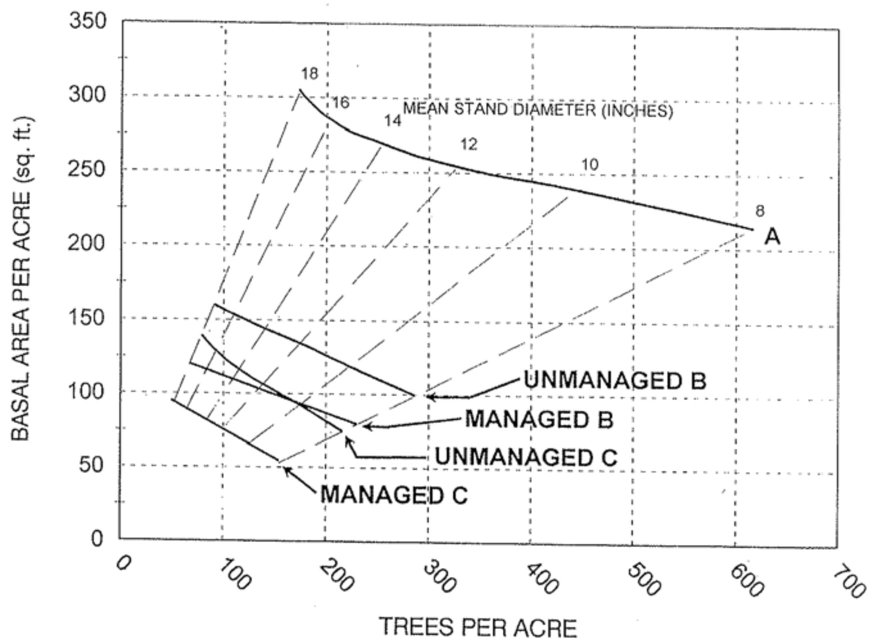
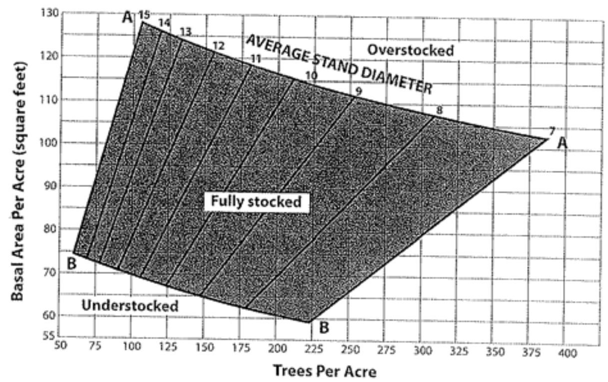
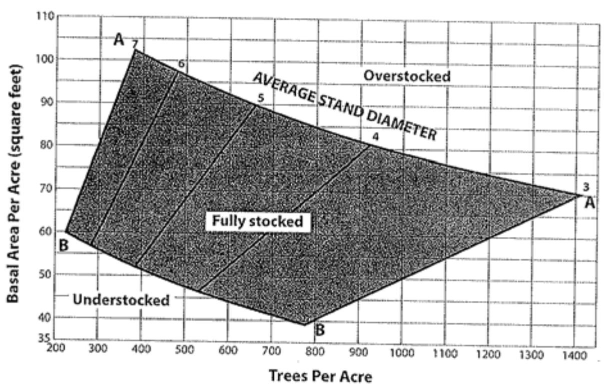


Figure 1. Revised white pine stocking guide for managed stands

5.8 Upland Hardwoods (oak-hickory) Stocking Charts

Upland hardwoods (oak-hickory) stocking charts. Use the upper chart for stands with larger diameter trees and the lower chart for stands with small diameter trees.





Source: Wisconsin Woodlands: Estimating Stocking Conditions in Your Timber Stand by Jeff Martin.

Textural Classification of Soils

Soil texture refers to the relative proportions of sand, silt, and clay particles that make up the soil mass. The chart below shows the percentage of these soil fractions in the basic textural grades.

Three classifications—sandy loam, loam, and silt loam—are common surface soils; they also may occur as subsoils. The rest of the classifications are subsoils.