For the Family Landowner:

Best Techniques to Increase Forest Productivity and Value in the Northeast U.S.

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Author: Charles A. Levesque

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I. Introduction

In thinking about new trends that are affecting the forests of the Northeast U.S., the State Foresters in Maine, New Hampshire, Vermont and New York came to the conclusion that increased demand for the use of forest-derived wood for energy production is a major change that could have significant ramifications for the forests of the region, as well as the economy that depends on them. In 2010, their North East *State* Foresters Association[1] (NEFA) decided to pursue a multi-pronged project to address the opportunities and challenges presented by this emerging demand for wood energy. This paper is one component of that effort.

The three-pronged effort included:

- Development of a publicly available computer simulation model and decision support tool that can be used to help understand localized and regional impacts and opportunities resulting from new and increased demand for wood energy in the region;
- A review of the multitude of biomass harvesting guidelines that have been promulgated world-wide and a determination of the commonalities and issues among these guidelines;
- An assessment of the various forest practice actions that can be used to increase forest growth in the northeast, to address potential increased wood demand for energy purposes.

This paper represents findings from the third item – readily adoptable practices to increase forest growth, productivity and value in the northeast. Though targeted for the family forest owner, this information is useful for all forest owners to review.

There are just a few variables that determine whether forests in the northeast grow well or poorly. The first key variable is soil type. Forest areas that have wet organic soils throughout the year or have little soil, such as steep slopes or areas where ledge is close to the surface, will grow more slowly than areas with deeper, well drained soils. The second major variable that affects how fast forest trees can grow is simple – competition for sunlight, water and nutrients in the soil.

While forest landowners can do very little about the poor soils issue – they can do a lot about competition for resources. According to the USDA Forest Service's Forest Inventory and Analysis, approximately fifty percent of the forests in New York, Vermont, New Hampshire and Maine are over-stocked or fully stocked. This means that trees in this region must vigorously compete for limited sunlight, water and soil nutrients because there are so many individual trees growing

1. The state foresters from Maine, New Hampshire, Vermont and New York working closely with the USDA Forest Service, State and Private Forestry

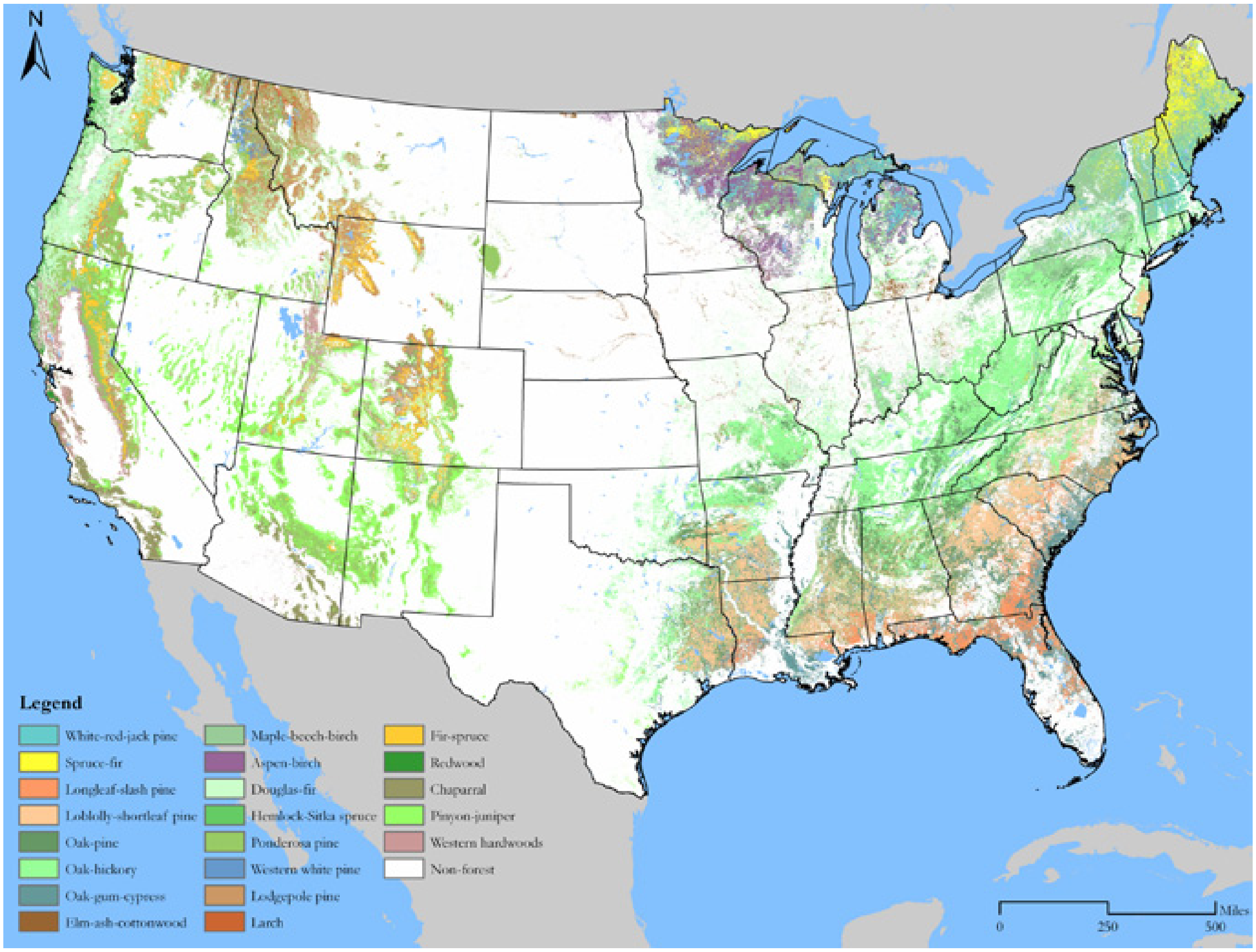
close together on an average wooded acre. As a result, the region's trees are, on average, growing much slower than they would be if they had ample resources, particularly sunlight. If the forest is left to grow naturally in this crowded situation, eventually the weaker trees will die because of the lack of adequate sunlight and other resources. The remaining trees will have lost growth during natural selection. The resulting forest may be less valuable to the landowner than one that is growing to its full potential.

Landowners that are interested in improving the productivity of their forests can use the techniques described in this paper to get the most from the land they own.

II. Northeastern U.S. Forests

There are challenges in discussing techniques to improve productivity in the forests of the northeast. This is not because suitable methods to address the issue are lacking – the methods are out there. Instead, there are simply fewer realistic and readily affordable approaches in comparison to other geographic regions – particularly the U.S. south. Additionally, a shorter growing season in the northeast means that growth rates are slower than they are in the south. There is also a diversity of tree species in the northeast U.S. as compared with some other areas of the country. This means that some species are fast growing and others are not. This makes for additional complexity in making choices about practices to increase productivity.

Lastly, there is varied terrain in the northeast which, again, adds complexity for the landowner in understanding soil productivity and the site advantages of one location over another. Despite these challenges, there is much that can be done to increase forest productivity in the northeast U.S. Ultimately the key question is – if I am going to expend effort to increase the productivity of my northeastern forest, how should I do that and on which acres should I concentrate my efforts?



Forest Area of the United States

III. Techniques to Improve Productivity and Value in Northeastern U.S. Forests

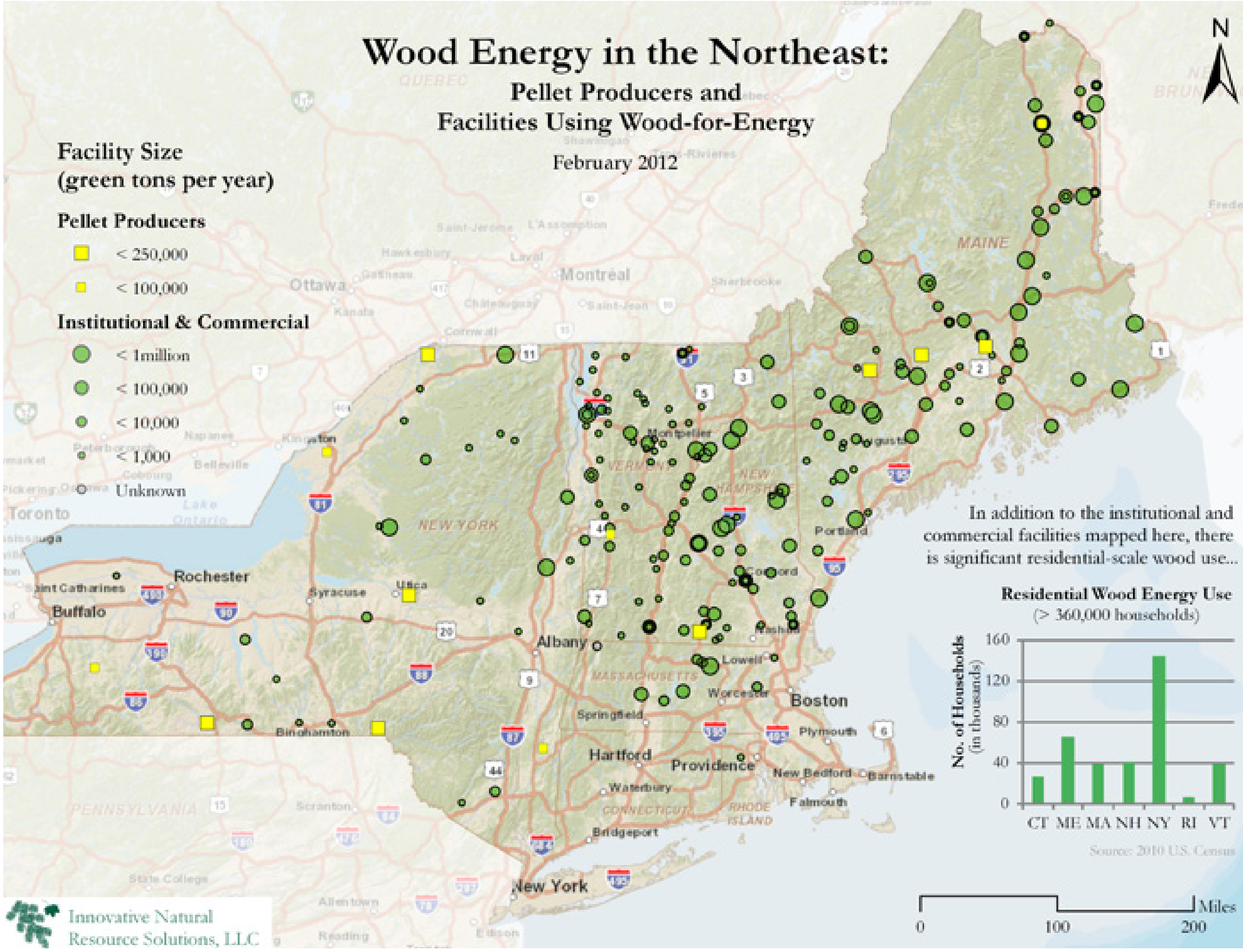
A. Natural Phenomena Increasing Forest Growth

The literature is now packed with research showing increasing carbon dioxide levels in our atmosphere. Some of this research is focused on how this phenomenon might benefit our forests, by providing more of the inputs needed for increased photosynthesis in trees – translated to increased tree growth.

In *Ecology Letters* in December of 2011, researchers Donald R. Zak, Kurt S. Pregitzer, Mark E. Kubiske, and Andrew J. Burton concluded that growth rates increase substantially under elevated CO_2 levels, based on a decade long study where elevated levels of carbon dioxide were artificially maintained in test sites in Wisconsin forests.

Another study, measuring actual growth in aspen stands in the Lakes States, showed growth increases due to elevated CO_2 in the atmosphere. In that study, entitled *Rising concentrations of atmospheric CO_2 have increased growth in natural stands of quaking aspen* and published in Global Change Biology in 2010, the authors write:

> "Aspen growth has increased an average of 53% over the past five decades, primarily in response to the 19.2% rise in ambient CO_2 levels. CO_2-induced growth is particularly enhanced during periods of high moisture availability."



Use of wood for energy in the Northeast U.S. is robust.

So, without any effort on their part, forest landowners in the northeast can probably bet on the fact that, given all other things being equal, their forests are growing faster than they were 50 years ago. Longer growing seasons are also being experienced in the northeast. If that trend continues, this would likely result in increasing tree growth, assuming that other critical variables, such as annual rainfall/snowfall levels, remain constant or increase.

Of course, the downside of this changing climate phenomenon, to the extent that it is occurring, is that non-desirable species, both native and invasive, will also grow faster with increased CO_2 levels and longer growing seasons. Competition from these non-desirable species may pose an extra challenge.

B. Practices Landowners Can Implement to Increase Forest Productivity and Value

The origin of this paper came from the notion that increased demand for energy wood from the northeastern forests will put new pressure on the timber resource and that increasing forest growth and productivity, at least in part, should be part of the suite of solutions addressing this increased demand for wood. It is clear in developing the paper that increased monetary value of the forest for the family owner goes hand-in-hand with the goal of increased productivity. This next section of the paper discusses the many techniques to increase productivity and value of the forest. It should be mentioned here that one of the more simple but important ways for the landowner to increase the revenue from their forest when harvesting timber is to simply sell the timber at the right time – when market demand and prices are up. Many family forest landowners can take advantage of these situations by planning for a window of years during which a harvest can take place instead of for a year certain. Foresters and others with good market knowledge can assist in this critical value decision making.

1. Early Stand Establishment

When a forest is harvested, the practice may be an intermediate cut (thinning in either an even-aged or uneven-aged stand[2]) or a final harvest designed to regenerate the next forest. While tree planting can be done in the northeast, it rarely is (see "artificial" below), so let us assume that the final harvest is designed to regenerate the next forest naturally.

When using natural regeneration, care must be taken in selecting the season and year of harvest because these factors can significantly affect how quickly the forest will regenerate. The quicker tree seedlings can become established, the better. Every year that goes by where seedlings do not take up the space created by a regeneration harvest, is a year of lost growth.

2. Uneven-aged forests have at least 2 distinct age classes growing. Even-aged forests have one distinct age class.

a. Natural Regeneration

No matter what silvicultural system is used (seed tree, shelterwood, clearcutting or selection), care can be taken to assure quick seedling establishment.

When natural regeneration will be relied upon to start the next stand of trees, it is important to carefully evaluate the potential seed source from the surrounding trees. Look at the trees that you are leaving after the harvest, in terms of:

- species,
- prevailing wind direction,
- seed source type and how it is generally disseminated (wind, animal, etc.,)
- distance between likely seed trees and the area to be regenerated, and
- soils relative to the seed source.

White pine regeneration can be dense and substantial.

If the species you are trying to regenerate requires some exposure to mineral soil for germination, such as white pine, then be sure the harvest occurs during the warmer weather months to assure logging equipment turns up the organic layer of soil to expose mineral soil. This technique also reduces competition by essentially grinding it up with the machinery.

Knowing the regeneration characteristics of the dominant trees found in your woodlot will greatly assist with choosing the harvesting techniques that will create the best opportunities to regenerate desirable species as quickly as possible following harvest.

Figure 1 (right) lists key regeneration characteristics of trees likely to be found in northeastern forests. The following offers further explanation of the table column headers:

Shade tolerance will help you determine whether you are providing enough light for a particular species to regenerate and thrive.

Seedling and sapling height growth is an important characteristic for when there will be a species mix in the regenerating forest. Knowing which trees will grow the fastest in

Figure 1. Silvicultural characteristics of some northern trees

Species	Shade tolerance	Seedling and sapling height growth	Years between good seed crops	Sprouting vigor	Delayed germination[1]
Hardwoods					
Paper Birch	Intolerant	Fast	2	Moderate (Small stumps)	None known
Quaking Aspen	Intolerant	Fast	4-5	High (Suckers)	None
Red Maple	Moderate	Moderate	1	High	Moderate
Sugar Maple	Tolerant	Slow	3-7	Moderate (Small stumps)	Negligible
Basswood	Tolerant	Moderate to fast	1	High	None known
White Ash	Intolerant	Moderate	Variable	High	Moderate
Black Ash	Intolerant	Moderate	1-8	Moderate	Complete
Red Oak	Moderate	Moderate	3-5	High	None
White Oak	Intolerant	Moderate	4-10	High (Small stumps)	None
Conifers					
Eastern White Pine	Moderate	Slow to moderate	3-10	None	Negligible
Red Pine	Intolerant	Fast	3-5	None	Negligible
Jack Pine	Intolerant	Moderate	Variable	None	Limited
Balsam Fir	Tolerant	Moderate	2-4	None	Negligible
White Spruce	Tolerant	Moderate	2-6	None	Limited
Black Spruce	Tolerant	Slow	2-6	Layering (Shoot produced from low branches)	Negligible

Delayed seed germination definitions

- None known - All seeds are believed to germinate following dispersal.
- None - All seeds germinate following dispersal.
- Negligible - Only a small percentage germinate the year following dispersal.
- Limited - A small percentage germinate one or more years following dispersal.
- Moderate - As much as 50 percent germinate one or more years following dispersal.
- Complete - Most seeds germinate one or more years following dispersal.

Source: Mathew Smidt and Charles R. Blinn, Logging for the 21st Century: Forest Ecology and Regeneration, Minnesota Extension website http://www.extension.umn.edu/distribution/naturalresources/DD6517.html the early years can tell you what kind of chance your desired species has for getting ahead of the crowd and becoming firmly established in a dominant position in the tree canopy.

Years between good seed crop can help you understand if your chosen harvest year will likely be followed by ample seed in the near future, given some knowledge about when the previous good seed year occurred.

Sprouting vigor for hardwood species tells whether sprout regeneration (commonly called coppice) is an option for the species you want to regenerate.

Delayed germination can tell you whether the seed is likely to regenerate immediately or take some time to throw up the tree shoot once it is on the ground.

Coppice regeneration, which is another natural regeneration method that relies on sprouts from cut trees (hardwood) instead of seed, is another technique that should be considered in the natural regeneration of hardwoods. Figure 1 also shows the species specific characteristics of coppice regeneration. Note that softwoods do not have this type of regenerative capacity, except that on certain species lower branches that are left uncut, after the main stem has been harvested, will turn upwards and take over as the central leader of the tree.

Using the coppice method in hardwood regeneration requires diligence after sprouting has occurred because many sprouts will usually grow from a single cut tree. If a quality tree is desired from coppice regeneration,

Coppice regeneration in red maple provides many stems which can be both useful and problematic.

Planting trees can supplement natural regeneration of forests in the northeast.

it will be necessary to remove some of the competing stems from the group of stem sprouts on an individual coppiced stump. The sooner these competing stems can be removed the better, after sprouts emerge and have grown in feet (not tens of feet). If thinning of sprouts does not occur, then a group of ill-shaped trees will likely grow from the stump, with weak V connections at the base. These tend to be weak if heavy winds arise. Leaving all the sprouts in a coppiced regenerating stand will result in a significant amount of biomass growth but less in the way of quality wood.

Whether coppice or seed as the source for regeneration, advanced regeneration – that which is already growing when the final harvest is accomplished – should be a very important part natural regeneration. This is especially true for white pine, red oak, hemlock and spruce/fir.

b. Artificial Regeneration

While tree planting is not a technique used extensively in the northeast, it is, nevertheless, a useful approach that could be explored in certain situations. Hardwood tree planting can be done but hardwood seedlings are rarely planted in the northeast. Although for some higher value species, particularly black cherry and black walnut, there may be an exception to this rule.

There are two main uses for planted tree seedlings in the northeast that should be contemplated and, given certain conditions, might be the best method to get regeneration started and ensure that growth occurs as quickly as possible following final harvest:

Interplanting – Probably the most useful reason to use planted seedling stock for forestry in the northeast is as a supplement to natural regeneration. The technique involves waiting for natural regeneration to become established in an area that was recently harvested and then, based on what trees become established, desired species can be interplanted among areas of natural regeneration where trees have not become established. Given the extra costs involved in tree planting, great care should be taken to plant only in areas that are 20 to 25 feet from existing natural regeneration. This will ensure that the planted tree does not die from the effects of overcrowding, which naturally regenerated forest trees experience.

Softwood planting – In the northeast, regeneration following the final harvest in softwood stands – particularly white pine, spruce and balsam fir – may result in heavy natural regeneration to hardwood when softwood regeneration is desired. This may result from a number of phenomena, such as a white pine harvest during the winter when soil is not scarified for good pine seed germination, or simply harvesting in a year when cones are not abundant on trees or in the several years following. In these situations, planting softwood trees may be desirable in the area receiving the final harvest.

In all situations where hardwoods are likely to colonize the site, efforts will be needed to assure that natural hardwood regeneration will not dominant and overtop the planted seedlings. In small areas, hardwood regeneration may be mechanically removed using hand tools or gas-powered brush saws. This is a labor intensive activity. Using herbicides such as glyphosate applied using backpack sprayers or, in larger area plantings, using ground sprayers mounted on skidders, is a quicker method to assure planted tree stock survival[3].

Either of these techniques may be useful in locations with heavy fern regeneration that prevents tree seedling establishment. Currently this challenge is seen mostly in locations in New York State.

Planting of hardwood or softwood species of trees for any reason in the northeast should be scrutinized by the landowner and/or forester. The expense may not justify the activity if the economics of the forestry activity is important to the landowner.

2. Wildlife Effects

Whether through natural regeneration or artificial planting, early establishment of forest stands can be severely limited through browsing of seedlings or saplings by wildlife species, particularly white-tailed deer and moose. While there is the possibility of severe loss of productivity from the killing or maiming of tree seedlings by these ungulates, currently this problem is being experienced severely in only a few areas of the region. All the states of the region are experiencing this in certain locations with deer browsing. Northern areas of Vermont, New Hampshire and Maine are seeing this phenomenon with moose browsing in isolated locations as well.

In either case, hardwood species are the primary target of deer and moose browsing. Softwoods remain largely untouched in heavy browsing areas except for balsam fir by moose. Two logical remedies to reduce or eliminate

3. A good source of information about use of herbicides for forestry purposes is *Herbicides and Forest Vegetation Management: Controlling Unwanted Trees, Brush, and Other Competing Forest Vegetation*, published by the Penn State Cooperative Extension in 2011 and available electronically at http://pubs.cas.psu.edu/freepubs/pdfs/uh174.pdf.

this threat to tree productivity include techniques to urge softwood regeneration (other than balsam fir), if appropriate for the site and, secondly, reducing the deer or moose population through hunting activities. The latter technique has been shown to be very successful in locations where increased harvesting of the animals occurs over an extended period of years.

3. Nutrient Supplementation

We cannot properly discuss potential for forest fertilization in the northeast U.S. without reviewing the tremendous progress made on that front in the southern U.S. Artificial fertilization of forests is common in the southern U.S. on the most aggressively managed pine plantations. Mid-rotation application of Phosphorus (P) and/or Nitrogen (N) occurs on planted pine stands that are properly thinned and have row widths that allow tractor application of dry fertilizer. This usually occurs after the first commercial thinning. In those scenarios, careful decision making is necessary to assure that soils are in need of P and N and that the trees are healthy enough to utilize artificial fertilizer application.

Pine plantations established in the 1950s and 1960s in the south, which produced less than 90 cubic ft./acre/year, have been replaced by plantations established in the 2000s, which may produce in excess of 400 cubic ft./acre/year as a result of mid-rotational fertilizer application. During this period, rotation lengths have also been cut by more than 50%, as a result of both fertilization and other aggressive silvicultural techniques included in site preparation for planting. Work conducted at North Carolina State University and other southern research establishments refined the fertilization practice to assure that the right fertilization technique and materials are used for any particular site.

Moose or deer browse such as this results in multi-stemmed poor quality trees. In areas of intensive browse, little or no regeneration may result.

Mid-rotation fertilization with nitrogen (150–200 lbs./ acre) and phosphorus (25–50 lbs./ acre) resulted in a large and consistent growth response on the majority of soil types. These responses have typically lasted for at least 6–10 years, depending on soil type, fertilizer rates, and stand conditions. Most of the application of these techniques has occurred on the coastal plain and piedmont (higher relatively flat plateau west of the coastal plain but east of the Appalachian mountains). Research was also used to determine whether fertilizer application was a sound economic choice (it often was) and in what situations.

In the northeast U.S., more limited results have come from research on the topic of fertilization in forests. The lack of large area forest plantations is partly to blame and the lack of suitable flat forest terrain along with the short growing season have also contributed to the fact that fertilization has taken a back-seat to regular silvicultural activities in the region.

In a study published in the Canadian Journal of Forest Research in 2007, a team of researchers described the results of a fertilization study conducted in New York, New Hampshire and Vermont in red spruce and balsam fir forests. On these forests over a 6 year period, nitrogen (N), calcium (Ca), and N + Ca treatments (of 100, 160, and 260 kg/hectare/year-1 of N, Ca, and N + Ca, respectively) were applied. Forest responses to Ca treatments were also determined in Vermont. Nitrogen treatments increased aboveground net primary production (ANPP) by 33% and 25% above controls in NY and NH, respectively. Similarly, N + Ca treatments increased ANPP by 27% and 28% in NY and NH, respectively. Calcium treatments increased ANPP by 25% and 21% above controls in NY and VT. Calcium treatment did not increase ANPP in NH, suggesting N, but not Ca limitation.

In addition to general increases in ANPP from fertilization, researchers found that leaf-litter quantity and quality, as well as soil C and N storage were greater in treated than in control plots. Fine-root mass and production did not differ among treatments. Trees, therefore, assimilated more soil nutrients without increasing root growth in treated plots. Red spruce ANPP, however, declined or remained unchanged in response to N and Ca additions.

In contrast to these northern studies, the research in the south that revealed potentially enormous gains in productivity was conducted largely on areas that had previously been in agriculture, i.e. areas more readily suitable for such fertilization activities. From 1960 to 2000, the acreage in pine plantations in the south went from under a million acres to over 30 million acres. For this reason, it is difficult to make a direct comparison between the two regions.

This is not to say that using artificial fertilizer would not yield results if applied on the forests of the northeast U.S. Lessons from the southeast should be taken to heart. In fact, some fertilization efforts have been made in the northeast since the 1970s, particularly in spruce-fir plantations of Maine. However, it is common knowledge that little of this activity occurs today due to the shorter-term ownership structure of the larger forest ownerships. Whereas the fertilization activities of the south occurred on both small and large ownerships, the limited fertilization activities that have occurred in the northeast forests have largely been on the large so-called forest industry lands.

Dominant, co-dominant and intermediate trees can be easily seen in this fall New England photo.

If your forest is on relatively flat terrain, and particularly if it is in softwood plantation, there may be a good opportunity to fertilize. Consulting an expert is warranted and both care and planning should be undertaken to determine the biological and economic likelihood of success for such an endeavor.

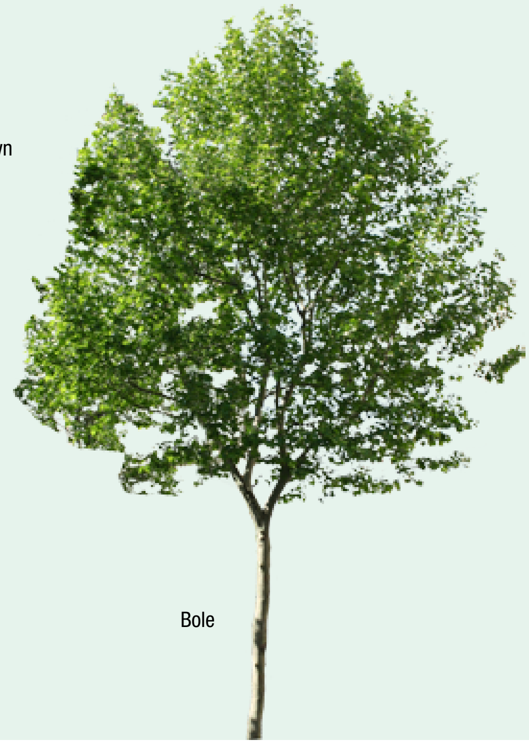
4. Intermediate Stand Treatments - Optimum Light & Space

Having spent some time in this paper discussing other important techniques that might be used to increase the productivity of the forests of the northeast U.S., significant review of forest thinning[4] is essential because this type of forest management activity is likely the best technique to use in the varied forests of the northeast and will yield the most for the landowner's efforts[5].

In forest situations, all trees compete with one another for light, moisture, and nutrients. Efforts by the forest landowner to increase tree growth should focus on activities that redistribute light to those trees that also meet other landowner objectives. In even-aged woods, understanding how trees compete in the forest canopy is important. Also critical, is knowledge of where individual tree crowns are located in the canopy and how they will respond to the increased light that becomes available as the result of thinning efforts.

The crown, the uppermost part of the tree, contains the smaller branches and the leaves that collect sunlight and enable the tree to carry on photosynthesis. Crown classes, a way of measuring the crown location in the forest relative to other trees, are referred to as being dominant, codominant, intermediate, and suppressed or overtopped. Dominant crowns are the largest in the forest. They receive sunlight from the top and some from all sides. Codominant crowns receive full sunlight

Figure 2 – Tree parts



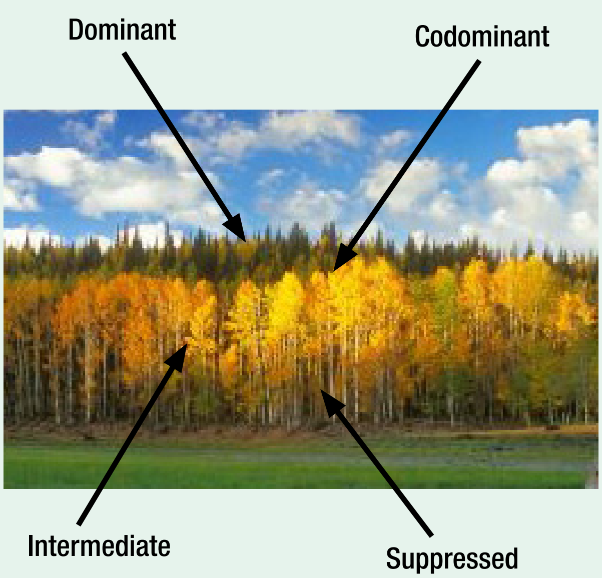
4. A forestry harvest made to reduce stand density of trees primarily to improve growth, enhance forest health, or recover potential mortality in the forest.
5. The introduction for this section of the paper relies heavily on *Managing Small Woodlots* by James C Finley, Lynn F. Kime, Jayson K. Harper, published through Pennsylvania State University, January, 2012

from the top and very little to no sunlight on the sides. These crowns are often flattened on one or more sides where they compete with other codominant crowns.

Intermediate crowns are shorter, but they extend into the upper canopy of the forest. They receive limited sunlight from the top and no sunlight from the sides. Suppressed or overtopped crowns are the smallest trees and receive no direct sunlight from any angle. Intermediate thinning harvests seek to improve conditions for the codominant trees by removing competition and encouraging them to develop fuller, more balanced crowns.

Intermediate crowns, depending on the tree species and its shade tolerance, may also respond to thinning. Shade-tolerant species, such as hemlock and sugar maple, will also increase their crown size with more sun. Intermediate shade-tolerant species, such as red and white oak and red maple, may increase crown size, but you need to evaluate the percentage of the crown relative to the total height and its overall health to make sure it is a worthy specimen to work around.

Figure 3 – Crown classes



A rule of thumb: If the trees you are looking to release through a thinning have less than 30 percent of their total height in leafy crown, they will likely respond very poorly. The important point to remember when conducting intermediate treatments is to avoid making cutting decisions that are driven solely by diameter or species, if it can be helped. In some situations, consideration of species, in addition to typical location and crown-derived thinning criteria, may be necessary to assure that higher value trees remain after the thinning. Select trees to improve the overall quality of the forest or woodlot. If you make tree selections based only on size or species (for example, all the red and white oak), this may be a form of high-grading (taking the best trees and leaving poor trees during a harvest) unless the quality of the trees you are leaving is high.

Tree diameter does not necessarily represent age well. Harvests that are designed to cut just big trees, in order to release smaller diameter trees, may be poorly designed and will likely remove the best trees while potentially leaving the weakest unless the large trees are overmature and will begin to die. The use of poor thinning practices will greatly reduce overall productivity and future income, as well as significantly extending the time it takes to grow large, high-quality trees. A qualified forester should be consulted for these difficult decisions.

Eventually, after several intermediate thinnings in an even-aged woodlot, you will have to consider when to regenerate the forest with a final harvest or overstory removal. If you have scheduled your thinning operations well, you should have advanced regeneration in place under the large overstory crowns.

a. Pre-Commercial Thinning

Pre-commercial thinning, thinning of trees accomplished when the trees are too small or of little value for a forest products market to pay for them, can be an important technique to use to increase growth in a small diameter forest stand. The challenge is that this kind of thinning cannot be paid for by the harvested timber and must be accomplished at a direct cost to the landowner. As a result of this challenge, very little pre-commercial thinning work occurs in either family forest ownerships or commercial ownerships. In the northeast U.S., the only kind of stands currently receiving wide-scale pre-commercial thinning work are spruce/fir sapling stands. In these cases, thinning is accomplished by crews of workers using gas-powered brush saws.

Efforts are being made and research is being done to find ways to turn this kind of thinning into a break-even operation by using small European style equipment. However, this technique is still in the research phase in this region. The material harvested from these types of thinning operations is sent to biomass power plants, along with whole tree chipped materials from regular commercial harvesting operations.

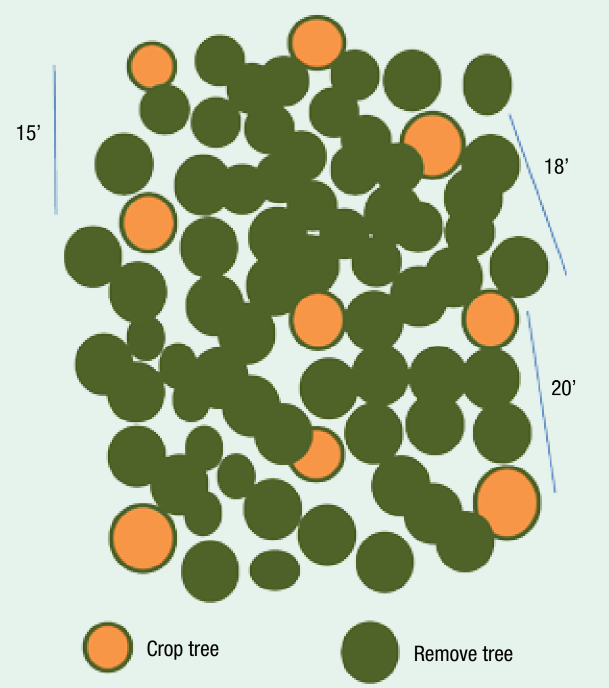
Despite this challenge, a family forest owner who wishes to jump-start a sapling-sized stand on a small

This northern hardwood stand is ripe for pre-commercial thinning.

area can do so with his or her own labor and a fairly inexpensive brush saw. Brush saws are similar to large gas-powered weed whackers, but the unit has a circular saw-like blade on the power end instead of a plastic weed line.

The key to carrying out this type of forest management operation is to develop a spacing technique and stick to it throughout the thinning work. Thinning should be conducted so that only healthy stems with 5-15 foot spacing remain, no matter if the stand is hardwood, softwood or mixed-wood. Wider spacing will have a greater effect on capturing future mortality than narrower spacing. Hardwood sapling stands are generally thinned later than softwood stands, when the hardwood saplings are at least 12 to 20 feet tall as compared to softwood which can be thinned at shorter heights. The goal in either case is to pre-capture any mortality that may occur later in the stand's growth, leaving trees that will survive until they are large enough for a final commercial thinning a decade or more before a final harvest in the latter stages of stand life. Beginning tree density may be between 2,000 and 10,000 stems to the acre or more. After thinning density in these small diameter sapling stands should be between 500 and 800 stems to the acre, though lesser densities can sometimes occur.

Figure 4 – Spacing for pre-commercial thinning in sapling stands



b. Commercial Thinning

Conducting thinning operations in forest stands with pole or sawtimber sized trees usually results in a saleable product in the northeast U.S. – hence our description of these activities as commercial. As with the pre-commercial thinnings we discussed above, the basics of this practice are relatively simple but the details are filled with nuance.

The simple part of commercial thinning is to remove lower quality trees that are taking valuable light and space, are competing with the trees you want to thrive (crop trees) and would otherwise die naturally if left alone, while leaving the remaining crop trees spaced for optimum light. When trees die, fall and decompose, they release greenhouse gases. By making use of this material, whether for energy or pulp and paper, the material will release greenhouse gases later, only after humans have received some benefit from its use. Carbon dioxide emissions are not the theme of this paper, but it is helpful to know that commercial thinnings do benefit the carbon equation at least to some extent.

A critical outcome of commercial thinnings is that resources are transferred to the chosen crop trees, which results in generally increased overall growth and biomass compared to a situation where trees are left to thin themselves naturally through competition-related mortality over time. It should be noted that sometimes you must remove a pretty good tree that happens to be very close to an outstanding tree to get the desired effect.

Crop tree decisions

Crop trees are those you wish to retain until later in the stand's development. Prior to a thinning harvest, the landowner or forester can select and mark these crop trees, indicating that they are to be left. Alternatively, they can simply leave the crop trees and instead mark the trees that are to be thinned. Marking crop trees in advance (it can be with flagging tape if you want) has some advantages because it causes you to focus on the trees you want to keep, which can help you more easily decide on the trees that need to be cut because they are competing for light and nutrients with your crop trees. Crop trees should be desirable species, that have healthy intermediate, codominant or dominant crowns, and have clean, defect-free trunks of good form – that means generally straight and as close to a cylinder as nature can make them.

Avoid spending time marking or harvesting trees that are clearly suppressed/overtopped unless you have a ready market for them or want to harvest them for some other reason. The literature is very clear that removing these trees does nothing to increase the growth of the trees in the upper crown classes. So, removing some of them is not harmful necessarily, but it does not address the goal of increasing growth.

Poor quality trees

Defects in these trees suggest they be harvested if looking to improve the growth and quality of the stand.

Crop trees

Trees like these, if in the right location for good spacing, are good candidates for crop trees.

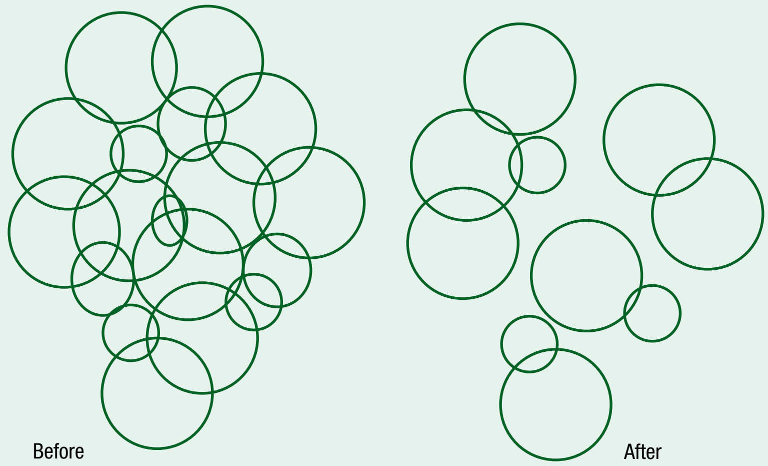
Choices about thinning in the main canopy or below

A study published in Forest Science in 1991[6] reviewed the results of work in a 50-year-old Allegheny hardwood stand in which the crown canopy had stratified into distinct species and crown class groups: dominant/codominant; intermediate and suppressed. The stand was thinned to 60% relative density leaving dramatically different stand structures and species composition. Treatments included thinning from the middle, thinning from above, thinning from below, combined thinning (above, middle, and below), and an unthinned control. Results indicated that individual tree growth was stimulated the most by thinnings that created openings in the main crown canopy; i.e. thinning the suppressed trees "from below" as it is called, did not affect diameter growth of the larger stems because the suppressed tree crowns are not competing with the crowns above. You can remove the suppressed trees if you have use for them but leaving these suppressed trees in an even-aged stand may also provide the added benefit of increasing the structural diversity of the forest for forest dwelling organisms. Certain birds, for example, will be more likely to frequent the stand because they can travel from the upper reaches of the crowns in the sun and also retreat to the lower shaded crowns of the suppressed trees.

Regarding the choosing of crop trees, avoid selecting crop trees with weak crowns or obvious defects. Crop trees should be evenly spaced when the stand matures, with 80–120 trees per acre (or fewer for species like oak). This is approximately one tree every 20 feet by

6. Marquis, David A., Ernst, Richard L., The Effects of Stand Structure After Thinning on the Growth of an Allegheny Hardwood Stand, Forest Science, September, 1991

Figure 5 – Before and after thinning in an over-crowded forest – an aerial view



A nicely thinned stand like this one provides ample light and resources to assure the trees are growing their fastest. The larger tree in the foreground was kept as a recruit for a future wildlife tree.

20 feet on average – or at least place your effort to get close to that result. Of course, these are only general guidelines and sometimes trees will be closer together or farther apart. Always look up and consider how you can remove competition and help balance or round out the crowns. Providing room to grow is your target.

Stocking guides are very helpful

Ultimately, the best way to determine how much to thin is by using the appropriate stocking guide for the species in question[7]. Reduce tree density to well below the A line. If the stand starts at or above the A-line, reduce tree density by 20-60% to bring the stand down to or near the B-line. In order to make a thinning determination in this way, you will need some kind of inventory information to tell you the initial stocking level of the stand. The first thinning should usually be the heaviest in the rotation period. You can begin thinning at nearly any age (unless the stand is clearly old aged and the trees are falling down), but it is best in pole stands[8] because that is the size class that should allow you to receive income from the thinning. Pre-commercial thinning is a great tool, but it is often difficult to justify because no income will be derived for the landowner.

There may be an opportunity to conduct early commercial thinnings as row thinnings in stands with average tree diameters in the 4-6" range by using some of the smaller equipment that is being used by loggers in the woods today, including the smallest of feller bunchers and skidders, or even some of the European equipment that is sized smaller than conventional equipment. It is essential to have a biomass market if you plan to attempt this early stand release operation without incurring prohibitive costs. The landowner may not receive revenue from this kind of operation, depending on the market price for the harvested product.

In stands with larger-sized trees, where average diameters are in the sawlog range (roughly over 11 inches in diameter at breast height – measured 4.5 feet from the ground[9]), care must be taken to assure that not too many of the highest quality trees are removed, otherwise the average quality of the remaining trees after the thinning might be reduced, resulting in a high-graded woodlot. This is not to say that large, mature trees that are in their decline (broken tops and thin crowns) should not be harvested; they should. Rather, this is to simply say that care should be taken in making selection for crop trees to leave and thinning trees to remove so that increased growth and the value of the remaining forest are maintained as the forest continues to grow following harvest.

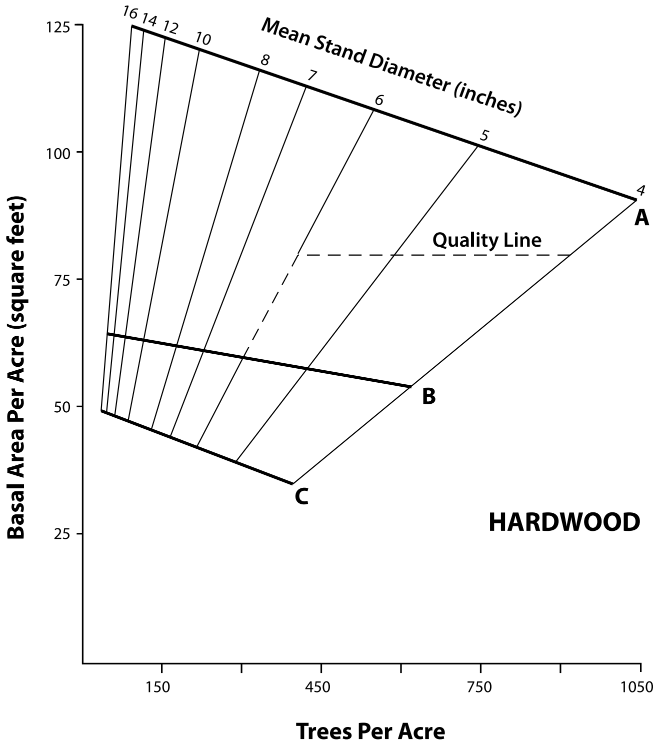
A quick note about white pine – there are now two schools of thought about how heavily to thin this species to get the best grow and value on the remaining trees. Older thinking suggested thinning down to the B-line as seen in the related stocking guide for white pine. Newer thinking developed by Dr. Robert Seymour and others at the University of Maine suggests thinning much more than that, i.e., way below the B-line in the stocking guides. Their study argues that by leaving a lot of space between thinned white pines, the remaining

7. A technical note that we will not dwell on here is that stocking guides are developed for even-aged stands, i.e. stands with one age class that has a limited range of ages. Stocking guides, for species or species group, show whether a stand of trees is overstocked, understocked or fully stocked based on the average diameter of the stand and density. Using the guides requires this initial knowledge about the stand.

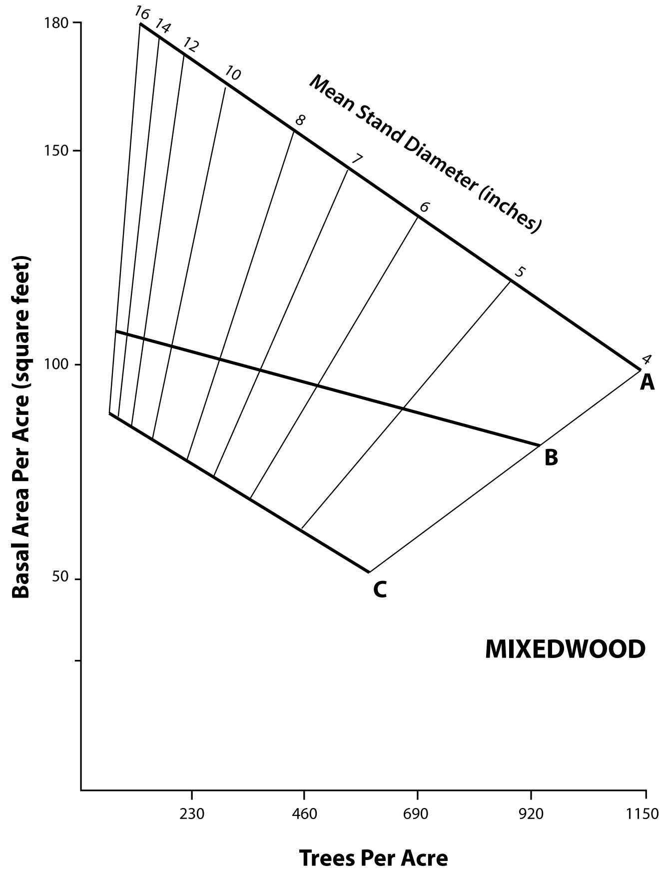
8. Pole-sized trees – larger than saplings and smaller than sawlogs. Generally between 4" and 11" DBH.

9. Diameter at breast height – 4.5 feet from the ground – is commonly known as DBH.

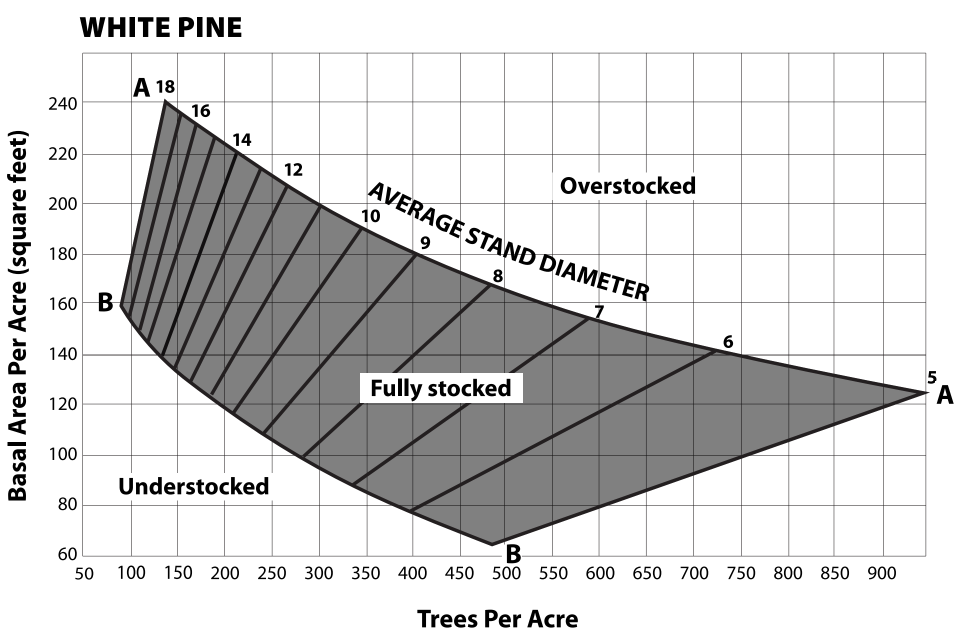
Figure 6 – Stocking Guides



Stocking chart for main crown canopy of even-aged hardwood stands (beech-red maple, beech-birch-maple) shows basal area and number of trees per acre and quadratic mean and stand diameter. The A-line is fully stocked, the B-line is suggested residual stocking. The C-line is minimum stocking. The quality line is the density required to produce high quality stems or beech, sugar maple, yellow birch, and red maple.



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



Sources: Hardwood, Mixedwood: Silvicultural Guide for Northern Hardwood Types in the Northeast (revised), N.E.F.E.F. Research Paper NE-603.
White Pine: Wisconsin Woodlands: Estimating Stocking Conditions in Your Timber Stand by Jeff Martin.

white pine crowns can fully expand much like they did in pre-Columbian times when white pine trees were often scattered, and very large in the forest (super-dominants above the tree canopy).

Species

As described above, decisions about commercial thinning activity should consider both growth and value, to achieve the most benefit for the forest landowner. The general issue of quality is always important, i.e. remove trees that have defects, are crooked, have thin crowns or broken tops. Beyond that line of thinking, it is also important to take species into account when making these decisions. Local timber markets vary and either state forestry agencies or forestry associations should be consulted for forest market information in your specific area. However, generally for strict value purposes in the northeast U.S., hardwood trees such as sugar maple, yellow birch, red oak and white ash should be favored over red maple, white birch, beech or aspen. For softwood, white pine and spruce/fir should be favored over hemlock or red pine (unless a pole market is available for good red pine). Obviously, other factors affect which trees to leave, including non-timber factors. Leaving one or two very large low quality trees per acre will be very beneficial to many wildlife species and they will not take up much growing space in your forest.

More specific guide to thinning prescriptions

Arlyn Perkey of the USDA Forest Service developed a helpful listing that can be used to aid decision making for commercial thinning situations. His recommendations on which trees to choose as crop trees and keep when thinning are for stands at least in the pole size category:

- Dominant/codominant trees (at least 25 feet tall)
  - Healthy crown, large in relation to DBH
  - No dead branches in upper crown
  - Either low-origin stump sprouts (less than six inches at groundline) or seedling-origin stems
  - U-shaped connections of multiple stem trees are acceptable; avoid V-shaped connections.
- High-quality trees
  - Butt-log potential of tree grade 1 or 2[10]
  - No epicormic branches (living or dead) on the butt log
  - No high-risk trees (leaners, splitting forks, etc.)
- High value commercial species (see above)
- Expected longevity after thinning of over 20 years
- Species is well adapted to the site.

Tree life expectancy

When conducting thinning operations and selecting crop trees, don't select trees with a short life expectancy. For example, in a 70-year-old, even-aged, Northern hardwood stand, it makes little sense to select a paper birch as a timber crop tree. This short-lived species isn't likely to respond well to release because it is already biologically old. However, sugar maple and yellow birch trees of that age can be expected to respond very well. Timber crop tree candidates should be at least 20 years younger than the normal biological maturity for that species.

10. Tree grades are a way of differentiating for quality. Grade 1 logs have less taper, no defects and few, if any, branches. Tree log grades are from 1 (best) to 5 (worst) and were developed for the USDA Forest Service Forest Inventory and Analysis as a way to estimate the quality of the lumber in a sawlog by looking at the log while it is still in a live tree.

Short and long-lived tree species in the northeast U.S.

From upper left, hemlock (long); upper right, white birch (short); lower right, yellow birch (long); lower left, sugar maple (long)

Stand age in northern hardwood

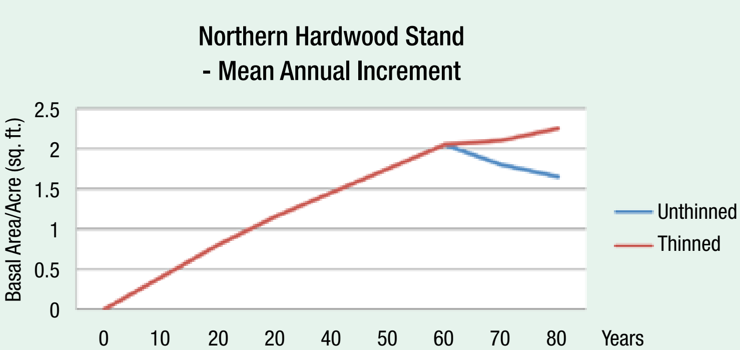
In an article in the Northern Journal of Applied Forestry in 1999, USDA Forest Service Silviculturist Bill Leak wrote:

"In northern hardwoods it is commonly believed that the maximum cubic volume production can be obtained by growing the stand to about 50-60 years when the annual cubic growth is at its maximum (culmination) – then clearcut the stand and start over. But extending the rotation age by thinnings may be better and can extend the mean annual increment in the stand. A commercial thinning at age 60 will extend the age when maximum cubic growth occurs to 85 years or so."

Leak also writes that, once thinned, the forest will continue to add more volume at an increasing rate, as compared to a forest that remains crowded without a thinning. The latter will eventually have a declining rate of annual growth. By thinning, the landowner can extend, by decades, the period where the forest increases its rate of growth. Figure 7, also from Leak's work, shows this graphically.

This bit of scientifically-based wisdom suggests that growing stands past their normal peak of total annual growth should be routinely explored by implementing simple thinning techniques previously described in this paper. The take home – thinning a stand of trees does many things. It increases the growth of individual trees, as well as whole stands of trees, and it increases the value of the remaining trees if it is done carefully.

Figure 7 Extending Northern Hardwood rotation age through thinning



5. Final Stand treatments

No forest will keep on growing forever, even if it is thinned judiciously during its lifetime. Whether we are thinking about increasing the growth rate or increasing quality, at some point the stand is no longer improving. For an even-aged northern hardwood forest[11], that may mean somewhere in the vicinity of 50-60 years old for an unthinned forest where the goal is simply wood volume (80-90 years when we thin as described above) or upwards of 100 to 120 years where we are trying to grow sawlog trees that will be harvested for the sawmill to yield boards.

This suggests that it is up to the landowner to decide the right time to regenerate the entire forest or an individual stand in their forest – and there are many factors involved in making this decision. Even-aged regeneration techniques (see footnote) may be more drastic than uneven-aged methods. In either approach, when it is time to regenerate the stand, the techniques described

11. We have not discussed even-aged vs. uneven-aged silvicultural systems in this paper. Most forests in the northeast, especially those owned by private landowners, tend to be uneven aged, where the majority of the trees are in 2 age classes or more. Uneven-aged forests have 2 or more distinct age classes and are regenerated by individual or group selection of trees to be harvested. A forest managed under the uneven-aged silvicultural system always retains a forest canopy since only individual trees and groups of trees are harvested at intervals. To regenerate even-aged forests, there is some point in time where the majority of the trees will be harvested. This could happen when there is little advanced regeneration – a clearcut, shelterwood or seed tree harvest. In a seed tree or shelterwood harvest, mature trees are left for seed source. Once the new forest is established, the mature trees are removed from the site.

A clearcut like this one on the top, with retention patches in the middle for wildlife purposes, is an evenaged method of forest regeneration. On the bottom, a group selection harvest (light area) can be seen through the low light of an unevenaged forest.

earlier in this paper regarding timely and adequate regeneration should be used. Growth concerns in your forest do not end when the forest is regenerated, rather they are just beginning.

For uneven-aged forests, the intent is to always have the forest stocked with trees. There may be small openings with trees removed but the forest never goes through a phase with large swaths of land with no trees. Uneven-aged management lends itself well to a landowner with a chainsaw and a tractor to continue management by selecting individual trees or groups of trees to harvest as thinning or final harvest using the guidelines in this paper. A conventional logger can also operate and maintain an uneven-aged forest.

6. Identifying Best Candidate Sites For Increasing Growth

The intent of the recommendations in this paper is to encourage forest landowners to get the most growth from the trees on their land. As such, there are some simple recommendations regarding the selection of appropriate sites for forest management, which are already intuitive to forest landowners. The following kinds of sensitive sites should not be chosen for the activities and practices that we have discussed in this paper because, frankly, there are many other sites that are much more productive and likely to yield growth benefits from improved and targeted practices.

First, eliminate from discussion all wetland forest sites. These sites, where standing water and/or wet soils exist year round yet where trees are present and growing, are not as productive as many other forested areas. These sites will continue to grow trees, but the wet soils, by their nature, prevent much gain in increasing growth through targeted silvicultural activities. If these sites are appropriate to harvest in the winter, they can be managed, but wetland forest stands should be the last pick in terms of prioritizing forest sites where these forest management practices will be applied.

Second, steep slopes of 25% or more, where harvesting equipment cannot be used or where using it creates additional expense and difficulty for the logger, should also be put on the second tier list. These sites typically have slopes that result in shallow soils and sometimes

Wet sites like this riparian area are probably poor choices for forest improvement work for growth and quality.

ledge and rocky outcrops. In these locations, soil erosion and rutting tend to be more severe than on average sites and extra care must be put in place with the use of Best Management Practices to protect soils and site quality. This is not to say that some of these areas cannot be managed for forestry purposes, it is simply to say that it is a better use of resources to focus on more productive sites for managing more intensively with the goal of increasing forest growth.

Third, riparian areas, those areas immediately adjacent to streams, rivers and ponds or lakes, are extremely important as wildlife habitat. The land immediately adjacent to the water source – the first 100 feet or so – is the most sensitive. These areas often have significant timber resources and can still be managed and harvested, within the constraints of state laws, but, again, should probably be put in a second tier of land relative to more intensive management to increase productivity.

There are other sensitive areas to consider as well, such as natural communities where rare plants are known to exist, old growth forests, forests over 2,700 feet in elevation, areas with large numbers of vernal pools or areas with significant cultural resources, but all of these tend to be small acreages across the landscape as compared to the other sensitive sites mentioned above.

After discounting most of these sensitive areas, the areas that remain have reasonable amounts of soil and moderate to little slope – the better sites to grow trees. Landowners should concentrate their activities on these areas.

7. Eliminating or controlling forest pests, disease and invasives

The reduction of forest pests and disease through silvicultural activities is an important consideration if improving growth and productivity is the goal of the landowner.

There are many detrimental insects and diseases that plague our northeastern forests. Some that are native, such as the forest tent caterpillar, tend to be less severe or limited in their outbreaks because the forest and the disease or insect have reached an ecological balance over the millennia. But there are exceptions, such as the spruce budworm, which has been very destructive to millions of acres of spruce and fir trees many times since Europeans settled in the northeast U.S.

Those that are non-native invasives, including balsam woolly adelgid, gypsy moth, pear thrips, Asian long-horned beetle, hemlock wooly adelgid and emerald ash borer tend to be more destructive when they get a foothold because these organisms often have no natural enemies. Exotic diseases such as Dutch elm disease and chestnut blight have virtually eliminated their host species across their historic range.

The topic of forest insects and disease is a complicated topic for forest landowners. The best course of action for forest landowners is to become aware of these phenomena and to stay informed over time through state forest insect and disease specialists and through forest landowner groups and associations. Thinning activities should be focused on removing malformed and diseased or insect ridden trees as part of the normal thinning process.

Lastly, landowners should always be on the lookout disease outbreaks on their properties, especially in the face of the exotic invasives, such as Asian longhorned beetle, hemlock wooly adelgid and emerald ash borer. Anything unusual should be reported to the state forestry agency. Early outbreaks of these potentially devastating pests have often been found by landowners.

Invasives can also take the form of plants and can be very destructive as well. In recent years in the north-east, a plethora of invasives plants have taken hold and, where infestations are especially severe, can displace native plants and trees and prevent regeneration of

Invasive insects such as the Asian longhorn beetle (top) hemlock wooly adelgid (middle), and emerald ash borer (bottom) can have a devastating effect on the productivity of your forest.

desired tree species from taking hold. Some invasive plants to be concerned about in the northeast include (there are many others):

Norway maple	various honeysuckles
tree of heaven	Japanese knotweed
Japanese barberry	common & glossy buckthorn
Oriental bittersweet	multiflora rose
autumn olive	

These plants can invade quickly or, in other cases, hang on with a few individuals until a change occurs – such as opening up the site to direct sunlight - and then they multiply quickly and take over the site. The key to dealing with invasive plants is to catch them early before populations are so large that it is nearly impossible to implement mitigation or removal techniques. Making sure that equipment that enters the forest is clean of plant material from the previous site it was on is a good preventive technique to slow or stop introduction of invasive plants.

Once the plants are established, it may not be possible to eradicate them from a site. Some techniques used to attempt eradication include

- Mechanical control like hand pulling, digging, mowing, blading, and tilling. This technique is labor intensive and may be difficult to implement in large infestations;
- Chemical control is probably the most effective method from a cost and effort perspective. The technique and herbicide used depend on the species of plant and size of the infestation among other considerations. Chemicals herbicides may be applied to the leaves of the plants in a mist application with a backpack sprayer, as a basal bark treatments, frill treatments, and cut-stem or injection treatments. Specific techniques and chemicals should be determined with the assistance of an expert – someone at the state pesticides office or a forester who has a chemical application license or experience. Biological control is not a viable technique for most plant species at this time but it may change as research yields new findings.

Regardless of the technique, they must be applied for years to assure eradication is complete.

8. Other issues

It is unclear how global climate change might affect woodlots in forests of the northeastern U.S. Some say that in a hundred years our forests might look more like those in North Carolina while others think the change may be much less drastic than that and, as discussed early in this paper, the result in the near-term may simply be that forests will grow faster with increased carbon dioxide in the atmosphere and longer growing seasons.

Moderating temperatures and seasons, however, will likely also bring the negative effects of increased populations of plant and insect invasives. Silvicultural techniques discussed above to address these new threats to our forests which likely can at least be partially attributable to climate change, should be aggressively pursued. Researchers are seeking to learn other techniques that might be used to address these forest issues. Keeping abreast of that work will benefit the landowner who seeks to improve the productivity and value of their forest.

IV. Government incentives to encourage practices to increase productivity and value of family forests

In each state in the northeast, there are government incentives available to encourage the kinds of practices discussed in this paper. These programs usually rely on the incentive programs of the federal US Dept. of Agriculture through its Natural Resource Conservation Service. The most prominent state funded incentives are usually beneficial property tax programs often called "current use". In these programs, property is taxed based on its current use as a forest rather than its potential use as house lots or some other commercial use.

The Natural Resource Conservation Service programs currently in place that provide the majority of incentives for the forest practices discussed in this paper fall under the Environmental Quality Incentives Program (EQIP) or Wildlife Habitat Incentives Program (WHIP). EQIP is a program created by the 1996 Farm Bill to provide primarily cost-sharing assistance, but also technical and educational assistance, aimed at promoting production and environmental quality, and optimizing environmental benefits. It cost-shares on practices such as: access roads; recreation area improvement; trails; tree establishment; early successional habitat development; forestry landings; and forest stand improvement.

WHIP is a voluntary program for conservation-minded landowners who want to develop and improve wildlife habitat on agricultural land, nonindustrial private forest land, and Indian land. It funds practices that: promote the restoration of declining or important native fish and wildlife habitats; protect, restore, develop or enhance fish and wildlife habitat to benefit at-risk species; reduce the impacts of invasive species on fish and wildlife habitats; protect, restore, develop or enhance declining or important aquatic wildlife species' habitats; and protect, restore, develop or enhance important migration and other movement corridors for wildlife.

V. Public Policy to Encourage Increased Forest Productivity

The subject of this paper has focused on user-friendly strategies that family forest landowners can use to increase the growth and productivity of their forests, thereby helping to increase the overall supply of wood in the northeast U.S. It is likely that this paper will fall in the hands of other readers. Public policy to encourage the kind of activities discussed in this paper is important since incentives and regulation have been historically influential and currently continue to have effects on the behavior of forest landowners in the northeast and elsewhere. Every time the federal Farm Bill[12] is discussed, the issue of whether the federal government should become or continue to be involved in the kinds of silvicultural activities we have discussed in this paper, is always ripe for discussion. Though state policy also affects these kinds of forest improvement activities on private forest land, most of the dollar incentives provided at the state level come from the federal government and are authorized for appropriation through the Farm Bill.

Many policy organizations and other writers have published papers and reports on this topic. A good bibliography of such writings and recommendations was compiled by the State of Maine in 2005 in a paper by the Maine Forest Service's Christopher Brooks entitled Tax and Economic Incentives toward the issue of: Making Good Silviculture Pay. This paper lists many key references on this topic and is a must read for anyone looking to find information about the current prevailing thought on the topic of the role of government in encouraging activities to increase productivity of our forests.

This annotated bibliography covers topics under the following logical headers:

A. Property Taxes

B. Estate Taxes

C. Harvest and Yield Taxes

D. Other Tax Incentives

E. International Strategies

F. Technical Assistance Programs

G. Stewardship Incentive Programs

These categories serve as a good outline on this subject. While it is beyond the scope of this paper to expound on these topic areas, it is important to note that public policy can have a significant effect on the actions of the hundreds of thousands of private forest landowners in the northeastern U.S. if incentives are available and access is reasonably straightforward. If increasing the growth and productivity of the region's forests, in order to increase the supply of woody material for energy uses, is deemed to be important to the economic and cultural future of the region or the country, then significant work in the public policy arena should be undertaken to assure that the thousands of necessary landowner decisions related to forests of the region do indeed occur.

12. Although referred to as the Farm Bill by both casual observers and Washington insiders, the current Farm Bill is titled the Food, Conservation, and Energy Act of 2008 (Public Law 110-246).

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North East *State* Foresters Association (NEFA)

P.O. Box 2911
Concord, NH 03302-2911
603-229-4965
nefa@inrsllc.com
www.nefainfo.org

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