Estimating the Sustainable Yield of the State of Connecticut Division of Forestry's Commercially Suitable Timberland

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1. Summary

This report 1) estimates the current standing volume and growth increment for the commercially suitable timberland[1] managed by the State of Connecticut's Division of Forestry; 2) estimates the long term sustainable yield for the commercially suitable timberland; and 3) explores the effects of several different 50-year management scenarios and the implications of these scenarios for trends in total harvest volume, harvest volume per acre, harvest acreage and standing volume.

If the DEP Division of Forestry managed, commercially suitable timberland was fully regulated and harvested using shelterwood regeneration cuts on a 100 year rotation, the sustainable yield would be 6-7 Million board feet per year (Mmbf/year). However, the forests are not currently in a fully regulated condition. Consequently, in the medium term one could harvest at a higher level without undermining the ability of the forest to produce 6-7 Mmbf/year in the future.

The average acre of DEP Division of Forestry managed, commercially suitable timberland contains 6.3 thousand board feet per acre (mbf/acre) of timber and is currently growing at 1.9% per year. Taking into account the compounding nature of growth, over a ten year period the average growth increment would be 0.13 mbf/acre/year. [2] Harvest volumes presented throughout this report are only for commercially suitable timberland. The volumes should be adjusted if the amount of commercially suitable timberland is increased (e.g., because of additional land purchases) or reduced (e.g., because additional acreage has been allocated to late successional reserves). Approximately 102,000 acres, or 60%, of the Division's roughly 169,500 acres of land is both capable of supporting and open to timber harvesting. The remaining 40% is inoperable, inaccessible, in late successional reserves, or otherwise not open to harvesting. The total current standing volume of timber is 645 Mmbf, which will grow at a rate of 13 Mmbf/year during the next decade.

As the forest ages, both the average growth rate (in percentage terms) and the net volume growth will decline. If no harvesting or natural disturbance occurred during the next fifty years, the standing volume would increase to 11.5 mbf/acre, volume increment would fall to 0.08 mbf/acre/year, and growth rate would fall to 0.8%/year (Figure 4).

An annual harvest of 10 million board feet per year (Mmbf/year) in thinning could be sustained for the next five decades and leave the same standing volume at the beginning and end of the period (Figure 6). Over this period the average volume increment would fall to 0.07 mbf/year. Despite a similar volume increment, the percentage growth rate would be higher than when no harvesting occurs because the standing volume would be lower (1.1%/year vs. 0.8%/year). At the end of this period the harvest rate (0.10 mbf/acre/year) would exceed volume growth (0.07 mbf/acre/year) by 0.03 mbf/acre/year. Subsequent harvesting would need to be reduced to

[1] Commercially suitable timberland is both capable of supporting a harvest and open to harvesting. It does not include land which could support a harvest but has been designated as a reserve.
[2] Henceforth, annual increment will be expressed in terms of average decadal growth increment rather than the growth increment in the first year of the decadal period.

around 7.5 Mmbf/acre/year if one desired to maintain the same level of standing volume in the following decade.

A harvest of 9 Mmbf/year could be sustained using shelterwood regeneration and overstory removal cuts during the next 50 years without reducing total standing volume from the beginning to the end of the management period (Figure 7). Again, at the end of this period harvest volume (.09 mbf/acre/year) would exceed volume growth (.06 mbf/acre/year) and subsequent harvesting would need to be reduced to 6 Mmbf /year if one desired to maintain the same level of standing volume during the next decade. As stands harvested at the beginning of the management scenario reached rotation age (~100 years), one could increase the harvest volume to 7 Mmbf/year.

2. Introduction

The sustainable yield of a forest is the amount of wood that can be harvested annually for an indefinite period of time. In a fully regulated forest sustainable yield is equal to the annual growth increment. In practice, few forests are fully regulated and the harvest in any given year may be greater than or less than the annual growth in that year. Current annual increment can be estimated by comparing two sets of periodic inventory data or by using a growth model to project current inventory data into the future. Future growth can be estimated using a growth and yield model. However, future growth depends not only upon the current state of the forest, but also upon future silvicultural interventions: thinning a stand will have a different effect on future growth than either regenerating the stand or allowing it to grow without any silvicultural treatment. In effect, the sustainable level of harvest is dependant on social and economic conditions, management goals, and preferred silvicultural pathways. This report 1) estimates the current standing volume and growth increment for the commercially suitable timberland managed by the State of Connecticut's Division of Forestry; 2) estimates the long term sustainable yield for the forests; and 3) explores the effects of several different 50-year management scenarios and the implications of these scenarios for trends in standing volume, harvest volume per acre, harvest acreage and standing volume.

3. Materials and Methods

3.1 Size of the Forest Estate

The Division of Forestry manages 39 properties throughout the state. The properties include 32 forests, several wildlife areas, two reservoir areas, and the Centennial watershed. The total area managed by the Division is approximately 169,500 acres. The Division continues to acquire small parcels of property throughout the state, so the exact area managed by the Division is not constant. Two sources were used to estimate the area of each property (Table 1): a report on 2008 state forest areas of responsibility (Parda 2008) and the partially completed State Forest Stands Database currently being developed by UCONN (Stocker 2008). We assumed that the true area of each forest was the greater of the two values given for each property. This is somewhat larger than the 169,250 acres of forest land which the Division owned in 2006 (Smith 2006).

Until recently the DEP has not maintained a central database of forest inventory information. Instead the information has been maintained by individual foresters and periodically compiled into 10 year property level management plans. An effort is underway at UCONN to integrate information into a single database and GIS system but only ~93,000 acres are included in the database. Rather than replicate the ongoing work to complete this database, the partially completed database was used to inform this analysis. It was assumed that the stands included in the database were representative of all stands throughout the forests. The analyses described in this report were structured so that it could be easily updated as more complete information is available.

3.2 Stratification of the Forest

Each forest stand has been or will be assigned to one of nine management classes (Table 2). Actively managed (commercially suitable) stands are both open to harvesting and capable of supporting harvests. Stands may be closed to harvesting because they have been reserved to provide non-timber values such as wildlife habitat, recreational opportunities, or late successional forest structures. Stands may be unsuitable for harvesting because they are inaccessible, on rocky slopes or in wetland areas. Fifty-two percent of the area currently in the database is classified as actively managed (i.e. it is both open to harvesting and suitable for harvesting). An additional 17% of the land base has not yet been assigned to one of the management classes. It was assumed that half of this acreage was commercially suitable. Thus, 60% of the land currently managed by the Division (102,000 acres) was classified as commercially suitable for this analysis. A prior analysis done within the Division of forestry (Smith 2006) assumed that 64% (108,500 acres) were commercially suitable.

Stands are assigned to one of eight size classes. For the purposes of this analysis the size class groups were collapsed into immature and mature. Approximately 10% of the landscape was in immature size classes (seedling, sapling, or pole). The remainder of the landscape was in mature size classes (sawtimber, saw seed, saw-sapling, saw-pole, sap-pole-saw). Stands were also assigned to one of 15 U.S. Forest Service defined cover groups based on species composition. Each cover group may be composed of more than one cover types. For example, both the white oak and mixed upland hardwood types fall within the oak-hickory cover group. The five most common cover groups for all forest lands included oak-hickory (67% of the landscape), white-red-jack pine another (10%), oak-pine (7%), elm-ash-red maple (6%), and maple-beech-birch (4%;
Table 3). The distribution of cover groups on actively managed land was similar with one notable exception: The wetland associated elm-ash-red maple group was rare in the actively managed landscape (1%). Together these five cover groups composed 92% of the total landscape and 98% of the managed landscape. For the purposes of this analysis, other cover

groups were combined with one of the five most common types. For example, the exotic softwood and spruce-fir groups were combined with the white-red-jack pine group.

A cross tabulation was performed to determine the percent of the actively managed landscape in each of ten cover group-size class combinations (Table 4). One combination, immature elm-ash-red maple, was not present in the actively managed landscape. Hereafter in this report, these combinations will be referred to as the management groups.

3.3 Estimating Current Volume and Growth

In the following discussion of standing volume and volume growth, estimates are expressed on a per area basis (mbf/acre) rather than in million board feet for the entire forest to facilitate comparisons with other sources. Two methods were used to estimate current standing volume.

First, the average volume per acre in actively managed stands for each of the 10 management groups was calculated using stand volume figures recorded in the stands database. The averages were weighted by the proportion of the landscape in each stratum to get the weighted average volume for commercially suitable timberland (Table 4). The weighted average standing volume per acre of commercially suitable timberland was 6.0 mbf/acre. Given that forest plans are updated on a 10-year cycle and that some forests do not currently have managers assigned to them, some of the data is inevitably dated. The database does not currently indicate the year in which inventory data was collected for a particular stand. Furthermore, the growth model commonly used to update inventory data (FVS-NE) relies on tree list inventory data. Such data were not available for all of the stands in the stands database. Consequently, it was not possible to take into account growth since the inventory was taken using this dataset, but it is likely that the true level of standing volume is greater than the 6.0 mbf/acre. In fact, an analysis of standing volume based on FIA data estimated that the standing volume on state owned lands was 6.6 mbf/acre (Hohl and Oliver 2008).

In order to estimate current growth rates a second method was employed. Tree inventory data were available from 4 forests: Cockaponset, Enders, Meshomasic,and Nepaug. The data consisted of species and dbh data collected using BAF 10 or BAF 20 prism plots. The complete dataset consisted of 1301 plots distributed among 280 stands. Six of the nine strata represented on the actively managed landscape were well represented within this dataset. Three immature types were not: oak-pine, pine, and maple-beech-birch. These three groups are rare among commercially suitable types on the Division's forests, together representing just 3% of the commercially suitable timberland. Inventory data from two actively managed CT forests with a greater representation of these young stand types were used to supplement DEP data. Inventory data from these forests were also used to represent the immature elm-ash-red maple group. All plot data were grouped into stands and imported into NED-2 (Twery et al. 2005). Inventories were projected to a common base year using FVS-NE (as instantiated in NED) to account for growth since the inventory was taken. The current standing volume was 6.3 mbf/acre. Data was subsequently projected one 10-year growth cycle to assess the current growth rate. The average annual increment for the first 10 year period was 0.13 mbf/acre/year. Annual growth rate (r) was calculated as:

$$r = (\frac{V_{n+1}}{V_n})^{\frac{1}{10}} - 1$$

Where V_n was the initial volume and V_{n+1} was the volume after 10 years. The annual growth rate was 1.9% and the annual increment for the first year of the 10-year growth cycle was 0.12mbf/acre (Table 5).

3.4 Modeling Silvicultural Pathways

Both the growth rate and annual increment of forests change over time. Young stands tend to have a high growth rate but a relatively low annual increment because the current standing volume is small. Older stands have a lower growth rate but may have a higher increment. For example, immature pine stands are currently growing at 5%/year, while mature pine stands are growing at 1.3%/year. However, the annual increment for immature pine stands is lower than that of mature pine stands (Table 5). Consequently, one should not assume that the forests will continue to accrue volume at 0.12 mbf/acre/year indefinitely. Furthermore, silvicultural interventions will change the annual increment.

In order to assess the long term effects of various silvicultural interventions on mature forest types, several analyses were performed. First, the stand volume estimates in the stands database were grouped by cover group and size class. Average age for the oldest cohort in each size class was calculated and average volume for each size class/cover group combination was plotted (Figure 1). In addition, mean trajectory (weighted by the area in each cover group) was plotted. The weighted average volume for even aged (single cohort) stands was also plotted (Figure 2). This represents the probable trajectory of an even aged stand over time following a regeneration harvest (either clearcutting or shelterwooding).

The effects of thinning could not be easily estimated from the stands database. Instead, they were modeled by applying the FVS-NE growth model to inventory data from the forests. Mature stands for each of the cover types were selected and projected forward. Each stand was thinned using stand density index thinning applied across all size classes. Stands were thinned to the 60% stand density index line (B-line). After testing various intervals between thinning, it was determined that 40-50 years was needed for mature stands to recover to approximately their pretreatment volume. Consequently, the stands were thinned again 50 years and 100 years after the initial harvest. The results for this treatment, weighted by the area of the actively managed forest in each management group, were plotted (Figure 3).

3.5 Developing Management Scenarios

The pathways developed in the previous section are adequate for describing the expected trajectory of the mature management groups treated within the next decade. However, it would be neither possible nor desirable to treat all of the commercially suitable acres in a single decade. Instead, if a regular flow of revenue is desired, harvesting operations must be carried out over time. Treatments carried out in subsequent decades will be carried out on stands that have continued to grow and long term management scenarios must take into account that growth. In order to account for the effect of growth and treatments at different times in the future, the response in volume growth to five silvicultural treatments was modeled for each of the nine strata over 50 years in decadal time steps (Table 6). These treatments were selected to correspond to treatments recommended in the silvicultural guides for northern hardwoods (Leak, Solomon, and DeBald 1986), oak-hickory (Roach and Gingrich 1968), and white pine (Lancaster and Leak 1978). With the exception of clearcutting, similar treatments are being carried out with varying frequency on the Division's forests.

Because treatments could be applied in any of the five 10-year time steps and some treatments could be applied in succession to the same stand (e.g., shelterwood seed cut followed by shelterwood removal cut or two cycles of thinning during the 50 year period), a rather large number of silvicultural pathways was needed to develop alternative management scenarios. Twenty eight pathways were developed for each of the ten management groups.

Because of computational limitations a compressed dataset was used for developing the management scenarios. The compressed dataset consisted of a subset of stands from each management group which, when averaged, closely replicated the dynamics of that group obtained for three pathways using the full dataset. The pathways modeled using the full dataset included: allowing the stands to grow for 50 years with no silvicultural intervention, using stand density index thinning in the first decadal time step, and using basal area thinning in the first time step. It was assumed that the compressed dataset would replicate the average trajectory of the complete dataset for the other 25 pathways.

The results of the NED based model runs for the stands in each management group and pathway were averaged and compiled in an Excel spreadsheet program, CT-Toggle. The CT-Toggle program facilitated the rapid development and comparison of different long term management scenarios.[3] Four scenarios are reported on below: 1) allow the forest to grow without harvesting any volume during the 50-year scenario time frame; 2) harvesting all volume growth in each decade relying solely on thinning operations; 3) maintaining an even flow of harvests from thinning in all five decades such that the standing volume at the end of the scenarios is equal to the standing volume at the beginning of the scenario; and 4) maintaining an even flow of harvests from shelterwood regeneration cuts in all five decades such that the standing volume at

[3] The tool is structured so that basic financial analyses can be run in tandem with the growth analyses, but financial results are not reported here.

the end of the scenarios is equal to the standing volume at the beginning of the scenario. In each scenario, harvesting occurred first in the five mature management groups, thus allowing the immature stands to continue to grow for as long as possible. To the extent possible harvesting was balanced across species groups.

The harvest volume and acreage for year 0 are based on the annual average harvests on division managed lands from 1997-2006. This facilitates comparisons between what has occurred in the recent past and what would occur in the future under one the modeled management scenarios.

4. Results

4.1 Silvicultural Pathways

The average stand reached pole timber size in around 50 years, saw-pole size in 81 years, and saw timber size by 92 years (Figure 1). Multi-cohort stands (sap-pole-saw, saw-seed, and saw-sap) tended to have less volume than single cohort stands whose oldest cohort was of the same age. At least some of the multi-cohort stands were the result of previous harvesting operations. For example, the first cut in a series of shelterwood cuts reduced the overstory volume while opening up growing space for seedlings and saplings. White pine stands tended to have substantial more volume than hardwood or hardwood conifer stands.

The average single cohort stand reaches ~7 mbf/acre in 100 years (Figure 2).[4] At this point it appears that growth rate and growth increment are slowing. Consequently, it seems reasonable to set 100 as a target rotation age. If the forest were fully regulated with a rotation age of 100, one would regenerate 1% of the commercially suitable timberland each year or just over 1,000 acres/year. Since shelterwood is the preferred method of regeneration, one would actually use 2 cuts in the regeneration process: a seed cut to establish regeneration and a final cut to release the regeneration. Thus, the total treated area would be slightly more than 2,000 acres/year. The yield for the two cuts would be ~7 mbf/acre. Consequently, the total sustainable harvest would be 7 Mmbf/year. However, the forest is not fully regulated. The analyses described in the next section detail several 50-year management scenarios which would move the commercially suitable timberland in the direction of full regulation.

Within the NED database stands, the average mature stand is currently ~80 years old and contains almost 7 mbf/acre (Figure 3). Such stands were projected to grow at a rate of 0.10 mbf/acre/year over the next decade to 8 mbf/acre. Harvesting these stands using stand density index during the first decade thinning yielded 5.5 mbf/acre. At age 140 they contained 6.8 mbf/acre and an SDI thining yielded almost 3mbf/acre. In the hundred years between age 80 and 180 the stands yielded 8.5 mbf/acre and had a standing volume at the end of the period of ~6 mbf/acre. Over this time frame, thinning exceeded the amount that could be harvested using a

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[4] The analysis in this paragraph is based on the chronosequence data derived from the stand database. Similar results are obtained using the growth model to project stand growth and yield.

regeneration cut at 100 years. However, a pure thinning regime could probably not be carried out indefinitely. At age 190 the stands would contain 6.6 mbf/acre but SDI thinning would yield just 1.6 mbf/acre.

The reason for the decline in harvestable volume over time, despite similar levels of standing volume is probably related to changes in size class distribution. A detailed exploration of this issue was beyond the scope of this report. However, if a commitment is made to use only uneven aged management (i.e. only thinnings rather than shelterwood or clearcut regeneration), it will be important to track the actual volume growth over time.

4.2 Management Scenarios

Current conditions:

Over the 10 years from 1997-2006, an area weighted average of 3.2 mbf/acre were harvested from slightly less than 1500 acres per year. During the period an average of 4.7 Mmbf/year were harvested by the division of forestry. During the last five years of the period (2001-2006) harvest area fell to under 1000 acres/year and only 2.7 Mmbf/year were harvested. The 10 year average conditions are depicted on the graphs below for year 0.

Scenario 1: Allow forest to grow without harvesting for 50 years

Under this scenario standing volume on commercially suitable timberland increased from 645 Mmbf to 1180 Mmbf (Figure 4). Growth increment gradually declined from 13 Mmbf/year to 8.5 Mmbf/year.

Scenario 2: Harvest all volume growth in each decade relying solely on thinning operations

In this scenario the total standing volume was maintained at 645 Mmbf throughout the five-decade model period (Figure 5). Harvest area doubled from the current average of 1500 acres/year to just over 3000 acre/year in the first decade of the scenario but fell to 1300 in the final decade of the scenario. Throughout the simulation harvest area averaged 2000 acres/year, but exhibited a wide range. Harvest volume more than doubled to 13 Mmbf/year in the first decade, but fell to 6 Mmbf/year in the final decade. The intensity of harvest on a per acre basis gradually increased from 4 mbf/acre in year 10 to 6 mbf/acre in year 50 as the stands matured. In both this scenario and in scenario 3, hardwood stands were thinned throughout the dbh range to a SDI of 60%. Conifer stands were thinned from below to a basal area or 110 square feet per acre. Thinning conifer stands using stand density index thinning would have resulted in a greater yield per acre and fewer acres harvested. Almost 40% of the commercially suitable timberland remained untreated at the end of the simulation period.

Scenario 3: Maintain an even flow of harvests from thinning in all five decade. Make total standing volume at the beginning and end of the period equal to each other.

In this scenario the total standing volume rose from 645 Mmbf in year 0 to 690 Mmbf in year 30 and then fell back to 645 Mmbf in year 50 (Figure 6). Harvest volume was held constant at 10 Mmbf/year. Harvest area initially increased to 2500 acres per year and averaged 2200 acres/year over the entire 50 years. In this scenario only 7% of the landscape remained untreated at the end of the simulation period. Fifteen percent was treated more than once.

Scenario 4: Maintain an even flow of harvests from shelterwood regeneration cuts in all five decades. Make total standing volume at the beginning and end of the period equal to each other.

Standing volume rose from 645 Mmbf in year 0 to 700 Mmbf in year 30 and then fell back to 645 Mmbf (Figure 7). Harvest volume was held constant at 9 Mmbf/year. Harvest area was 2000 acres/year in year 10 and fell to 1500 in year 50. Treatment averaged 1700 acres/year for the 50 years of the scenario. One third of the acreage remained untreated at the end of the scenario. Half was treated with both a regeneration cut and an overstory removal cut.

At the end of the 50 year period harvest volume would need to be reduced. At this point, the long term sustainable yield of 7 Mmbf/year could be harvested. However, volume growth would remain below this level until the stands harvested at the beginning of the scenario reached merchantable age (i.e age 80-100).

5. Discussion

The analysis in the report has been conducted using the best available data. It is clear that the forests can support a harvest greater than the 2.7 Mmbf/year which were harvested from 2001-2006 or the 4.7 Mmbf/year harvested from 1997-2006. However, the data have a number of limitations. First, since several of the state's forests do not currently have an assigned forester, inventory data and stand cover type classifications are not available for all forests. For the purposes of this analysis, it was assumed that the forests without inventory were generally similar to the forests with inventory, but this can only be confirmed using an appropriate sampling methodology. Second, this report relied on a chronosequence and growth modeling to estimate growth rates rather than empirical measures of growth rates. Ideally, growth rates would be calculated based on plot remeasurement data. Remeasurement data is especially critical if one is using uneven aged management. This could be done by establishing a continuous forest inventory system in which a series of fixed area plots are be established and remeasured at 5 or 10 year intervals. Actual growth and harvest rates on these plots could be compared to the expected level of growth and removals.

Furthermore, if it is decided to substantially increase the harvest level (especially if a decision is made to cut at or near the estimated current annual growth of 13 Mmbf/year), then it would be important to conduct a more complete inventory on an ongoing basis.

The state is already taking certain steps that should be helpful in improving the inventory. Stand summary data are in the process of being converted from a paper based record keeping system to a computer based system. Some foresters are using computer based inventory procedures. Ideally, plot level data including tree species and dbh, rather than simply stand summary data, should be kept in electronic form. This would allow more accurate projection of growth. The NED suite of decision support tools provides an inventory program for handheld computers which can be used to facilitate inventory taking. NED is maintained by the US Forest Service's Northern Research Station and can be freely downloaded.

Many studies have shown that thinning can extend the time during which stands experience high growth rates, thus delaying the culmination of mean annual increment. The results presented here also suggest that over the next 50-100 years a judicious use of thinning may yield more volume than simply regenerating all mature stands. Whereas using shelterwood regeneration cuts allowed an even flow of 9 Mmbf/ year to be harvested for the next 50 years without reducing the total standing volume, using thinning allowed 10 Mmbf/year to be maintained over the next 50 years. This suggests that the sustained yield could be increased from the 6-7 Mmbf/year estimated here. However, quantifying the exact level of this increase would require long term monitoring of thinned stands and was beyond the scope of this study. Furthermore. the analyses presented here are based on averaging data from many stands. Individual stands vary quite broadly around average conditions. Whether an individual stand should be thinned or regenerated is a decision that must be made based on the best judgment of the forester about the condition of the specific stand. For example, a stand that lacks vigorous, high quality trees may not warrant being thinned. Additionally, it may be desirable to regenerate some stands early in order to diversify the age class structure of the forest.

6. Conclusion

Of the 169,500 acres of forest lands managed by the state of Connecticut's Division of Forester, an estimated 102,000 are commercially suitable. The total standing volume on these acres is 645 Mmbf. Over the past 5 years these forests have been harvested at 1000 acres/year and yielded 2.7 Mmbf/year. Over the next 50 years, it is projected that 9-10 Mmbf/year could be harvested without decreasing the standing volume. However, it would be prudent to implement a more rigorous inventory system if this level of harvesting is to be carried out. Over the long term, the forests could support harvests of 6-7 Mmbf/year. The acreage that would need to be harvested would depend upon the silvicultural treatments that were employed. A judicious use of thinning might increase the level of the sustainable yield by prolonging the length of time in which large trees are rapidly accruing merchantable volume.

forest	area (Parda 2008)	area (stand database)	assumed acres
Algonquin	2,545		2,545
American Legion	789	1,040	1,040
Camp Columbia	599	600	600
Centennial Watershed	15,370		15,370
Cockaponset	15,958	14,712	15,958
Enders	2,097	1,945	2,097
Goshen Wildlife Area		962	962
Great Hill Reservoir		327	327
Goodwin	2,003	2,016	2,016
Housatonic	9,661		9,661
Massacoe	400	338	400
Mattatuck	4,390		4,390
Meshomasic	9,075	7,283	9,075
Mohawk	3,943		3,943
Mohegan	500	923	923
Nassahegon	1,352		1,352
Natchaug	13,216	11,045	13,216
Nathan Hale	1,545	1,542	1,545
Naugatuck	5,037	1,712	5,037
Nehantic	4,387	4,007	4,387
Nepaug	1,374	1,112	1,374
Nipmuck	9,113	9,286	9,286
Nye Holman	815	876	876
Pachaug	24,804	8,661	24,804
Paugnut	1,646		1,646
Paugussett	2,000	773	2,000
Pease Brook Wildlife Area		138	138
Peoples	2,900	3,081	3,081
Pootatuck	1,154	1,016	1,154
Quaddick	1,009	572	1,009
Quillinan Reservoir		584	584
Salmon River	6,863	4,359	6,863
Sessions Woods Wildlife Area		215	215
Shenipsit	6,943	6,293	6,943
Topsmead	609		609
Tunxis (E. Hrtlnd and Hrtlnd Hllw Blks)	5,656	5,887	5,887
Tunxis (West Hartland)	3576		3,576
Wopowog Wildlife Area		497	497
Wyantenock	4,100		4,100
total	165,429	91,800	169,486

Table 1 Estimated area of properties managed by the Division of Forestry.

management status	total	% of total
active	48,348	52%
blank	14,854	16%
inaccessible	5,088	5%
inoperable	11,807	13%
natural area	696	1%
old forest	9,845	11%
recreation area	473	1%
unknown	499	1%
wildlife	1,229	1%
grand total	92,837	100%

Table 2 Management status for acreage included in the stand database.

	entire forest		actively managed	
cover group	acres	%	acre	%
unknown	140	0%	17	0%
aspen-birch	118	0%	112	0%
blank	1215	1%		0%
Douglas-fir	10	0%		0%
elm-ash-red maple	5672	6%	307	1%
exotic softwoods	378	0%	333	1%
loblolly-shortleaf pine	19	0%	2	0%
maple-beech-birch	2625	3%	2103	4%
oak-gum-cypress	539	1%	3	0%
oak-hickory	62559	67%	33637	70%
oak-pine	6406	7%	4951	10%
other	3500	4%	487	1%
pinyon-juniper	34	0%	14	0%
spruce-fir	63	0%	6	0%
white-red-jack pine	9568	10%	6376	13%
total	93845	100%	48348	100%

Table 3 Cover group for acreage included in the stand database.

cover type	% actively managed landscape	average volume (mbf/acre)
elm-ash-maple immature	0%	
elm-ash-maple mature	1%	5.0
maple-beech-birch immature	1%	2.7
maple-beech-birch mature	4%	6.1
oak-hickory immature	10%	2.6
oak-hickory mature	60%	5.1
oak-pine immature	1%	2.7
oak-pine mature	9%	6.9
pine immature	1%	4.4
pine mature	13%	13.2
area weighted total		6.0

Table 4 Average standing volume calculated from the stands database.

cover type	% actively managed landscape	average volume (mbf/acre)	annual rate of growth (%)	annual growth (mbf/acre/ year)
elm-ash-maple immature	0%			
elm-ash-maple mature	1%	5.6	1.7%	0.10
maple-beech-birch immature	1%	2.9	2.0%	0.06
maple-beech-birch mature	4%	6.5	1.3%	0.08
oak-hickory immature	10%	1.7	6.4%	0.11
oak-hickory mature	60%	5.2	2.1%	0.11
oak-pine immature	1%	4.4	4.0%	0.18
oak-pine mature	9%	6.5	2.1%	0.13
pine immature	1%	3.5	5.0%	0.17
pine mature	13%	14.7	1.3%	0.20
area weighted average		6.3	1.9%	0.12

Table 5 Average standing volume and current growth calculated using updated inventory data.

treatment	explanation
no action	Allow stand to grow without management intervention.
clearcut	Remove all trees in a single cutting and allow stand to regenerate.
SDI thinning	Thin stand to 60% stand density index proportionally according to size.
thinning from below	Thin trees greater than 6 inches dbh, leaving 60 square feet of basal area (hardwood) or 110 square feet of basal area (conifer).
shelterwood regeneration cut	Thin trees from below leaving 30 square feet of basal area.
shelterwood removal cut	Remove overstory trees following a shelterwood regeneration cut.

Table 6 Silvicultural treatments modeled for this analysis.

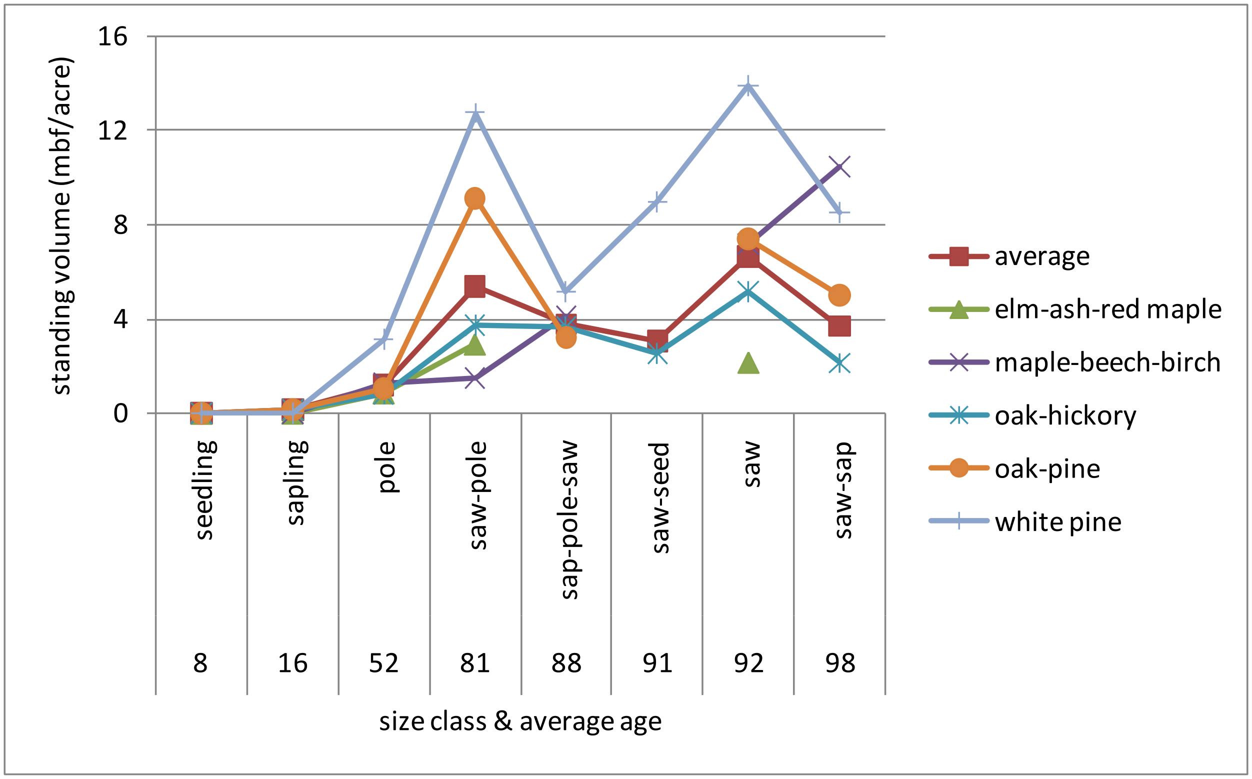

Figure 1 Summary of forest cover type, size class, and volume relations in the Stands database.

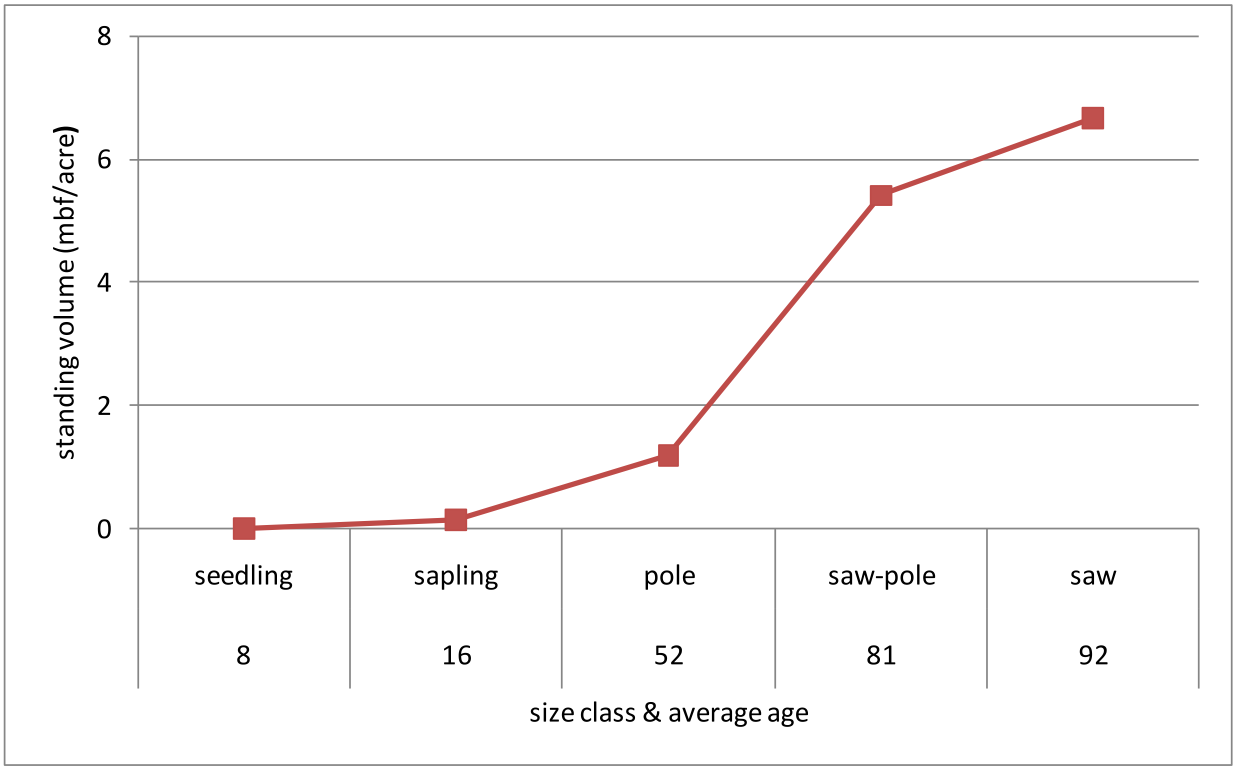

Figure 2 Average trajectory of volume from data in the stands database

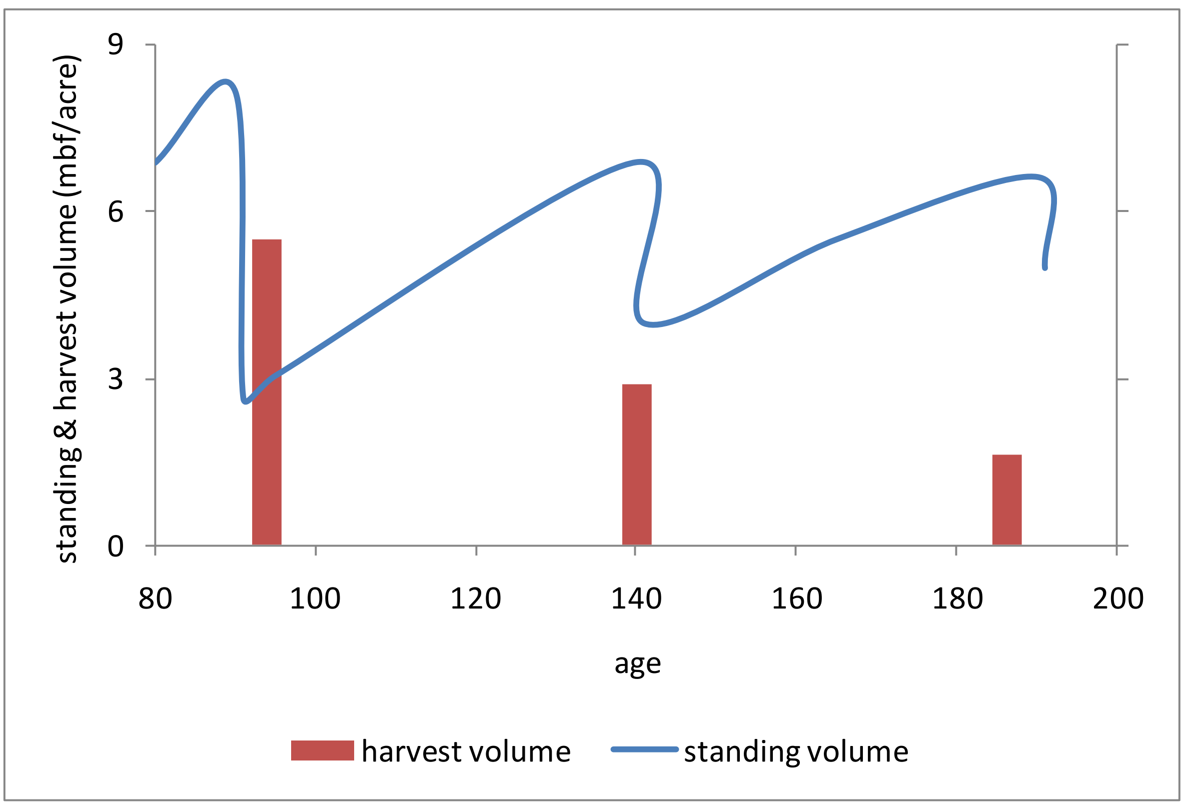

Figure 3 Average trajectory for multiple stand density index thinning.

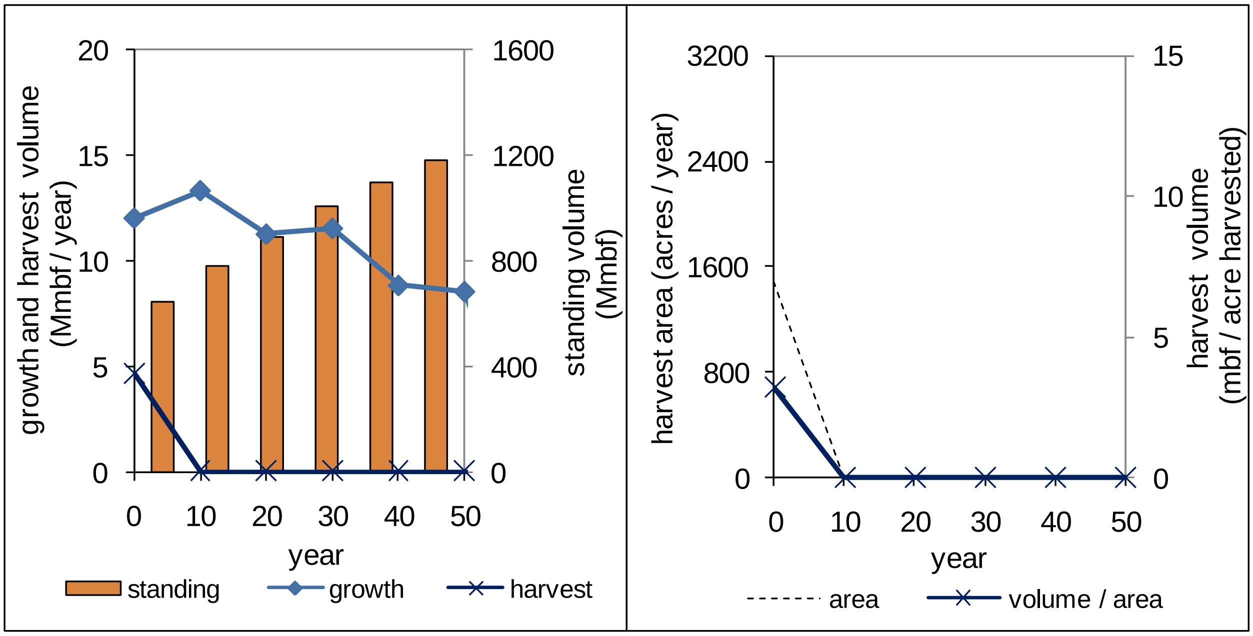

Figure 4 Results from scenario 1: Allow forest to grow without harvesting.

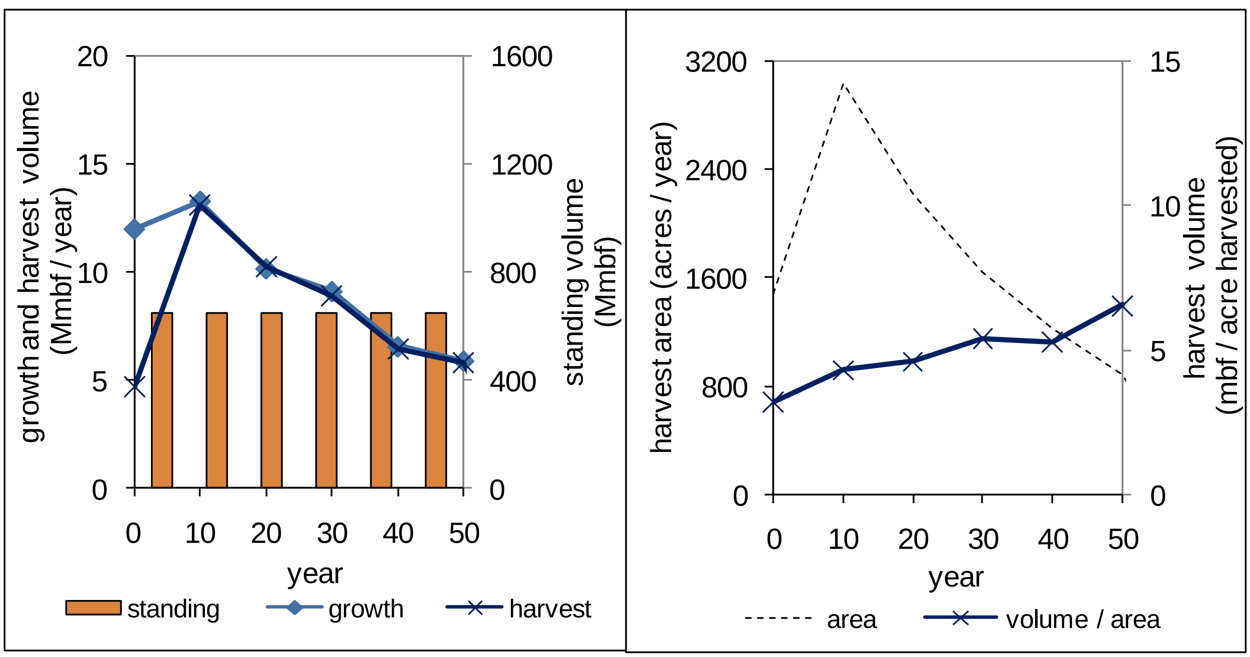

Figure 5 Results for scenario 2: Harvesting all volume growth in each decade using 60% density index thinning (B-line) for hardwood stands and basal area thinning for conifer stands.

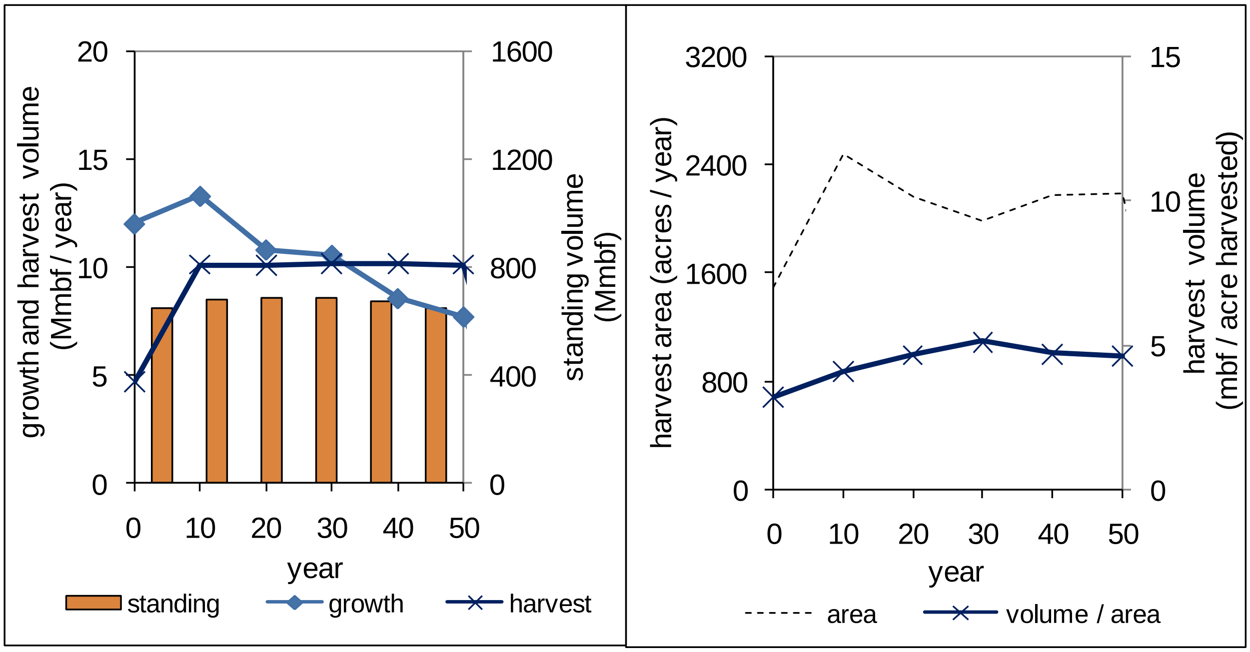

Figure 6 Results for scenario 3: Maintaining an even flow of timber using 60% density index thinning (B-line) for hardwood stands and basal area thinning for conifer stands while maintaining the same standing volume at the end of the 50-year modeling period as at the beginning.

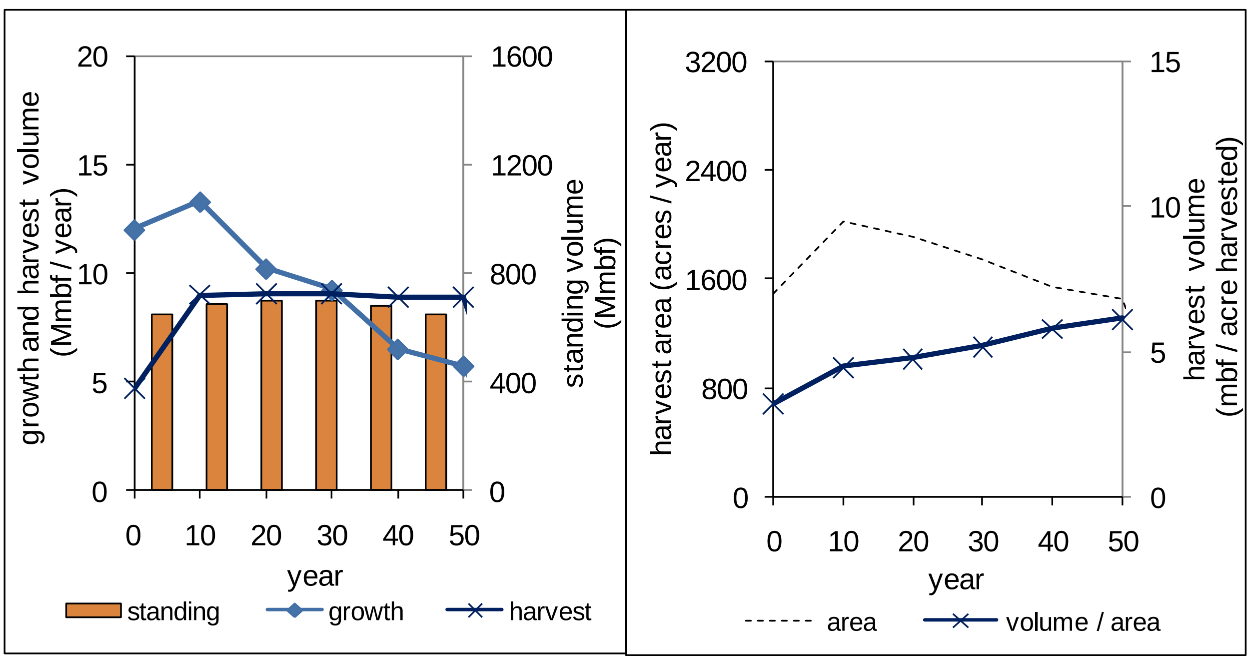

Figure 7 Results for scenario 4: Maintaining an even flow of timber using shelterwood regeneration cuts while maintaining the same standing volume at the end of the 50-year modeling period as at the beginning.

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