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REPORT

Maine Wood Volume and Projection Study

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1. EXECUTIVE SUMMARY

The State of Maine is going through significant change in its forest industry. A consortium of forest industry organizations are working together to develop a long-term vision and roadmap for the Maine forest products sector. A first step in that journey is to have a current inventory and projections for major commercial species groupings on which to base their planning. This study addresses that need.

Maine's timberlands were aggregated into four primary owner types: Large Private (or corporate) landowners, smaller private landowners , Federal lands (National Forest, Department of Defense and Other Federal), and Other Public (State, County/Municipal and Local Government). Table 1.1 depicts the acreage breakdown by ownership category.

Table 1.1. Timberland Acreage by Ownership Type

Owner Type	Timberland Acres	Percent
Federal	67,162	0.4%
Other Public	929,045	5.5%
Large Private	9,021,940	53.9%
Small Private	6,734,227	40.2%

Table 1.2 depicts the acreage breakdown by megaregion.

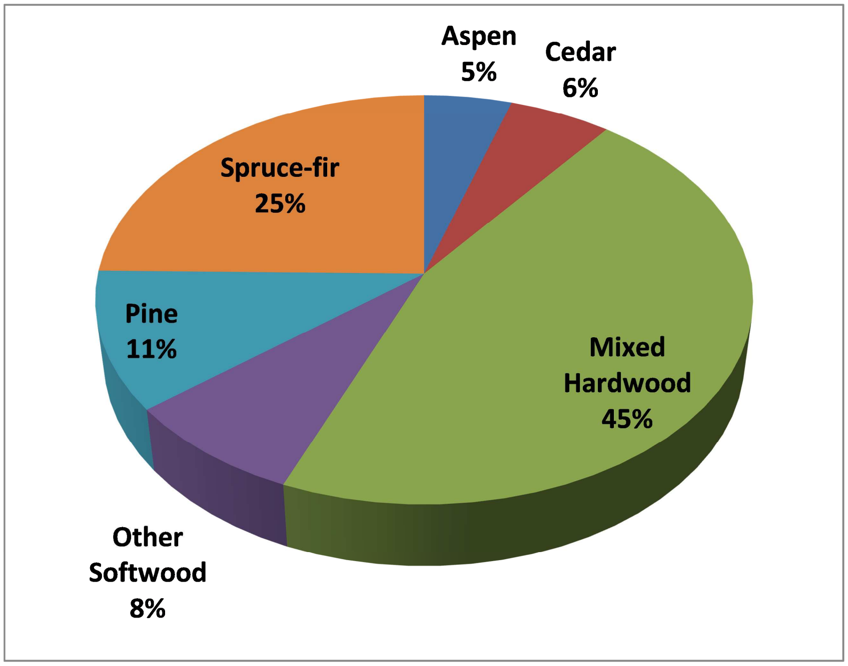
Table 1.2. Timberland Acreage by Megaregion

Megaregion	Acres	Percent
Northern	8,157,711	48.7%
Eastern	4,184,743	25.0%
Southern	2,260,165	13.5%
Western	2,149,755	12.8%

It should be noted that approximately half of the timberlands is in the Northern region, one-quarter in the Eastern megaregion and about an eighth in each of the Southern and Western megaregions.

SUMMARY BY SPECIES GROUP

Figure 1.1. Relative Size of Resource by Species Group



While FIA data is the best basis to form our current inventory, it is important to note it is backward looking. Each of the five years of 2012-2016 represents 20% of the dataset, so average inventory is 4.5 years old as of the writing of this report. Modeling is our best predictor of the future, but it also has limitations as applied over an area as large and diverse as the State. For these reasons, the authors recommend utilizing the data in broad strokes. It is reliable at the State and sometimes megaregion levels. It can assess and predict large trends, but no individual numbers should be taken as fact. They are as close an estimate as the sample and modeling allow.

In addition to analyzing the FIA data and trends, Sewall biometricians modeled the timberlands forward for 50 years in ten periods of five years each. Bothe the FIA and modeled summary results are presented for each species group.

Table 1.3. Summary Table of Model Results – First 25 years

	25-year Modeling (Run3)		
	Green tons/year (thousands)		
Species	**Modeled Maximum**	**Discounted**	**Estimated 2017**
Dense Hardwood	9,240	7,391	6200*
Aspen	1,042	1,027	900
Spruce-fir	5,915	5,751	3,200
Pine	1,714	1,664	1,100
Other Softwood	1,418	1,363	750
Cedar	259	249	200
* Commercial consumption of 5,200 plus 1,000 of unreported fuel wood			

Spruce-fir data analysis reveals a resource that has begun an impressive rebound as the large acreage established after the prior spruce budworm outbreak reaches merchantability. There is a marked contrast between the negative annual dynamics in 2008 vs. strongly positive in 2016; significant gains in inventory have already been measured. These gains will continue, and accelerate. At the same time, spruce-fir pulpwood consumption has declined by one million tons per year to an estimated 2.1 million tons/year. Fifty-year modeling predicts that the total spruce-fir available for harvest could increase sustainably by 84% to 5.9 million green tons/year for the next 25 years and then increase to 7.6 million GT/year in years 26-50.[1] Of the species groups examined, the spruce-fir resource offers the most significant potential for industry expansion for both pulpwood and sawable material.

Mixed Dense Hardwood presents two different resource pictures by landowner type. On large landholdings, the FIA inventory volume has declined in recent decades. However, the most recent data shows sharply higher annual growth rates and somewhat reduced harvesting. As a result of intensive even-aged management from the 1930s through the 1990s, the age class structure has a strong pipeline of stands entering merchantable size in the peak growth years. On industry lands, a resource recovery phase for mixed hardwood has begun. At current consumption levels, the inventory should gradually rise over the next two decades. Current levels of commercial utilization (estimated 5.2 million tons/year)[2] will be supported, and there will be some room for a degree of expansion over time. The resource on Small Private lands is characterized by mature stands, slower growth, and lower levels of utilization. Based on current trends, the growth rates will continue to slow, average tree size will increase, and the proportion of sawlogs to pulpwood will rise.

[1] No impact of the budworm was programmed in.
[2] 6.2 million green tons/year if we assume 1 million tons of unreported firewood.

Modeling predicts that the forest resource can theoretically sustain a cut as high as 9.2 million tons/year, a 78% increase over reported current harvest; 48% increase if one factors in the estimated million tons of firewood that is not reported annually. This number however includes harvest (at growth rates) from all lands, and includes all commercial dense-hardwood species.

Pine has shown relatively strong gains in total inventory and has very positive current annual dynamics. Pine pulpwood utilization has declined in recent years to an estimated 1.1 million tons/year. There is current opportunity for pulpwood utilization, and the next decade should see resource inventory gains for both pulpwood and sawlogs. Because the majority of inventory is in the Western, Southern, and Eastern Megaregions, pine is situated on small landownerships. Subject to the challenges of working with these smaller landowners, the pine resource offers immediate and sustained capacity for a moderate to strong degree of industry expansion using pulpwood and sawlogs. Fifty-year modeling predicts an annual sustainable harvest level of up to 1.7 million tons, a 56% increase over 2017 estimated harvest. Again, this number implies that all landowners are willing to harvest at a rate of annual growth, and all commercial species of pine are included.

Other Softwood inventory, which is primarily hemlock pulpwood, is level to slightly gaining across the past two decades. With very recent declines in utilization by pulp mills (total estimated harvest of 750,000 tons/year), the annual dynamics are now such that we should see even stronger gains in inventory in the next decade. The hemlock resource offers immediate and sustained capacity for a moderate degree of industry expansion. Modeling predicts an available supply to allow a harvest level of 1.42 million tons/year starting immediately. This is an 89% increase over 2017 estimated harvest levels. Older hemlock tends to develop ring shake, which prevents it from being sawn; however, no deduction has been made for this in the report.

Aspen total inventory is level to slightly declining. The acreage of aspen forest cover type has been declining for two decades; the age class structure indicates that this trend will continue. A majority of the aspen volume is now a minor component of mixed hardwood or other stands and too scattered to economically harvest on its own, which means that the harvest of aspen is limited by the level of mixed hardwood harvest. The estimated 2017 harvest of 900,000 tons/year roughly equals growth. Modeling indicates a slight opportunity for an increased harvest with a sustainable level just greater than 1.0 million tons/year, if 100% of that growth is harvested. Therefore, aspen resource offers no significant opportunity for industry expansion.

Cedar is a small resource with stands widely scattered across the northern two-thirds of the State. The statistics on annual growth and removals are weak. The strongest measure, total inventory, is declining. There is an unusually wide gap between reported harvest and measured harvest, implying that small operators or individuals do most of the harvesting. Modeling results are also the least certain of the species groups – they depict an average sustainable level of 258,800 tons/year over the next 50 years. Because of the scattered nature of stands and accessibility issues, we report that the cedar resource offers no significant opportunity for industry expansion.

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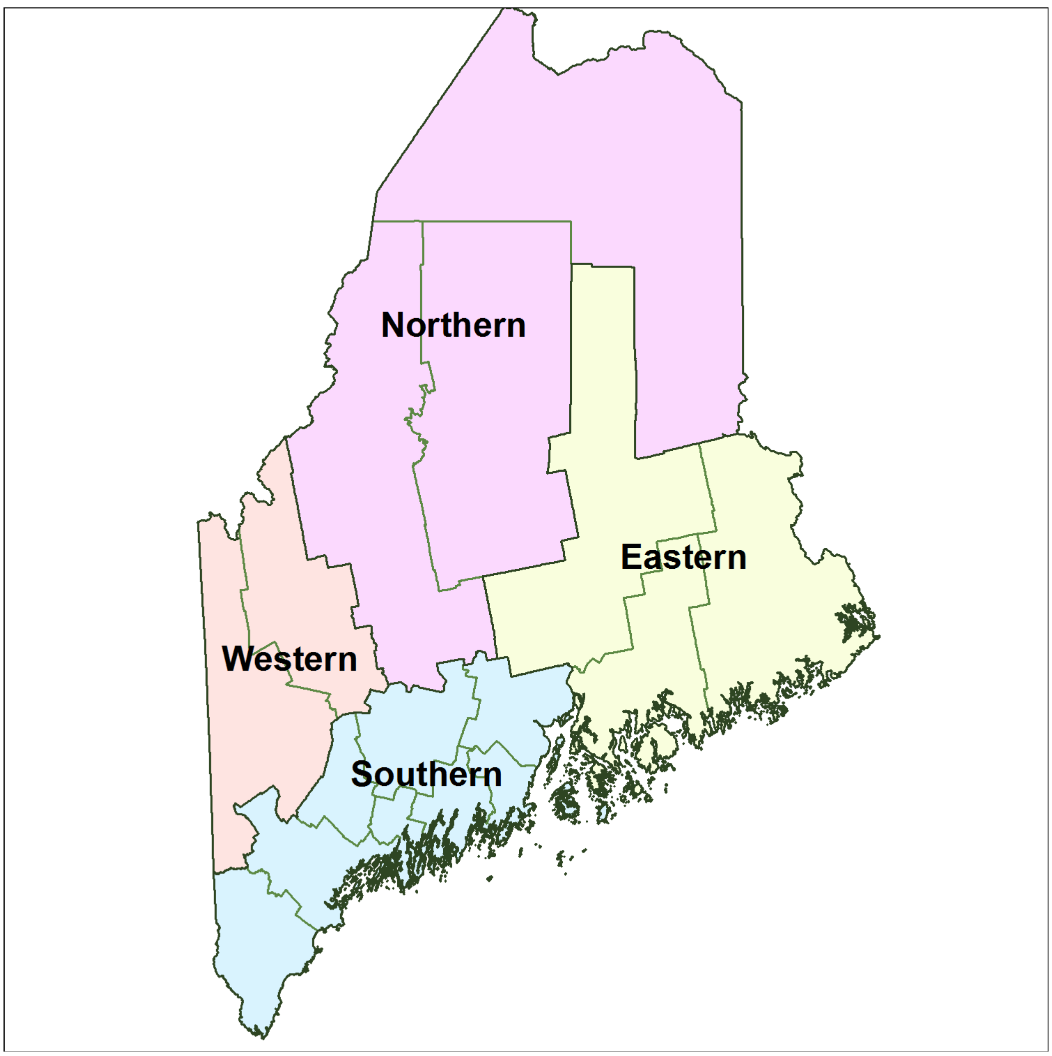
SUMMARY BY MEGAREGION

Table 1.4. Resource Potential for Industry Expansion by Megaregion and Species Group

Species Group	Reource Potential by Megaregion				Historical End Uses (WPR %s)
	Northern	Eastern	Western	Southern	
Aspen	Weak	Weak	Weak	Weak	Pulpwood and OSB
Cedar	Weak	Weak	Weak	Weak	Specialty Products
Mixed Hardwood	Weak	Moderate	Weak	Weak	80% Pulpwood, 20% Sawlogs
Other Softwood	Weak	Moderate	**Strong**	Moderate	83% Pulpwood, 17% Sawlogs
Pine	Weak	**Strong**	Moderate	Moderate	30% Pulpwood, 70% Sawlogs
Spruce-fir	**Very Strong**	**Very Strong**	**Strong**	Weak	33% Pulpwood, 67% Studwood/Logs

Figure 1.2. Megaregions



2. INTRODUCTION

BACKGROUND AND PURPOSE

The State of Maine is going through significant change in its forest industry. A consortium of forest industry organizations are working together to develop a long-term vision and roadmap for the Maine forest products sector. A first step in that journey is to assess current inventory conditions and develop projections for major commercial species groupings on which to base their planning. Sewall was awarded the task for these wood fiber inventory analyses and projections, and this study presents the results of that work.

METHODOLOGY - CURRENT

This "current-state" resource supply analysis is based on the USDA Forest Service Forest Inventory and Analysis (FIA) database, which is in turn built on a set of permanent sample plots with a density targeted at one plot per 6,000 forested acres. In recent decades, the FIA program team in Maine has remeasured 20% of the plots each year. Each remeasured plot provides new inventory and a measure of average net annual growth since the last measurement (normally five years). If harvesting has occurred on the plot, then average annual removals are calculated. Because harvesting does not occur on more than a small percentage of plots each year, average annual removals is the weakest of the estimates, and is reliable only for large areas.

Forests are complex, dynamic systems that respond over decades to harvesting and other loss or disturbance. To understand the future trajectory of a particular timber resource, it is best to use a series of snapshots at different points in time.

In the present study, we use the 2008 FIA dataset as the first observation. Because of the five-year remeasurement cycle, the 2008 data actually reflects inventory conditions in 2005-2006, and average growth and removals across the period 2000 to 2008.

We use the most current measurement year available, 2016, for the second observation. Again, the inventory actually reflects conditions in 2013-2014, and growth and removals across the period 2008 to 2016.

FIA identifies the county in which each plot falls; this information was used to separate data into megaregions. Plots on Other Public lands are also identified, but no distinction between ownership classes of private lands is provided. Exact plot locations are not released; the agency shifts the location data a kilometer or so in random directions and sometimes swaps data between plots. The Sewall team relied on an overlay of a proprietary

Sewall GIS database to identify plots on large landholdings in Maine. For timberland areas of two million acres or more (333 plots), such as the zones in this study and the large landholdings (as a single group), the "edge effects" of plots falling in the wrong polygon are not serious enough to prevent meaningful study.

FIA growing stock volumes on timberland are in units of cubic feet of wood in the main stem only. We used the following conversion factors to estimate tons of delivered roundwood:

Aspen 26.9 tons per MCF	Cedar 20.0 tons per MCF
Mixed Hardwood 33.8 tons per MCF	Other Softwood 27.1 tons per MCF
Pine 25.3 tons per MCF	Spruce-fir 24.7 tons per MCF

Estimates of estimated 2017 harvest and the methodology can be seen in section 4 of this report.

METHODOLOGY - MODELING APPROACH

Sewall used biological data on the State's forest resources from FIA, widely used growth models[3], and software for harvest scheduling/optimization (Woodstock), to study the supply of the commercial species groups across the four megaregions of the State over the next five decades (ten periods of five years each).

Growth models were used to develop a set of yield tables for use in the Woodstock model. Yields were developed for the major forest types considering the various silvicultural practices commonly applied across the region. Silvicultural practices included two stage shelterwood system, and clearcutting. Planting was allowed on Large Private ownership, while the majority of areas were assumed to regenerate naturally, as is commonly the case across the Northern Forest.

The yields were incorporated into Woodstock, which can be used to develop harvest schedules that optimize a desired objective subject to user-specified constraints. It can be applied in a manner that seeks not only to build a harvest schedule, but also to determine the highest level that the objective can reach. By setting the maximization of harvest volume across the modeling period as the objective, we were able to use Woodstock to test the productive capacity of the forest given its initial condition, subject to constraints that reflect real-world conditions and trends.

[3] Forest Vegetation Simulator, or FVS. The Fiber model was applied for certain conditions where FVS was not appropriate.

It is important to note that during the modeling phase, Sewall did not limit the full growing capacity of the timberlands within the constraints described in the Appendix. The reader should therefore view the initial modeled results as the theoretical maximum available. Post modeling, the sponsor team recommended the following discounts: 100% of Federal land unavailable for commercial harvest (all species), 30% of Other Public lands unavailable (all species), and on Small Private Timberlands a division by megaregion for hardwood only: 50% of hardwood unavailable in the Sothern megaregion, and 20% unavailable in the remaining three megaregions. These discounted volumes are reported at the end of each species section.

Three runs were made with the model, as follows:

1. Base run: maintain constant harvest levels
    a. Harvest stays the same as estimated for 2017
    b. Inventories by species group were non-declining (except for cedar)
    c. Inventories at end of the study period had to be greater than or equal to starting inventories
2. Maximize harvest volumes while sustaining inventory over the study period
    a. Harvest levels in the first year were set to the 2017 estimated levels and then allowed to increase/decrease within reasonable constraints reflecting likely expansion in harvest and demand capacity
    b. Inventories allowed to increase/decrease throughout the study period
    c. Inventories at end of study period had to be greater than or equal to starting inventories
3. Non-declining harvest levels, while sustaining starting inventories
    a. Harvest levels in first year greater than or equal to harvest level estimated for 2017
    b. Harvest levels allowed to increase, but not decrease over the study period
    c. Inventories allowed to increase/decrease throughout the study period
    d. Inventories at end of study period had to be greater than or equal to starting inventories

Run1 and Run3 produced salient results which are reported in this report. Run2 was interesting from an academic standpoint because it often gave a slightly higher overall volume of harvest. That said, it did this by fairly significant swings in harvest levels over the ten five-year periods which does not represent how industry would operate. For this reason we minimized reporting on the results of Run2.

Modeling assumptions and constraints can be viewed in the Appendix.

MIX BY LANDOWNERSHIP

Large landownerships make up the majority of timberland in Maine (54%, yet consistently in our modeling only supply the heaviest harvest volume in two species groups (spruce-fir and cedar). Smaller private landowners make up the second largest category; Other Public is third and the Federal lands are the smallest group. Table 2.1 depicts the percentage of average harvest over the 50–year modeling period from each ownership type.

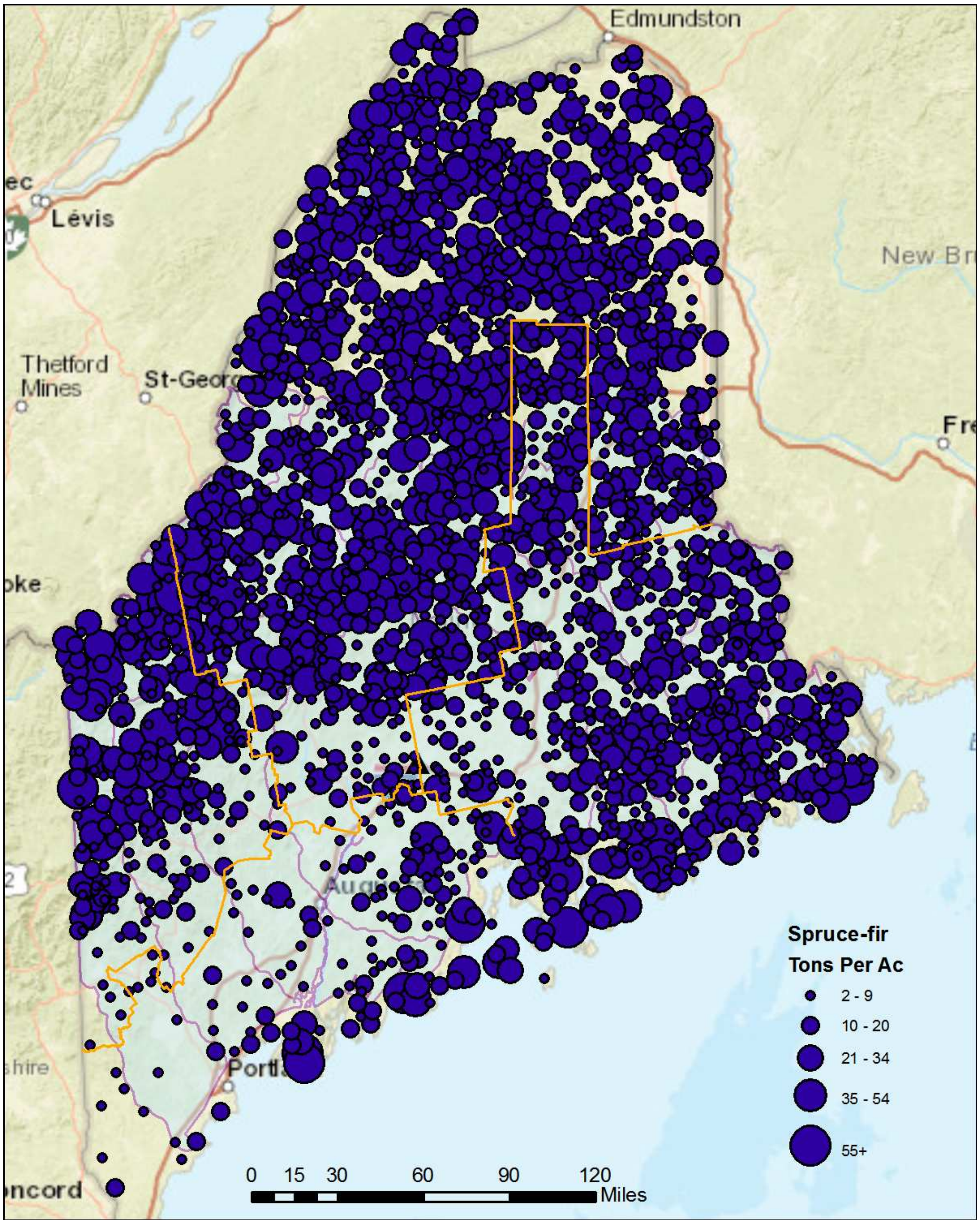
Table 2.1. Predicted Percentage of Average Harvest by Ownership Type and Species Group (50 year projection – Run3).

	Species Group					
Owner	Spruce Fir	Pine	Other Softwood	Cedar	Dense Hardwood	Aspen
Federal	0%	0%	2%	0%	0%	0%
Large Private	66%	19%	32%	50%	46%	36%
Other Public	6%	7%	3%	13%	6%	4%
Small Private	28%	74%	63%	37%	48%	60%

3. MAINE'S TIMBER RESOURCE: CURRENT STATUS, RECENT AND FUTURE TRENDS

SPRUCE-FIR – CURRENT

Figure 3.1. Spruce-fir Volume Per Acre on Approximate FIA Plot Locations



Spruce-fir is primarily a northern and eastern resource in Maine. The distribution is characterized by a very pronounced gap extending about 65 miles inland from the coast beginning in the Bangor area and continuing to the southern tip of the State. Historically, the reported harvest has been 67% studwood or sawlogs, and 33% pulpwood. When now-common studwood specifications are applied to the FIA tree list (inventory) the product mix is 70% studwood/sawlogs and 30% pulpwood[4]. If a small log mill definition is utilized, then 98% of the FIA volumes reported are sawable product.[5] These percentages might be slightly overstated as the FIA data often fails to capture stem form or quality issues.

Table 3.1. Spruce-fir Inventory Trend

Region	Million Tons		Change
	2008	2016	
Eastern	36.6	41.6	14%
Northern	85.1	91.8	8%
Southern	8.2	9.3	14%
Western	17.7	19.6	11%
Total	**147.5**	**162.2**	**10%**

Landowner Type	Million Tons		Change
	2008	2016	
Lg Private	92.3	98.2	6%
Public	9.6	14.3	49%
Sm Private	45.7	49.7	9%
Total	**147.5**	**162.2**	**10%**

One-fourth of all commercial timber volume in the State is spruce-fir, which is primarily (82%) in the Northern and Eastern megaregions. Statewide, the inventory expanded 10% in eight years. The expansion occurred across all regions and owners.

Table 3.2. Spruce-fir Growth and Removals (Thousand Tons)

Annual Average for the Period 2000 - 2008

Region	Annual Growth	Annual Removals	G/R
Eastern	965	1,082	0.9
Northern	2,414	3,026	0.8
Southern	1	54	0.0
Western	273	419	0.7
Total	**3,653**	**4,580**	**0.8**

Landowner Type	Annual Growth	Annual Removals	G/R
Lg Private	2,531	3,212	0.8
Public	183	327	0.6
Sm Private	940	1,041	0.9
Total	**3,653**	**4,580**	**0.8**

Annual Average for the Period 2008 - 2016

Region	Annual Growth	Annual Removals	G/R
Eastern	1,542	630	2.4
Northern	4,233	2,487	1.7
Southern	196	71	2.8
Western	658	574	1.1
Total	**6,629**	**3,763**	**1.8**

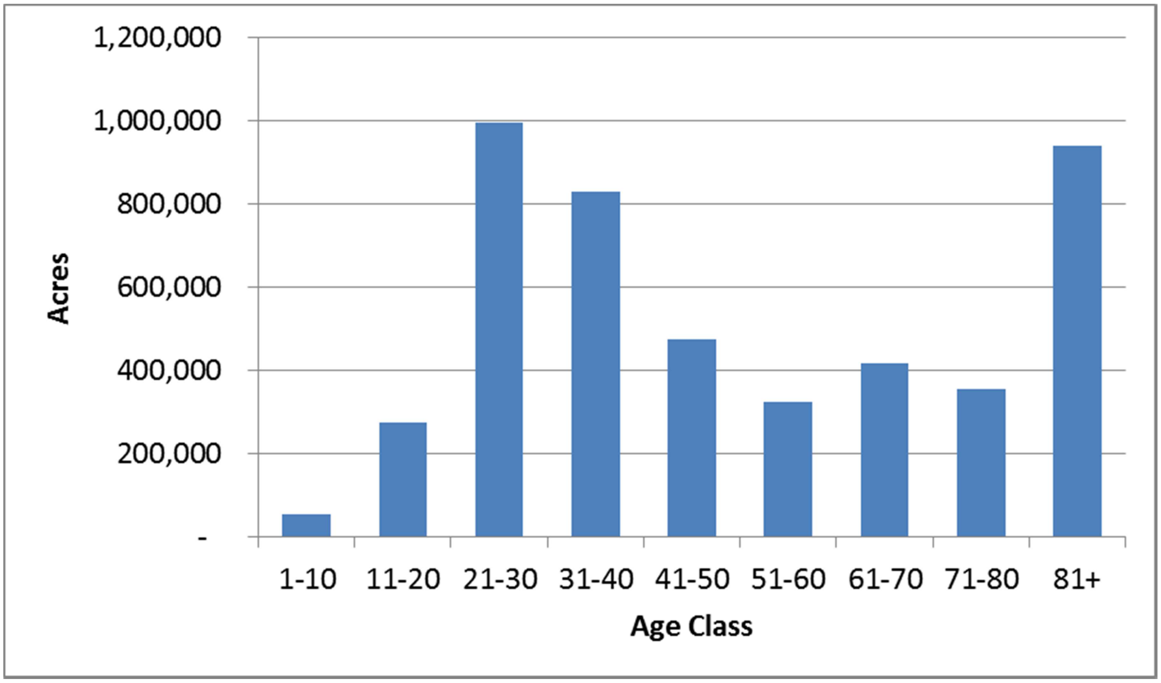
Landowner Type	Annual Growth	Annual Removals	G/R
Lg Private	4,407	2,629	1.7
Public	432	309	1.4
Sm Private	1,791	825	2.2
Total	**6,629**	**3,763**	**1.8**

[4] Studwood specifications vary slightly among mills and over time. For this first product definition, Sewall looked at all FIA trees 7.0" dbh and greater. The tree was characterized as studwood if it had a 7" dbh, was at least 16'6" long from stump to a 5.0" top diameter - outside bark.

[5] For this definition, the sponsor team gave Sewall the following definition: all FIA trees 5" dbh and greater. 5" dbh log, minimum 8'6" long to a 4" top diameter – outside bark. This is the definition of bole volume utilized by the US Forest Service in FIA. Sewall applied a 2% discount for (tree bole) form.

Spruce-fir saw the most dramatic change in annual dynamics of all species groups. Annual growth increased by more than 80%, while removals declined. The combination led to an increase in the growth/drain ratio from 0.8 to 1.8. This change is a good illustration of the fact that the growth to removals ratio will vary widely over time for a sustainably managed resource that has a "bulgy" age class distribution rather than textbook area regulation (where every age class is the roughly the same acreage).

Figure 3.2. Age Class Distribution of Spruce-fir Forest Cover Types



The spruce-fir age class distribution has a pronounced bulge at age 21-40, which is the result of the late 1970s and early 1980s spruce budworm outbreak. Mainly due to this bulge, the next two decades should see continued increases in annual growth.

Table 3.3. Spruce-fir Growth to Removals Ratio Using Estimated 2017 Removals

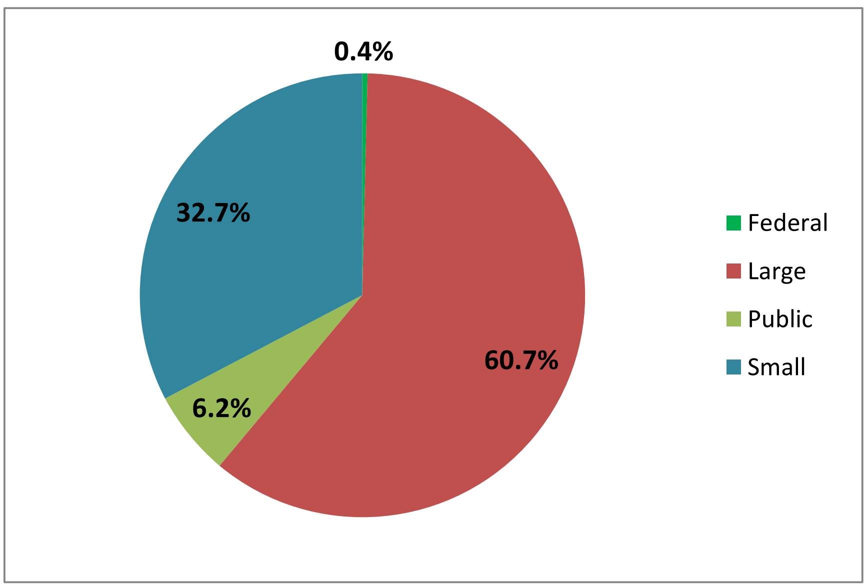
Annual Growth vs. Estimated 2017 Removals			
Region	**Annual Growth**	**Annual Removals**	**G/R**
Eastern	1,542	536	2.9
Northern	4,233	2,115	2.0
Southern	196	60	3.3
Western	658	488	1.3
Total	**6,629**	**3,200**	**2.1**

With estimated 2017 removals, the spruce-fir annual dynamics are even more positive. If this level of removals continues, the next decade should see strong gains in total inventory Statewide, with the strongest (proportionally) in the Eastern region. If all landowners could be enticed to harvest growth, the FIA data would indicate there is a sustainable additional 3.4 million tons/year available Statewide.

SPRUCE-FIR - MODELED FORWARD

In the base scenario (constant harvest levels), the percentage of potential harvest of spruce-fir over the 50-year period is about 61% Large Private owners, one-third Small Private timberlands, 6% from Other Public lands and less than 1% from Federal lands (Figure 3.3). This makes sense since the largest volumes of spruce-fir are in the northern and eastern portions of the State where Large Private landowners are prevalent.

Figure 3.3. Run1, Distribution of Average 50-year Modeled Harvest of Spruce-fir Across Landowner Types

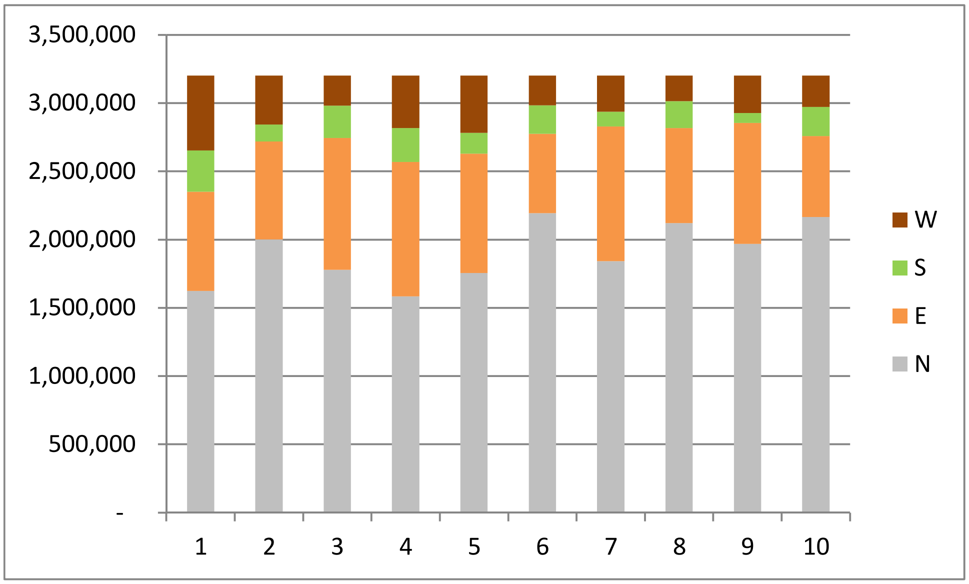


In both of the subsequent model runs (where harvest is maximized) these percentages change to 66% (Large Private) and 28% (Small Private); with Other Public and Federal staying relatively constant (at 6% and 0.3%, respectively).

Modeled harvest levels of 3.2 million green tons remain fairly consistently distributed among the megaregions (Figure 3.4), with the harvest greatest (average = 59%) in the north, 25% in the east, 10% in the west and 6% in the south.

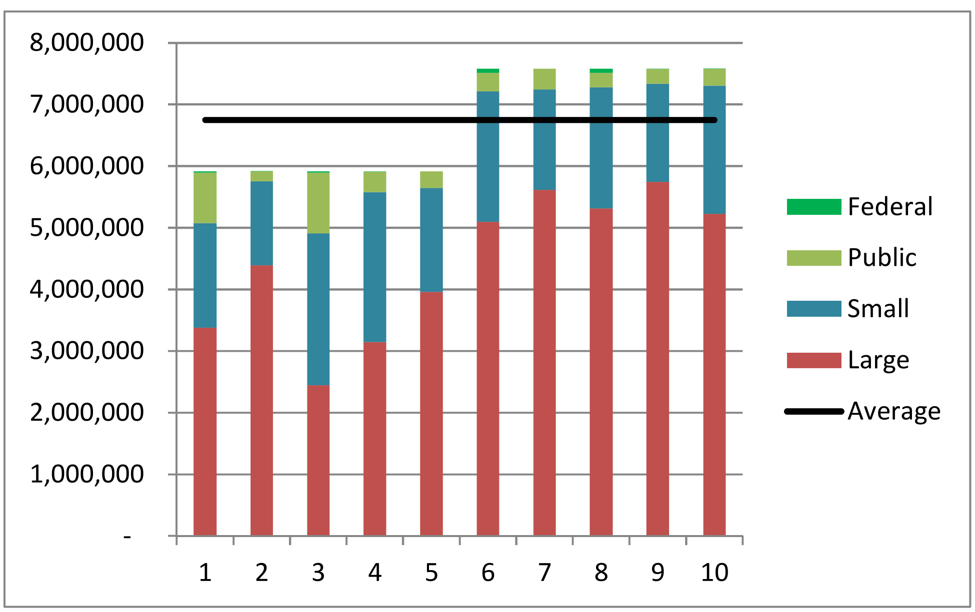
Modeled inventory of spruce-fir grows to 2.4 times current inventory if the harvest level is held at estimated 2017 levels of 3.2 million tons.

Figure 3.4. Run1, 50-year Harvest of Spruce-fir Across Megaregions



If the model is programmed to maximize harvest in a non-declining manner (Run 3– Figure 3.5) then the model will immediately harvest at a rate of 5.9 million tons and hold that through period 5 (25 years). In period 6 (2043-2047), the modeled harvest increases to 7.6 million tons/year. This biological capacity represents increases over 2017 estimated harvest levels of 84% and 137%, respectively.

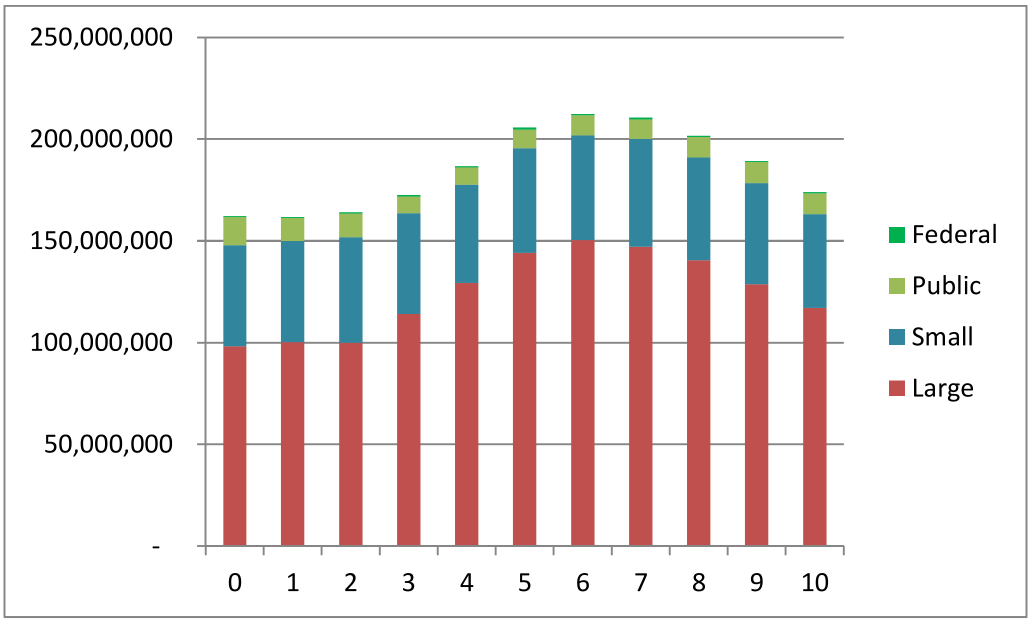
Figure 3.5. Run3, 50-year Harvest of Spruce-fir by Landowner Type



The average biological capacity over the 50 years is 6.75 million tons per year in this scenario, versus 7.75 million when the model is allowed to optimize harvest without the non-declining constraint.

In Run3, in order to accomplish this high level of non-declining spruce-fir harvest, the model builds inventory through period 6 and then brings it back to starting values in periods 8-10 Figure 3.6).

Figure 3.6. Run3, 50-year Inventory of Spruce-fir by Landowner Type

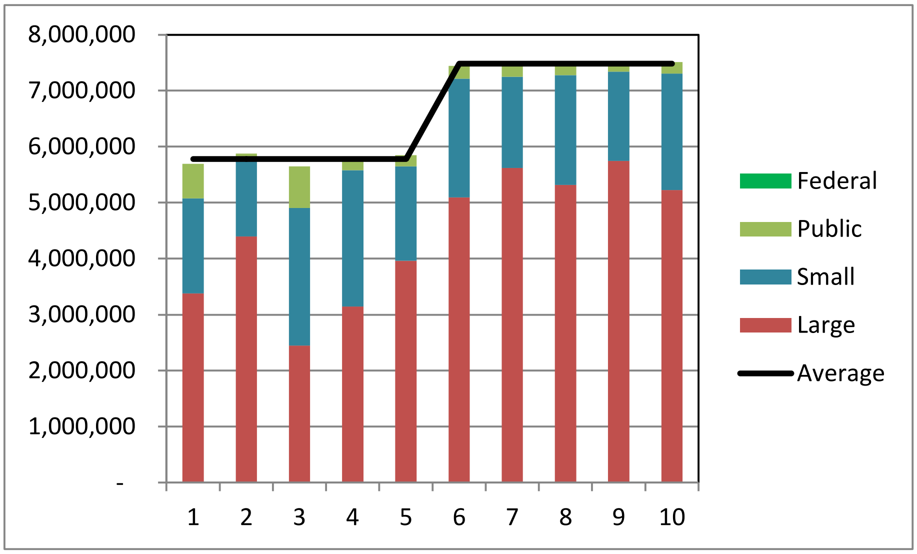


There are apt to be numerous readers that will want to discount Federal, Other Public and Small Private harvests to less than modeled growth on harvestable acres. For illustration purposes we discounted harvest/biological levels as follows:

- Federal -100%
- Other Public - 30%
- Small Private (dense hardwood only)- 20% Eastern, Western and Northern megaregions, 50% in Southern megaregion
- Large Private - 0%

This still allows an increased harvest level of spruce-fir of 5.8 million tons/year over the next 25 years and 7.5 million tons/year in years 26-50 (Figure 3.7).

Figure 3.7. Run3, 50-year Inventory of Spruce-fir by Landowner Type, with Discounts



As reported above, the current mix of spruce-fir inventory is anywhere from 70% to 98% sawable material depending on the mill specs for roundwood. Utilizing the 70% sawable material level, and the discounted harvest percentages yields the 50-year average potential harvest levels in Table 3.4.

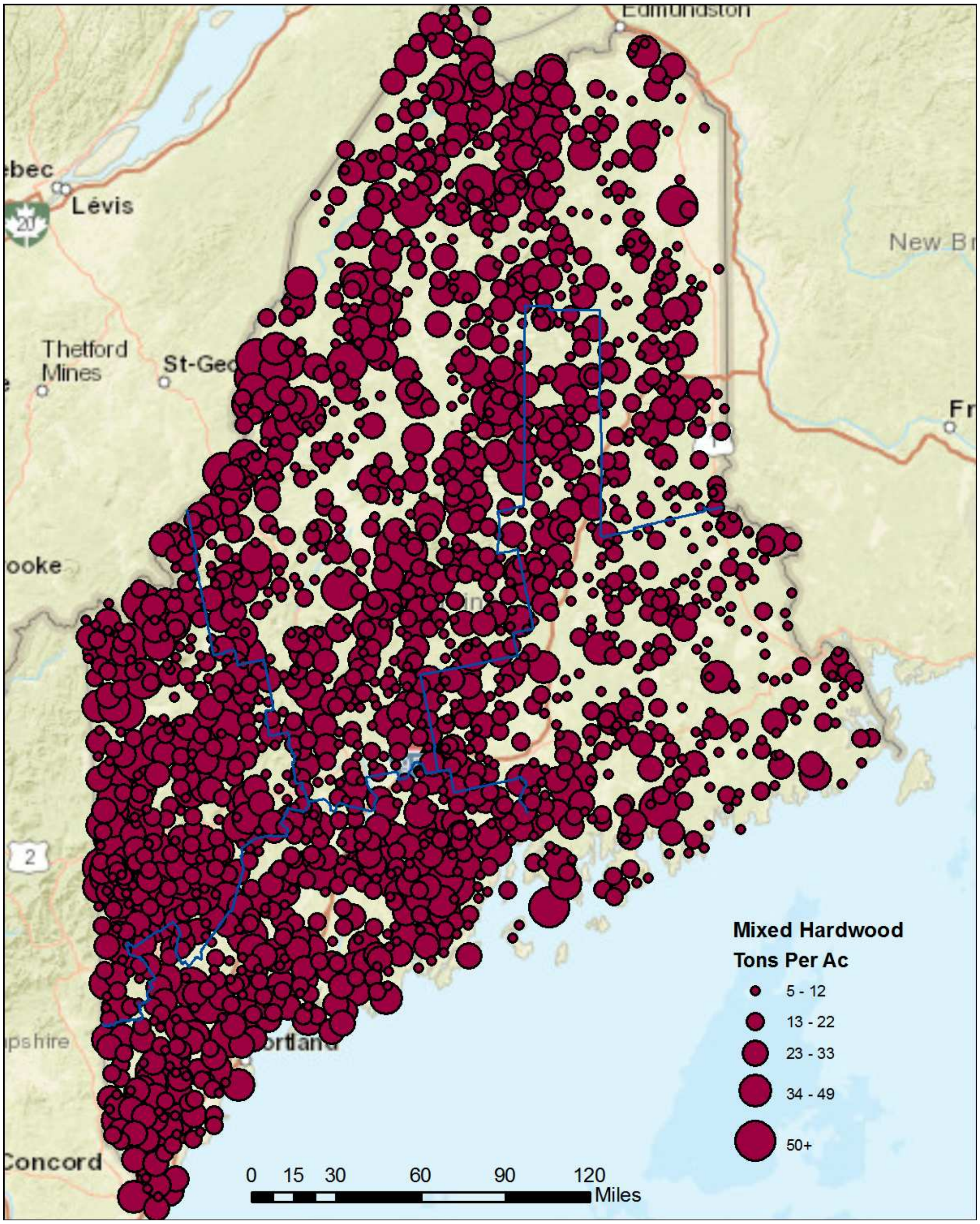
Table 3.4. Run3, Discounted Modeled Potential Harvest Levels of Spruce-fir in Maine

Studwood Specifications	7" dbh - 16'6" min to a 5.0 top		5" dbh - 8'6" min to a 4.0 top	
Period	Year 1-25	Year 26-50	Year 1-25	Year 26-50
Pulp Only (GT/year)	1,733,122	2,244,564	115,541	149,638
Sawable (GT/year)	4,043,952	5,237,317	5,661,533	7,332,244

Sewall anticipates that the percentage of sawable timber will increase as the spruce-fir forest matures, but product merchandizing was not part of the scope, so better predictions of product mix are left to a phase II deliverable.

MIXED DENSE HARDWOOD – CURRENT

Figure 3.8. Mixed Dense Hardwood Volume Per Acre on Approximate FIA Plot Locations



Mixed dense hardwood[6] (hardwood) and spruce-fir together make up 70% of the volume in the State. Hardwood is more highly concentrated in the south and west, where spruce-fir is more concentrated. The harvest volume is typically 80% pulpwood, with approximately one million tons per year of reported sawlog harvest since 2000.[7]

Table 3.5. Mixed Dense Hardwood Inventory Trend

Region	Million Tons		Change
	2008	2016	
Eastern	52.7	50.5	-4%
Northern	132.5	117.5	-11%
Southern	65.6	72.9	11%
Western	62.9	58.3	-7%
Total	**313.7**	**299.2**	**-5%**

Landowner Type	Million Tons		Change
	2008	2016	
Lg Private	149.6	129.0	-14%
Public	20.1	24.0	19%
Sm Private	144.0	146.2	2%
Total	**313.7**	**299.2**	**-5%**

The group of hardwood is by far the largest species group at 46% of all tree volume. Eastern, Northern, and Western megaregions saw a decline in inventory, while gains were recorded in the Southern megaregion. Inventory showed a marked decline on Large Private lands, and a slight increase on Small Private.

Table 3.6. Mixed Dense Hardwood Growth and Removals (Thousand Tons)

Annual Average for the Period 2000 - 2008

Region	Annual Growth	Annual Removals	G/R
Eastern	1,193	1,351	0.9
Northern	2,340	3,919	0.6
Southern	2,024	643	3.1
Western	1,228	1,218	1.0
Total	**6,785**	**7,131**	**1.0**

Landowner Type	Annual Growth	Annual Removals	G/R
Lg Private	2,501	4,423	0.6
Public	377	451	0.8
Sm Private	3,907	2,257	1.7
Total	**6,785**	**7,131**	**1.0**

Annual Average for the Period 2008 - 2016

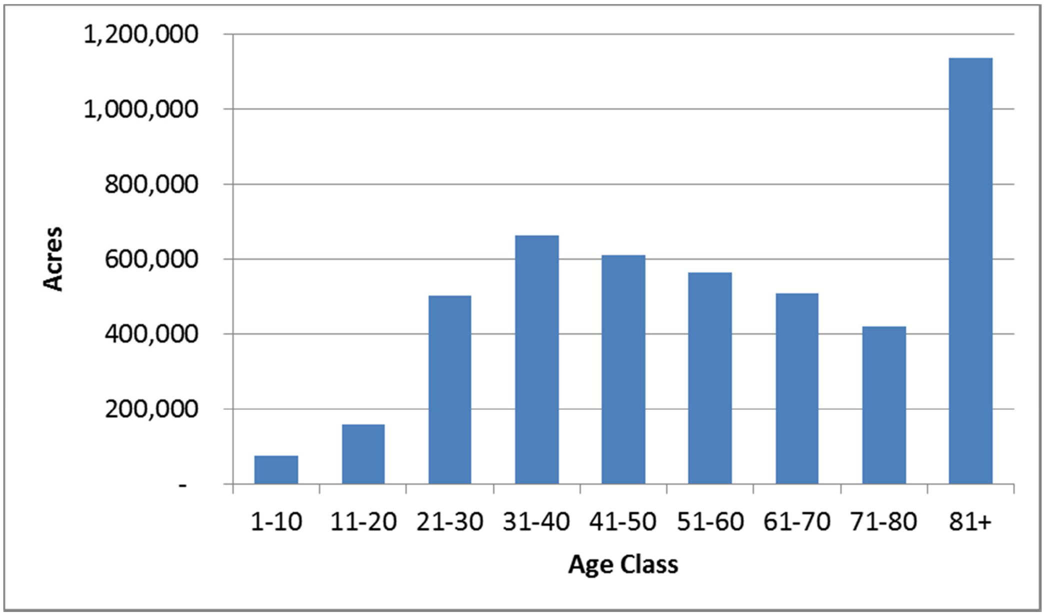
Region	Annual Growth	Annual Removals	G/R
Eastern	1,529	1,313	1.2
Northern	3,308	3,889	0.9
Southern	2,215	921	2.4
Western	1,379	1,288	1.1
Total	**8,431**	**7,410**	**1.1**

Landowner Type	Annual Growth	Annual Removals	G/R
Lg Private	3,368	4,536	0.7
Public	560	369	1.5
Sm Private	4,504	2,505	1.8
Total	**8,431**	**7,410**	**1.1**

[6] Excludes aspen species group
[7] Maine Wood Processor Report (WPR) – figure 4.3

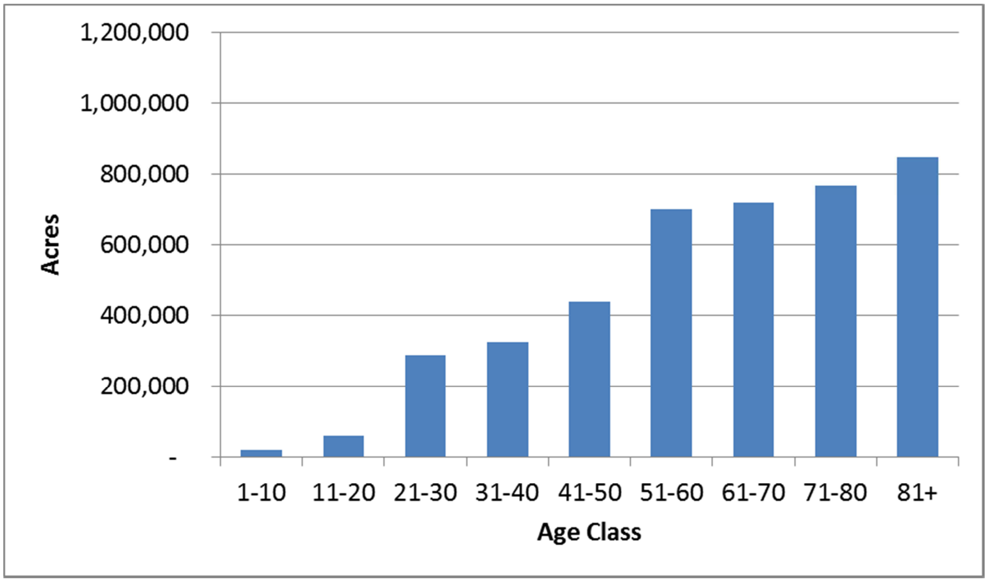
In spite of overall rising removals, the Statewide growth to removals ratio for hardwood has improved slightly. The most striking change is the 25% increase in average annual growth, which implies a significant acreage maturing from juvenile into volume-bearing, higher growth rate stands. While both owner classes showed improvement, the annual dynamics are quite different on Large Private lands (ratio 0.7) vs. Small Private (1.8).

Figure 3.9. Age Class Distribution of Hardwood Cover Types on Large Private Lands



With the exception of the larger age 81+ class and the smaller acreage less than age 21, the age distribution of hardwood on Large Private landowners is level (regulated) to slightly "bulgy" at age 35 (Figure 3.9). The distribution reflects a history of intensive management across a period 20 to 80 years ago, from 1936 through 1996. Since that time, more reliance on selective harvesting has reduced the pipeline of young stands. With this distribution, we see lower inventories than in the past, but higher growth rates which are likely to persist for the next few decades.

Figure 3.10. Age Class Distribution of Hardwood Cover Types on Small Private Lands



Somewhat in contrast to hardwood on Large Private lands, the age class distribution on Small Private lands is more "right-side-heavy" (Figure 3.10). Younger cohorts exist, but they represent a smaller proportion of all acreage. This tends to reinforce the theory that not all landowners are harvesting on their lands.

Table 3.7. Mixed Hardwood Growth to Removals Ratio Using Estimated 2017 Removals

Annual Growth vs. Estimated 2017 Removals			
Region	**Annual Growth**	**Annual Removals**	**G/R**
Eastern	1,529	921	1.7
Northern	3,308	2,729	1.2
Southern	2,215	646	3.4
Western	1,379	904	1.5
Total	**8,431**	**5,200**	**1.6**

Hardwood removals have been reduced in very recent years with the closure and curtailment of some pulp mill operations. When 2017 estimated removals are weighed against annual growth, we see a relatively healthy ratio of 1.6. If Sewall's best estimate of under-reported firewood is added in, the ratio is 1.4. Growth rates will continue to rise, and, absent any new consumption, the total hardwood inventory will show significant gains. Even the Northern region, where the inventory declines have been the steepest, should see a turnaround to inventory gain under these conditions.

Table 3.8. Mixed Dense Hardwood Growth to Removals Using Estimated 2017 Removals by Landowner Type

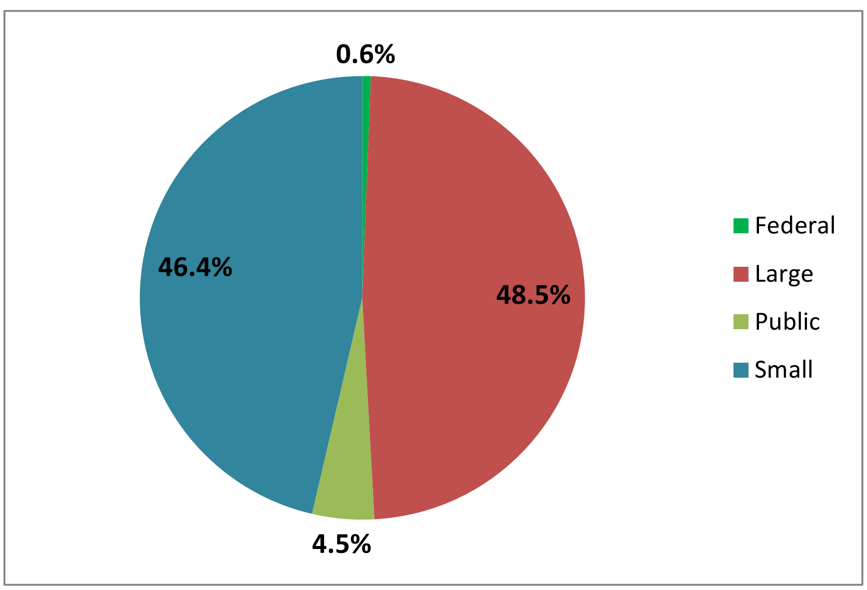
Annual Growth vs. Estimated 2017 Removals			
Region	Annual Growth	Annual Removals	G/R
Lg Private	3,368	3,183	1.1
Public	560	259	2.2
Sm Private	4,504	1,758	2.6
Total	**8,431**	**5,200**	**1.6**

When 2017 estimated removals are allocated to landowner classes based on historic proportions of removals, even the Large Private landowner class has a (barely) positive ratio, which is in contrast to the experience of the past two decades. Note however, that most of the available excess growth is on the Small Private lands, and to a lesser extent the Other Public lands (combined just over 3 million tons/year). If we assume that the majority of under-reported fuel usage is from the Small Private lands, then that ratio is 1.7.

MIXED DENSE HARDWOOD - MODELED FORWARD

In the base scenario (constant harvest levels), the percentage of potential harvest of dense hardwood over the five decade period is about evenly distributed between Large Private (industrial) owners, and Small Private timberlands, with 4.5% from Other Public lands and less than 1% from Federal lands (Figure 3.11).

Figure 3.11. Run1, Distribution of Average 50-year Modeled Harvest of Mixed Dense Hardwoods Across Landowner Types

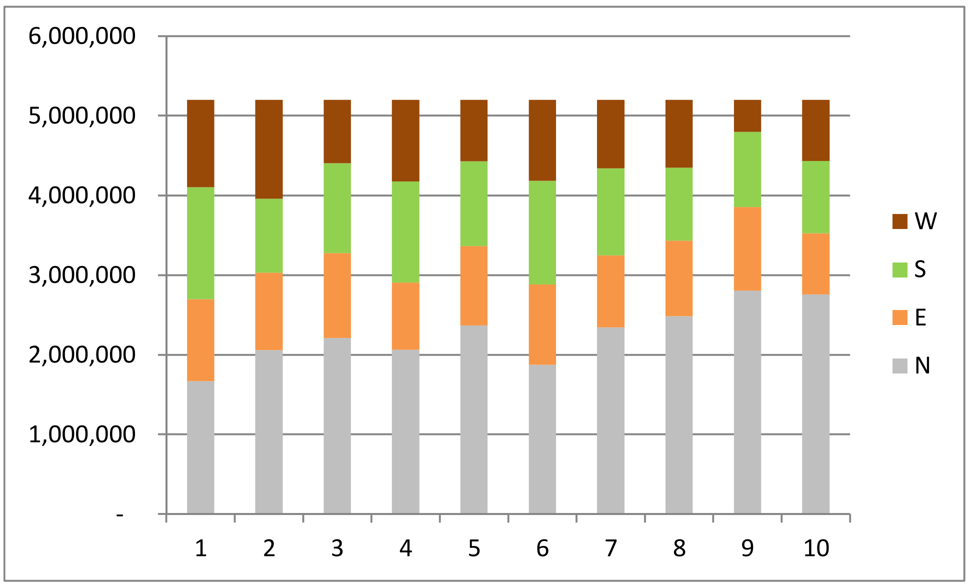


In Run3 (maximizing harvest) these percentages remain within 1% of the base run.

Harvest levels of 5.2 million green tons in Run1 remain fairly consistently distributed among the megaregions (Figure 3.12), with the modeled harvest greatest (average = 44%) in the north, 18% in the east, 17% in the west and 21% in the south.

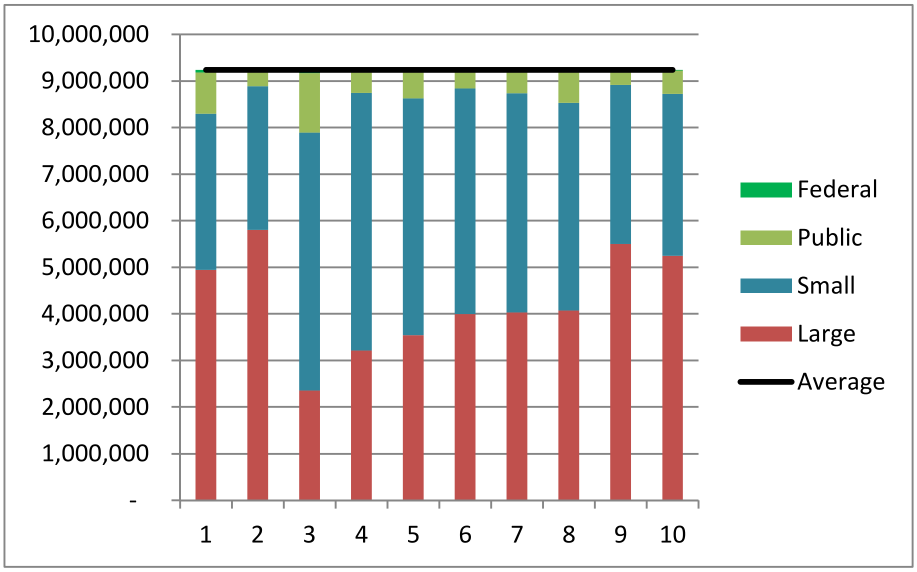
Inventory of hardwood models to 1.6 times the current inventory if the harvest level is held at 2017 estimated commercial levels of 5.2 million tons.

Figure 3.12. Run1, 50-year Distribution of Modeled Harvest of Mixed Dense Hardwoods Across Megaregions



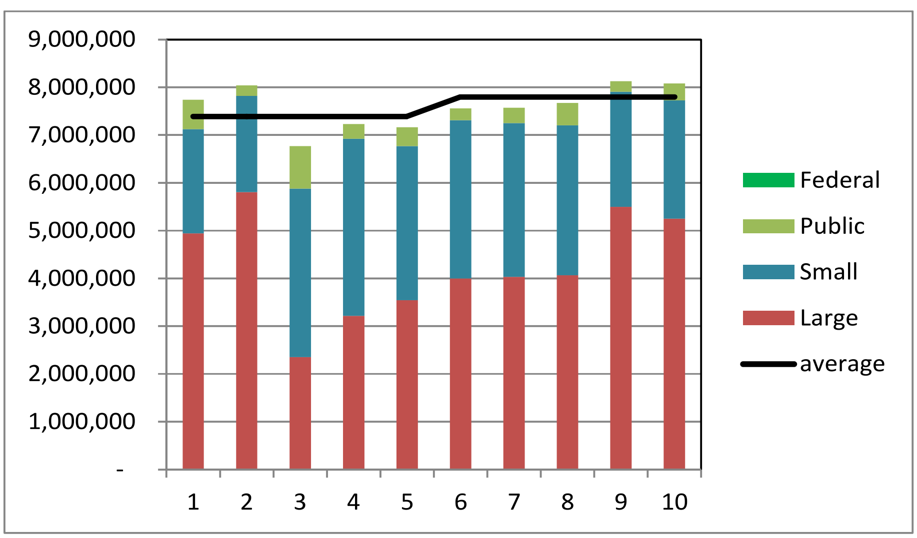
As the objective function of the model is programmed to maximize harvest in a non-declining manner (Run3) it will immediately harvest at a rate of 9.2 million tons and hold that through the entire 50 years (Figure 3.13). This biological capacity represents increases over 2017 estimated commercial harvest levels of 78%. This reduces to a 48% increase if we assume 1 million tons of under-reported fuel wood annually.

Figure 3.13. Run3, Modeled, Non-declining, 50-year Harvest of Mixed Dense Hardwood by Landowner Type



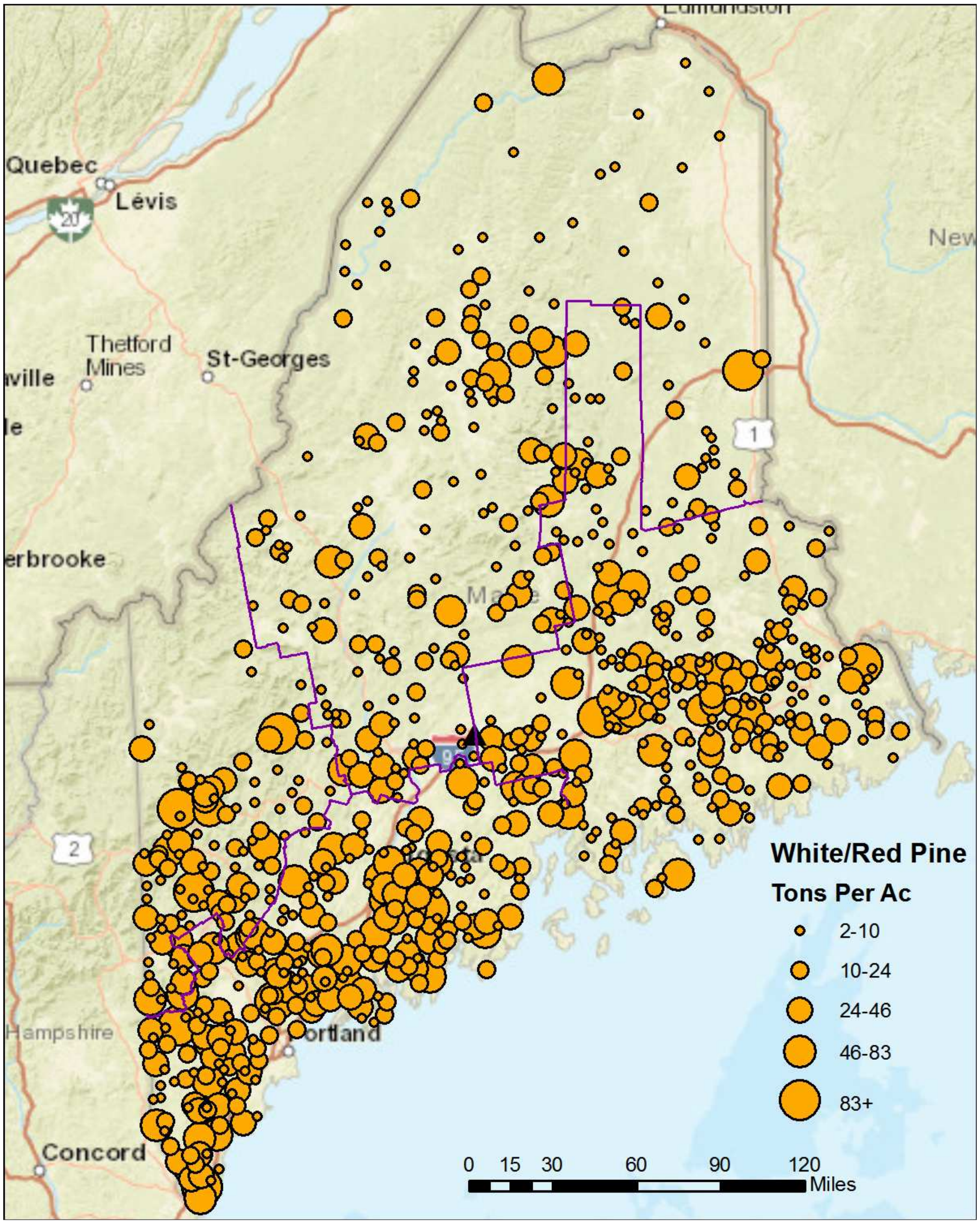
Utilizing the same discounting factors for percentage of harvestable acres that might be available to the market over the 50-year cycle (Federal -100%, Other Public - 30%, Small Private – hardwood only of 50% in Southern megaregion and 20% in other megaregions) still allows an increase harvest level of hardwood to 7.4 million tons/year over the next 25 years and 7.8 million tons/year in years 26-50 (Figure 3.14). At these discounted levels 39% of projected harvested dense hardwood (2.9 million tons/year) would still need to come from Small Private lands.

Figure 3.14. Run3, Modeled, Non-declining, 50-year Harvest of Mixed Dense Hardwood by Landowner Type, With Discounts



PINE CURRENT

Figure 3.15. Pine Volume Per Acre on Approximate FIA Plot Locations



The pine resource is heaviest in a band within 30-40 miles of the coast, and common in the range of 40 to 70 miles, but then rare further inland and north. Historically, 70% of all pine harvest has been used for lumber production, with 30% used as pulpwood.

Table 3.9. Pine Inventory Trend

Region	Million Tons		Change
	2008	2016	
Eastern	14.8	18.4	24%
Northern	11.2	13.2	18%
Southern	30.2	30.2	0%
Western	9.2	9.8	7%
Total	**65.4**	**71.6**	**10%**

Landowner Type	Million Tons		Change
	2008	2016	
Lg Private	12.4	15.6	26%
Public	3.6	5.7	58%
Sm Private	49.4	50.4	2%
Total	**65.4**	**71.6**	**10%**

Pine has roughly twice the volume of aspen or cedar and represents 11% of all merchantable commercial volume. Two-thirds of the volume is in the Eastern and Southern Megaregions. Due to its coastal and southerly location, it is largely (70%) on Small Private lands. Statewide, the total pine inventory has expanded since 2008. The pace of increase is higher on Large Private lands than on Small Private, and also especially evident in the Eastern region..

Table 3.10. Pine Growth and Removals (Thousand Tons)

Annual Average for the Period 2000 - 2008

Region	Annual Growth	Annual Removals	G/R
Eastern	627	225	2.8
Northern	454	179	2.5
Southern	774	517	1.5
Western	292	293	1.0
Total	**2,146**	**1,213**	**1.8**

Landowner Type	Annual Growth	Annual Removals	G/R
Lg Private	651	254	2.6
Public	69	43	1.6
Sm Private	1,427	916	1.6
Total	**2,146**	**1,213**	**1.8**

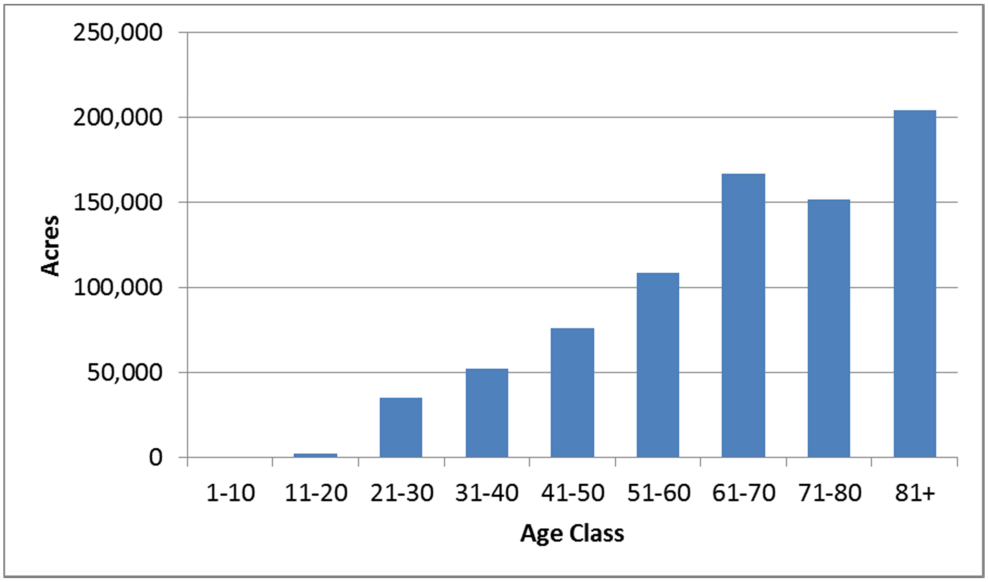
Annual Average for the Period 2008 - 2016

Region	Annual Growth	Annual Removals	G/R
Eastern	824	178	4.6
Northern	565	238	2.4
Southern	690	455	1.5
Western	244	245	1.0
Total	**2,323**	**1,116**	**2.1**

Landowner Type	Annual Growth	Annual Removals	G/R
Lg Private	776	210	3.7
Public	103	-	
Sm Private	1,444	906	1.6
Total	**2,323**	**1,116**	**2.1**

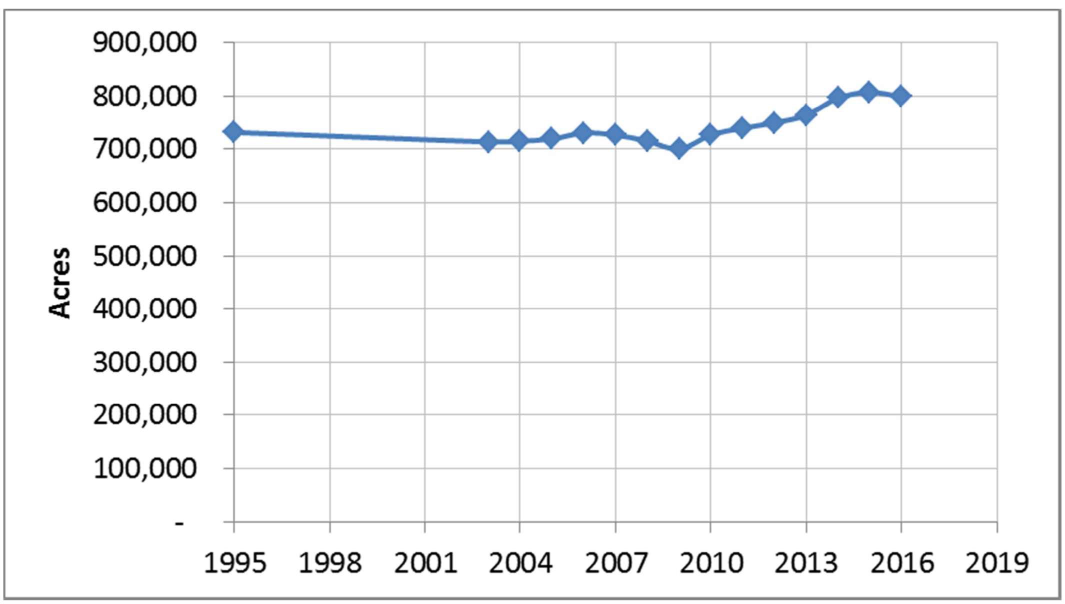
For pine, when sampling error is taken in to account, both growth and removals were essentially unchanged, and the growth/removal ratio remained in the vicinity of 2.0, which is consistent with gains in total inventory that were observed.

Figure 3.16. Age Class Distribution of Pine Forest Cover Types – All Owners



Half of the pine volume in Maine is found in stands that are classified as pine forest cover types. The remainder of the pine volume is in other softwood or hardwood stands. The age class distribution for the pine cover type is skewed to the right toward mature stands (Figure 3.16). Only 11% of the acreage is younger than age 41. Half of all trees are 16.0" or greater in diameter.

Figure 3.17. Acres of Pine Forest Cover Types Since 1995



The acreage classified as white or red pine cover type has shown some modest gains since 2008 (Figure 3.17). White pine survives to 150+ years and the increase in acreage is probably due to other species being removed or declining in proportion, leaving white pine as dominant (and sometimes as seeding shelterwoods).

Table 3.11. Pine Growth to Removals Ratio Using Estimated 2017 Removals

Annual Growth vs. Estimated 2017 Removals			
Region	**Annual Growth**	**Annual Removals**	**G/R**
Eastern	824	176	4.7
Northern	565	235	2.4
Southern	690	448	1.5
Western	244	241	1.0
Total	**2,323**	**1,100**	**2.1**

Pine is the one case where our estimate of 2017 estimated removals is very close to the FIA average for the period 2008 to 2016. Hence the comparison with growth is the same.

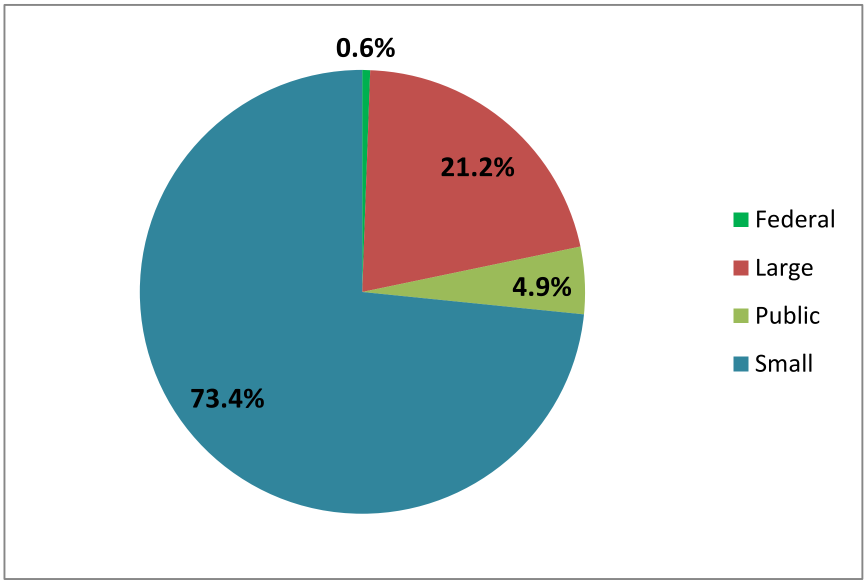
Approximately 70% of the pine volume in FIA inventory is in sawlog trees with a diameter at breast height of 11"+. Sewall discounts this down by 10% due to pulp volume likely in the tops due to weevil damage. At 60%, this indicates a potential[8] additional sustainable harvest of 734,000 tons of sawlogs and 490,000 tons of pine pulpwood.

PINE - MODELED FORWARD

In the base scenario with harvest levels equal to the estimated 2017 cut, the percentage of potential harvest of pine over the next five decade period is heavily weighted to the smaller private timberlands at 73%, with 21% from Large Private landowners, 5% off Other Public lands and less than 1% from Federal lands (Figure 3.18).

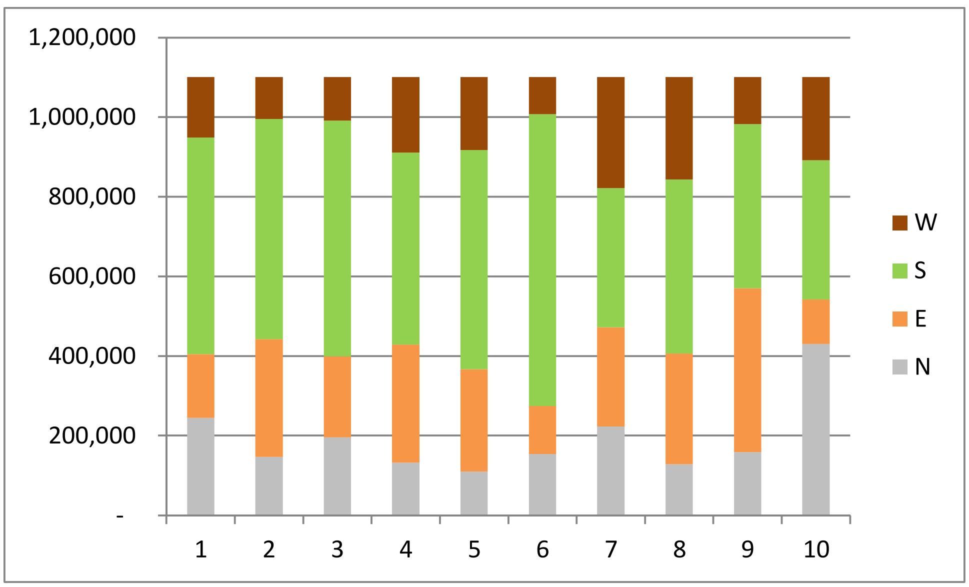
[8] Assumes all landowners would harvest the equivalent of growth.

Figure 3.18. Run1, Distribution of Average 50-year Modeled Harvest of Pine Across Landowner Types



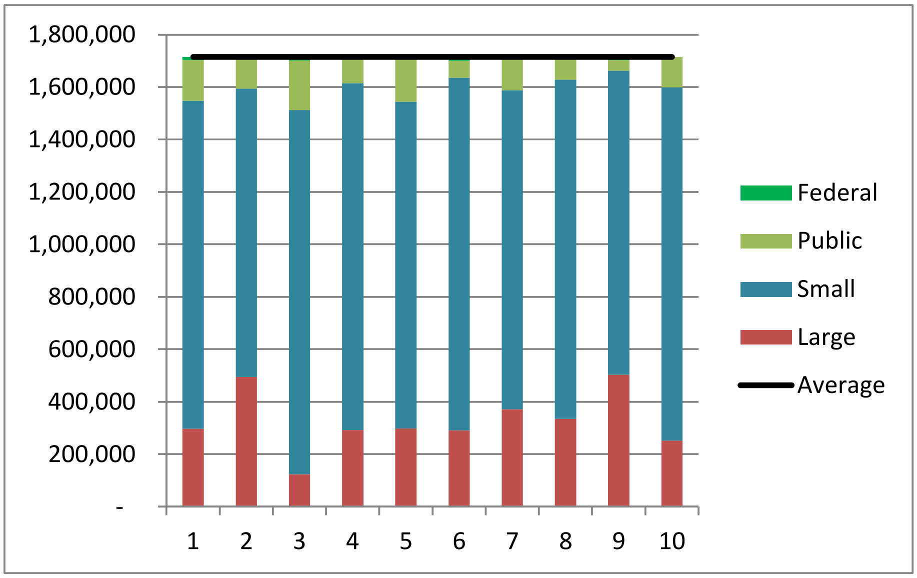
In Runs 2 and 3, these percentages remain within 1-2% of the base run.
Modeled harvest levels of 1.1 million green tons fluctuate in distribution among the megaregions (Figure 3.19), with the average 50-year harvest as follows: 45% in the Southern megaregion, 22% in the Eastern, 18% in the Northern and 15% in the Western.

Figure 3.19. Run1, 50-year Distribution of Modeled Harvest of Pine Across Megaregions



Modeled inventory of pine increases by 1.4 times the current inventory under this base scenario (harvest of 1.1 million tons/year).

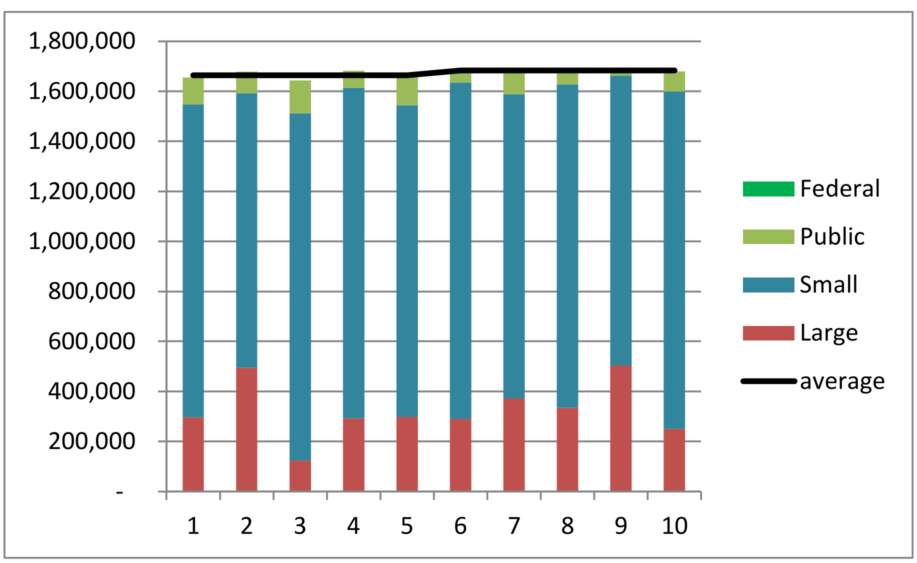
Figure 3.20. Run3, 50-year Harvest of Pine by Landowner Type



In Run3, as the model is programmed to maximize harvest in a non-declining manner than it immediately selects an annual harvest level of 1.71 million tons (Figure 3.20) and holds that through the modeled period. This biological capacity represents increases over 2017 estimated harvest levels of 56%.

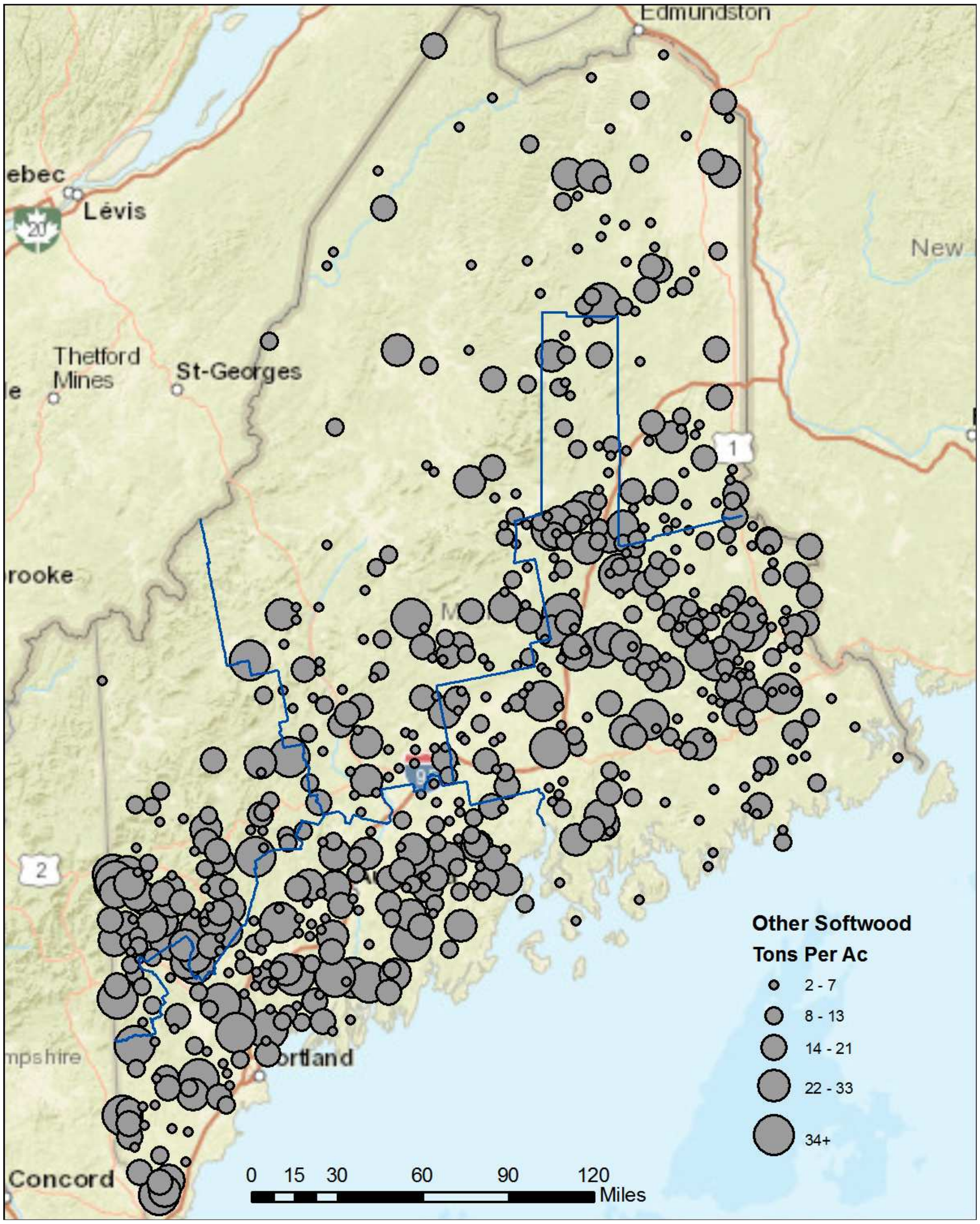
Utilizing the same discounting factors of Federal -100%, and Other Public - 30%, the model nets out to a harvest level of 1.7 million tons/year (Figure 3.21) or 150% of estimated 2017 estimated harvest levels. At this level of harvest, 76% of the volume is modeled off Small Private lands (1.27 million tons/year), so the pine availability is heavily tied to Small Private landowners' willingness to harvest.

Figure 3.21. Run3, 50-year Harvest of Pine by Landowner Type, With Discounts



OTHER SOFTWOOD (PRIMARILY HEMLOCK) – CURRENT

Figure 3.22. Other Softwood Volume Per Acre on Approximate FIA Plot Locations



The distribution of Other Softwood (92% hemlock) is similar to that of white pine, with the exception of the lower portions of the Eastern region, where it is light. The reported harvest is 83% pulpwood, with recent years' sawlog harvest at about 150,000 tons per year.

Table 3.12. Other Softwood Inventory Trend

Region	Million Tons 2008	Million Tons 2016	Change
Eastern	17.7	18.8	6%
Northern	11.2	10.5	-6%
Southern	14.9	14.8	-1%
Western	8.1	8.9	11%
Total	**51.8**	**53.0**	**2%**

Landowner Type	Million Tons 2008	Million Tons 2016	Change
Lg Private	19.5	19.8	1%
Public	2.2	3.0	41%
Sm Private	30.1	30.1	0%
Total	**51.8**	**53.0**	**2%**

Other Softwood is 92% eastern hemlock, the remainder being tamarack and larch. The inventory is essentially unchanged.

Table 3.13. Other Softwood Growth and Removals (Thousand Tons)

Annual Average for the Period 2000 - 2008

Region	Annual Growth	Annual Removals	G/R
Eastern	585	396	1.5
Northern	264	345	0.8
Southern	441	133	3.3
Western	222	74	3.0
Total	**1,512**	**948**	**1.6**

Landowner Type	Annual Growth	Annual Removals	G/R
Lg Private	565	607	0.9
Public	29	29	1.0
Sm Private	917	313	2.9
Total	**1,512**	**948**	**1.6**

Annual Average for the Period 2008 - 2016

Region	Annual Growth	Annual Removals	G/R
Eastern	700	429	1.6
Northern	206	152	1.4
Southern	462	430	1.1
Western	271	82	3.3
Total	**1,638**	**1,093**	**1.5**

Landowner Type	Annual Growth	Annual Removals	G/R
Lg Private	611	467	1.3
Public	80	20	4.1
Sm Private	947	607	1.6
Total	**1,638**	**1,093**	**1.5**

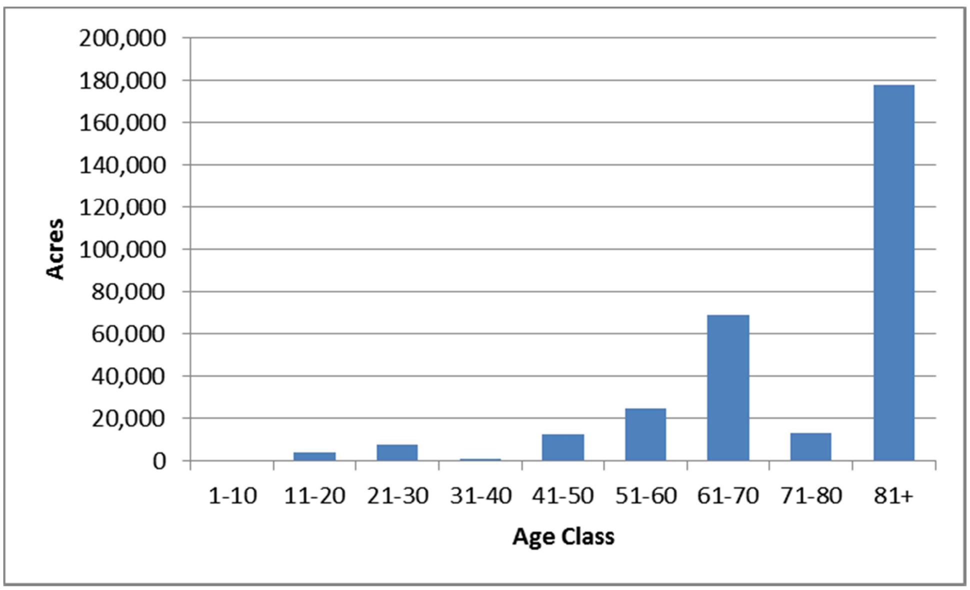
As with aspen, cedar, and pine, removals estimates for Other Softwood are subject to large sampling errors. Growth is the more reliable indicator. Annual growth was level to slightly higher, indicating a stable resource trajectory, neither expanding nor contracting.

Table 3.14. Other Softwood Growth to Removals Ratio Using Estimated 2017 Removals

Annual Growth vs. Estimated 2017 Removals			
Region	**Annual Growth**	**Annual Removals**	**G/R**
Eastern	700	295	2.4
Northern	206	104	2.0
Southern	462	295	1.6
Western	271	56	4.8
Total	**1,638**	**750**	**2.2**

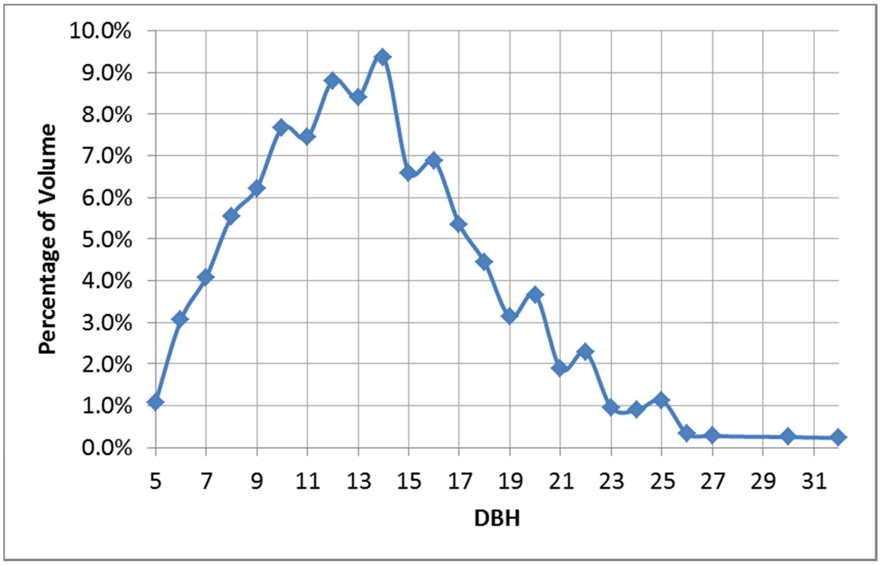
Because removals have declined recently due primarily to lower use by pulp mills, the Other Softwood resource balance is now strongly positive (Figure 3.14). Inventories will show some gains in the next decade. If all lands would be harvested at a rate equal to growth, FIA data would predict that there is a sustainable additional 888,000 tons/year available.

Figure 3.23. Age Class Distribution of Hemlock Forest Cover Type



Most of the State's Other Softwood volume occurs as a minority component of other forest cover types. Only 21% of hemlock is found in hemlock forest cover type, and often occurs in mixed stands with red spruce. The modest acreage of hemlock forest cover type is dominated by stands age 81 and older (Figure 3.23).

Figure 3.24. Hemlock Volume by Diameter Class

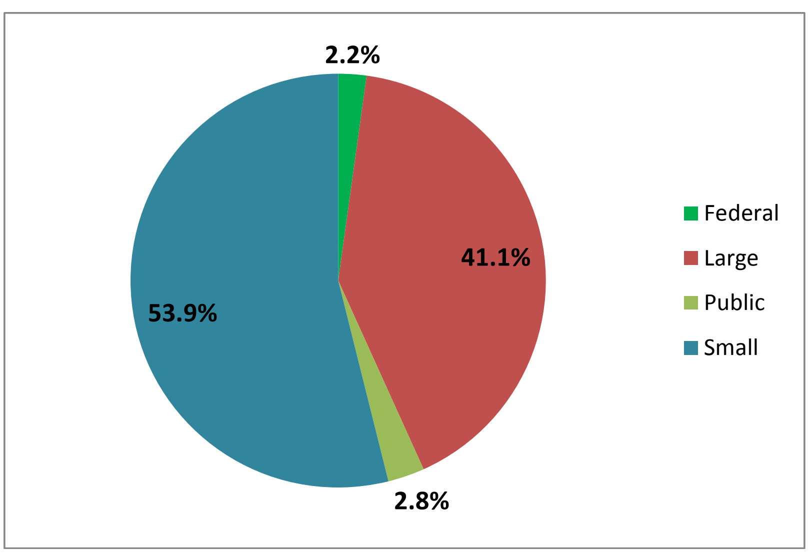


The distribution of hemlock volume is about one-third trees of 11 inches or less, one-third trees 12 to 15 inches, and one-third trees 16 inches or greater (Figure 3.24). Older, larger hemlock trees often have limited value for sawn products due to ring shake.

OTHER SOFTWOOD (PRIMARILY HEMLOCK) - MODELED FORWARD

In the base scenario with harvest levels equal to the 2017 estimated cut, the percentage of potential harvest of Other Softwood over the five decade period is weighted to the smaller private timberlands at 54%, with 41% from Large Private landowners, 3% from Other Public lands and 2% from Federal lands (Figure 3.25).

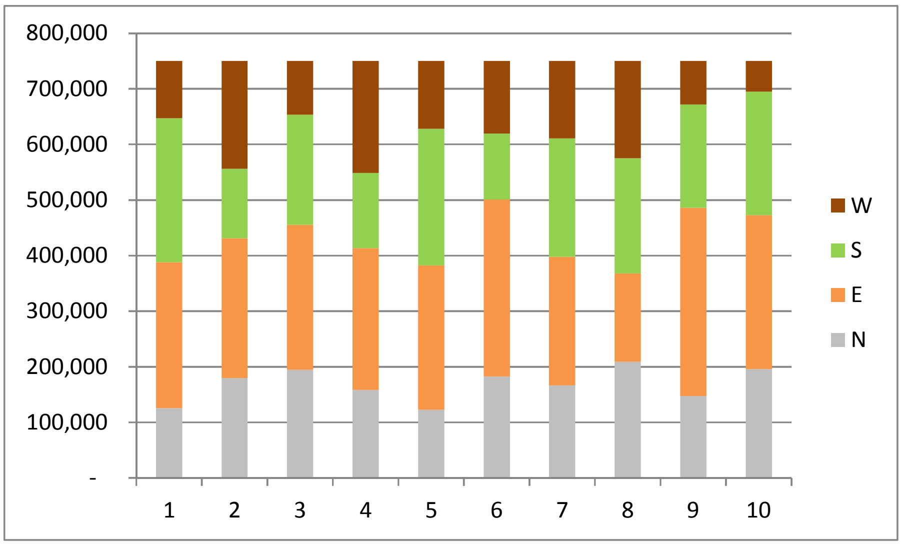
Figure 3.25. Run1, Distribution of Average 50-year Modeled Harvest of Other Softwood Across Landowner Types



In both of the runs where harvest is maximized, the percentage of Small Private harvest increases to 63% and Large Private decreases to 31-32%.

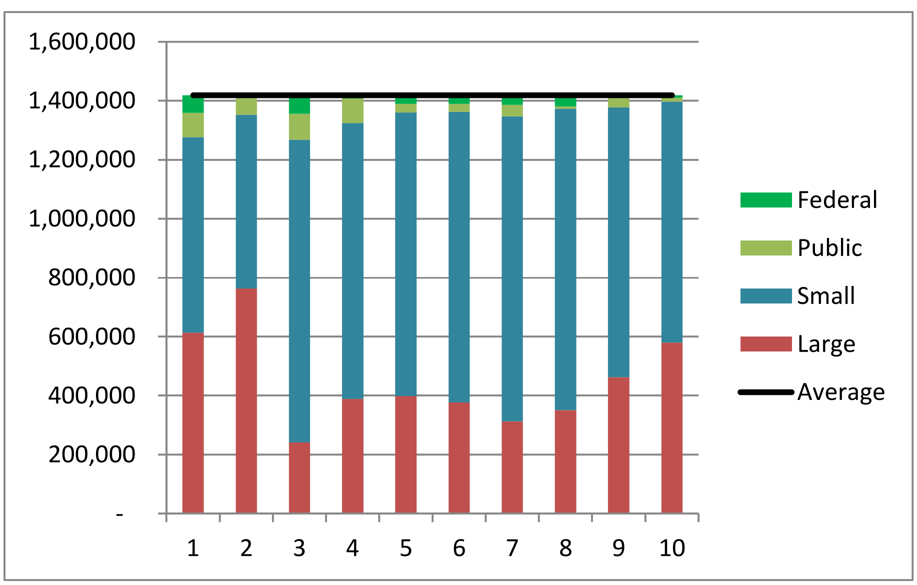
Modeled harvest levels of 750,000 green tons per year are fairly consistently distributed among the megaregions, with the average 50-year harvest as follows: 35% in the Eastern Megaregion, 26% in the Southern, 22% in the Northern and 17% in the Western (Figure 3.26).

Figure 3.26. Run1, 50-year Distribution of Modeled Harvest of Other Softwood Across Megaregions



Modeled inventory of Other Softwood increases by 36% under this base scenario (harvest level of 750,000 tons/year).

Figure 3.27. Run3, 50-year Harvest of Other Softwood by Landowner Type

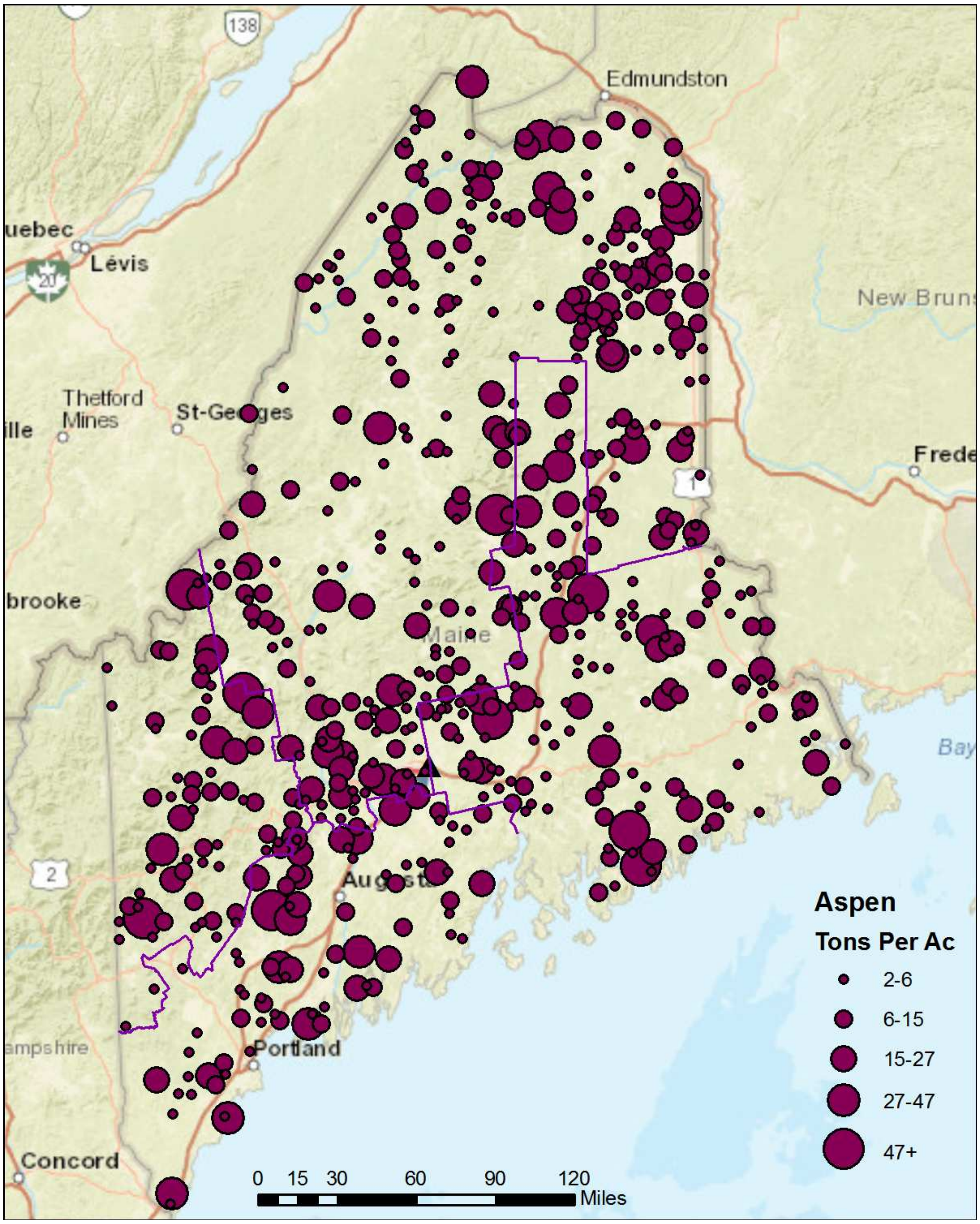


When programmed to maximize harvest in a non-declining manner (Run3 - Figure 3.27), the model selects an annual harvest level of 1.42 million tons and holds that through the study period. This biological capacity represents increases over 2017 estimated harvest levels of 89% (an additional annual volume of 670,000 tons/year).

Utilizing the discounting factors for percentage of harvestable acres that might not be available to the market over the 50-year cycle (Federal -100%, Other Public - 30%) results in an average harvest level of 1.38 million tons/year (or 84% higher than 2017 estimated harvest levels). These harvest volumes still require harvesting an average of 894,000 tons/year from Small Private lands (or more than the total 2017 estimated harvest).

ASPEN – CURRENT

Figure 3.28. Aspen Volume Per Acre on Approximate FIA Plot Locations



Aspen occurs in low concentrations across the entire State. Pure stands follow severe disturbance such as intense wildfire. A series of fires and an abandonment of farmland led to the somewhat higher density of aspen in the northern megaregion. Nearly all of the harvest volume is used as pulpwood or for oriented strand board (OSB).

Table 3.15. Aspen Inventory Trend

Region	Million Tons		Change
	2008	2016	
Eastern	7.3	7.2	-1%
Northern	15.8	15.1	-4%
Southern	4.7	5.2	10%
Western	4.6	4.4	-3%
Total	**32.4**	**31.9**	**-1%**

Landowner Type	Million Tons		Change
	2008	2016	
Lg Private	12.8	11.7	-8%
Public	1.2	1.7	36%
Sm Private	18.3	18.5	1%
Total	**32.4**	**31.9**	**-1%**

Approximately half of all aspen volume is in the Northern region, where the aspen inventory is declining. Statewide, the total volume is essentially unchanged. It is the smallest of the species groups at 4.9% of merchantable commercial volume. It is declining on Large Private lands, while stable on Small Private, and gaining on Other Public lands.

Table 3.16. Aspen Growth and Removals (Thousand Tons)

Annual Average for the Period 2000 - 2008

Region	Annual Growth	Annual Removals	G/R
Eastern	217	317	0.7
Northern	500	685	0.7
Southern	93	106	0.9
Western	100	179	0.6
Total	**909**	**1,287**	**0.7**

Landowner Type	Annual Growth	Annual Removals	G/R
Lg Private	366	650	0.6
Public	23	101	0.2
Sm Private	520	536	1.0
Total	**909**	**1,287**	**0.7**

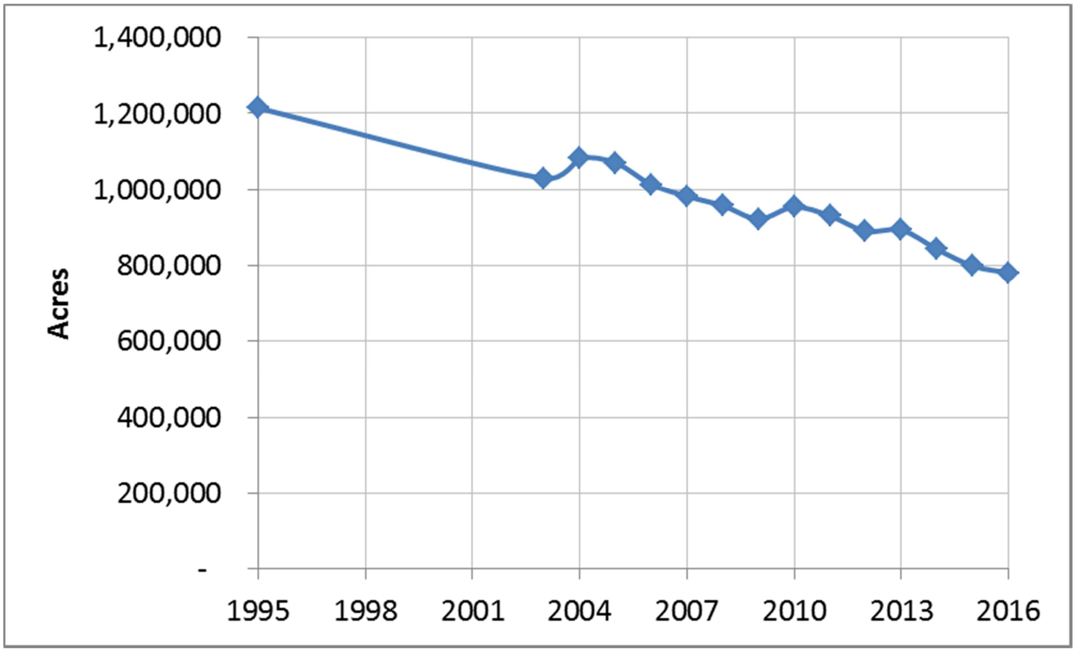
Annual Average for the Period 2008 - 2016

Region	Annual Growth	Annual Removals	G/R
Eastern	250	227	1.1
Northern	606	698	0.9
Southern	102	69	1.5
Western	157	198	0.8
Total	**1,115**	**1,192**	**0.9**

Landowner Type	Annual Growth	Annual Removals	G/R
Lg Private	455	508	0.9
Public	52	59	0.9
Sm Private	608	625	1.0
Total	**1,115**	**1,192**	**0.9**

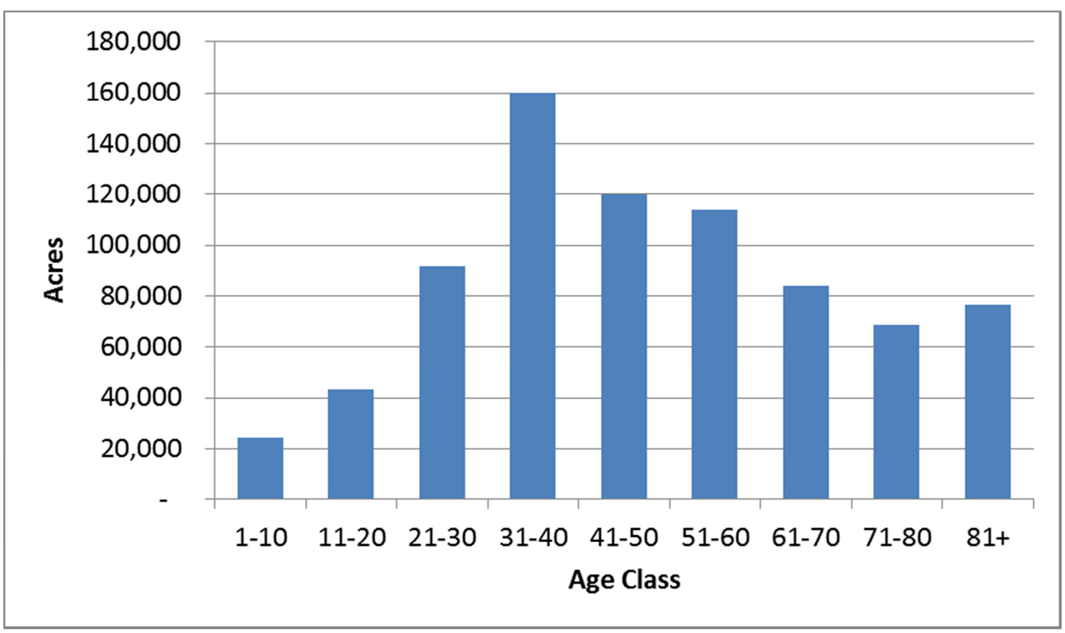
Aspen annual dynamics improved slightly, but the ratio remains below 1.0 which is consistent with level to declining inventory.

Figure 3.29. Acreage of Aspen Forest Cover Type Since 1995



The aspen forest cover type has declined since 1995 (Figure 3.29), losing about 19,000 acres per year. If the trend continues, by 2020 there will be only about 60% of the 1995 acreage remaining. Across the same time period, the *total volume* of aspen has remained fairly constant, however, in 1995, 60% of the aspen volume was in aspen stands while today 60% of the aspen volume is mixed in stands of other cover types.

Figure 3.30. Age Class Distribution of Aspen Forest Cover Type



Aspen has a weak "pipeline" of stands age 30 or younger, which make up only 20% of the acreage (Figure 3.30). The decline in the total acreage is likely to continue.

Table 3.17. Aspen Growth to Removals Ratio Using Estimated 2017 Removals

Annual Growth vs. Estimated 2017 Removals			
Region	**Annual Growth**	**Annual Removals**	**G/R**
Eastern	250	172	1.5
Northern	606	527	1.2
Southern	102	52	2.0
Western	157	149	1.1
Total	**1,115**	**900**	**1.2**

Based on the estimate of 2017 removals, the aspen growth to removals ratio is about 1.2. Absent new demand, the aspen inventory will remain constant in the near term. However, the shift from its occurrence in pure stands of aspen to a minor component of other forest cover types will continue. If all landowners harvested growth, FIA data would predict there is a mild sustainable increase of 215,000 tons available Statewide.

ASPEN - MODELED FORWARD

In all three modeled scenarios, the percentage of modeled potential harvest of aspen over the five decade period is greatest on Small Private timberlands (59-60%), then Large Private timberlands (35-36%), with 4.5-4.8% from Other Public lands and less than 0.5% from Federal lands (Figure 3.31).

Harvest levels of 900,000 green tons are modeled to come from the Northern megaregion at 49%, followed by Eastern at 22%, Southern at 16%, and lastly by the Western megaregion at 13% (Figure 3.32).

Inventory of aspen models to 111% of the current inventory if the harvest level is held at 2017 estimated levels of 900,000 tons/year.

Figure 3.31. Run1, Distribution of Average 50-year Modeled Harvest of Aspen Across Landowner Types

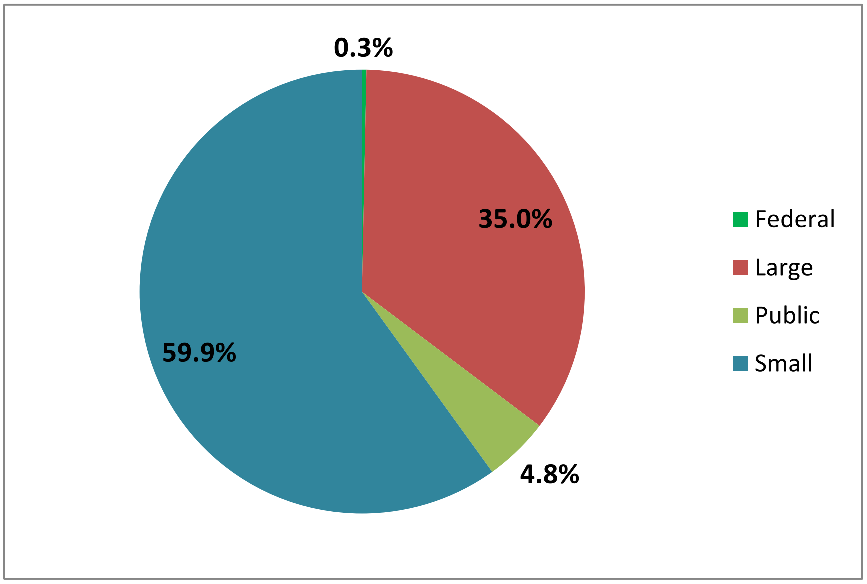


Figure 3.32. Run1, 50-year Distribution of Modeled Harvest of Aspen Across Megaregions

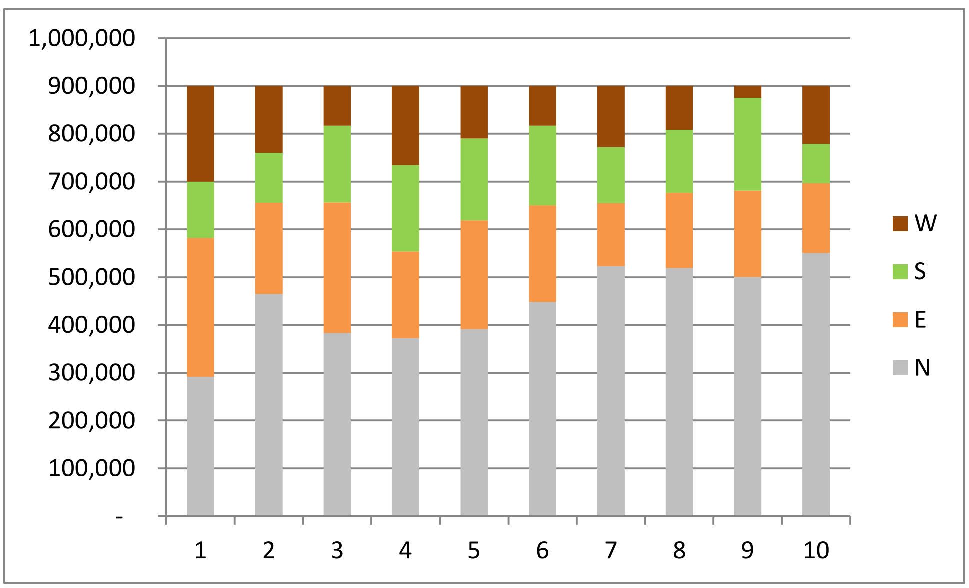
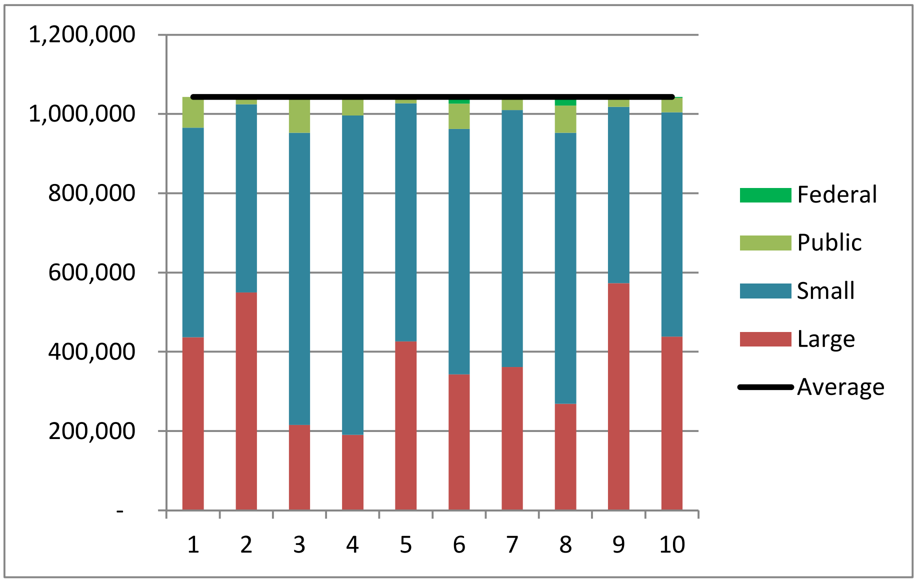


Figure 3.33. Run3, 50-year Harvest of Aspen by Landowner Type

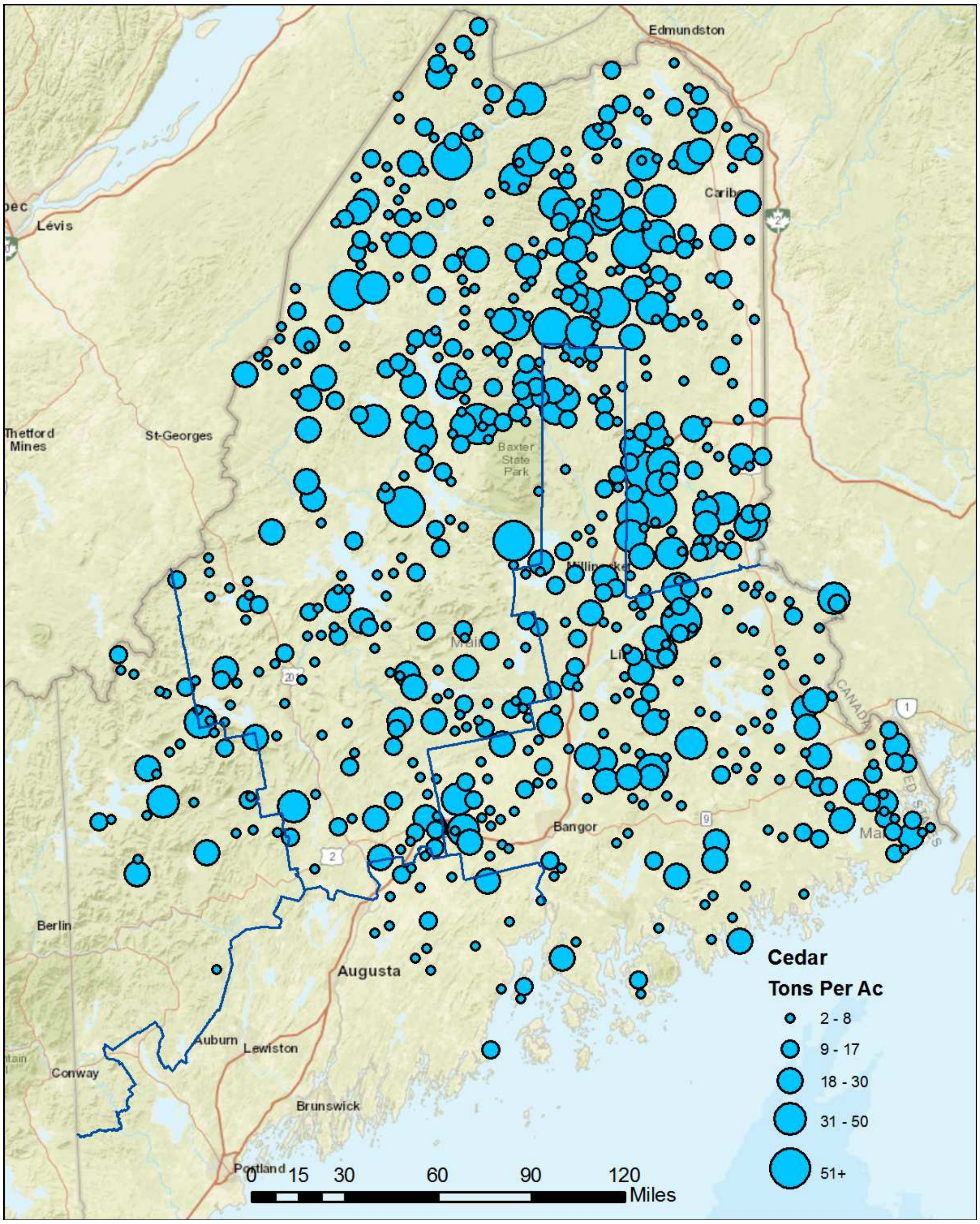


As the objective function of the model is programmed to maximize harvest in a non-declining manner (Run3 – Figure 3.33), it will select and hold a harvest rate of just over 1 million tons/year. This modeled biological capacity represents increases over 2017 estimated harvest levels, but given the statistical accuracy of the modeling we recommend thinking about it as sustainable at 2017 rates of harvest.

Utilizing the same discounting factors for percentage of harvestable acres that might be available to the market over the 50-year cycle (Federal -100%, Other Public - 30%) still allows an increased harvest level of aspen to 1 million tons/year over the next 50 years. At these discounted levels over 60% of the projected harvested aspen (611,000 tons/year) would still need to come from Small Private lands.

CEDAR – CURRENT

Figure 3.34. Cedar Volume Per Acre on Approximate FIA Plot Locations



For the most part, cedar was not observed on the FIA plots south of Augusta, and is weaker in the western portions than in the eastern. Where it occurs, it is with stands widely scattered in low concentrations. All of the harvest volume is used for specialty products (fencing, cedar homes, shingles, etc.).

Table 3.18. Cedar Inventory Trend

Region	Million Tons 2008	Million Tons 2016	Change
Eastern	10.7	10.3	-4%
Northern	26.0	24.7	-5%
Southern	0.6	0.7	14%
Western	1.5	1.5	-2%
Total	**38.8**	**37.2**	**-4%**

Landowner Type	Million Tons 2008	Million Tons 2016	Change
Lg Private	24.3	22.0	-9%
Public	2.8	4.0	40%
Sm Private	11.7	11.2	-4%
Total	**38.8**	**37.2**	**-4%**

Nearly all cedar (94%) is in the Northern and Eastern Regions, where cedar inventory is declining. The decline is more rapid on Large Private lands than on Small Private lands. Cedar barely edges out aspen as the second smallest species group in volume.

Table 3.19. Cedar Growth and Removals (Thousand Tons)

Annual Average for the Period 2000 - 2008

Region	Annual Growth	Annual Removals	G/R
Eastern	189	150	1.3
Northern	375	313	1.2
Southern	2	-	
Western	14	12	1.2
Total	**581**	**474**	**1.2**

Landowner Type	Annual Growth	Annual Removals	G/R
Lg Private	324	332	1.0
Public	40	6	6.3
Sm Private	216	136	1.6
Total	**581**	**474**	**1.2**

Annual Average for the Period 2008 - 2016

Region	Annual Growth	Annual Removals	G/R
Eastern	120	71	1.7
Northern	283	177	1.6
Southern	13	2	6.3
Western	19	38	0.5
Total	**435**	**288**	**1.5**

Landowner Type	Annual Growth	Annual Removals	G/R
Lg Private	236	175	1.3
Public	42	7	6.1
Sm Private	158	106	1.5
Total	**435**	**288**	**1.5**

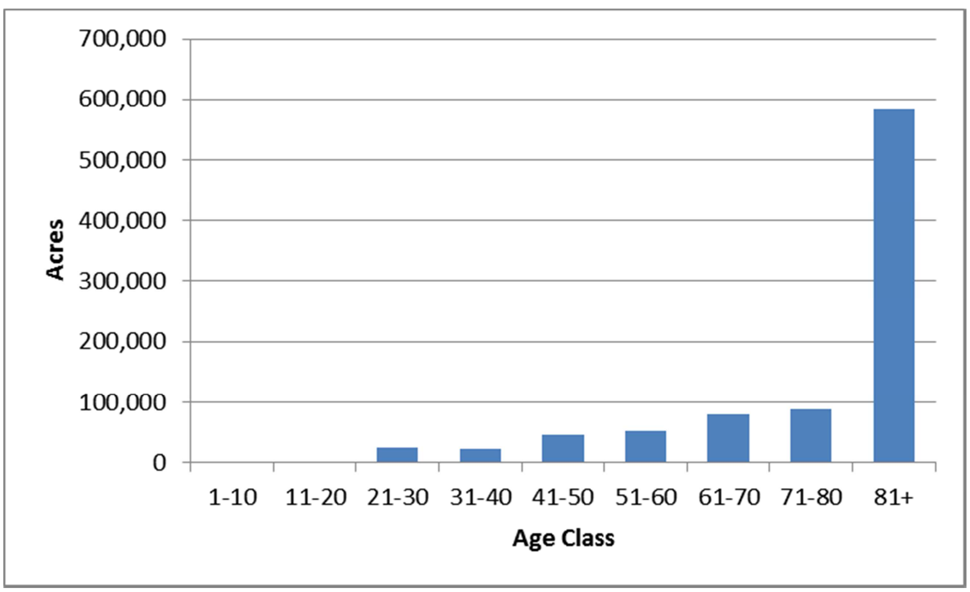
Cedar removals are so low that the FIA estimates for less than the entire State are unreliable, and as a result the growth-to-removals ratio is also statistically unreliable. Annual growth is a stronger measure, and it declined by 25%, indicating a resource that is shrinking or aging or both.

Table 3.20. Cedar Growth to Removals Ratio Using Estimated 2017 Removals

Annual Growth vs. Estimated 2017 Removals			
Region	**Annual Growth**	**Annual Removals**	**G/R**
Eastern	120	49	2.4
Northern	283	123	2.3
Southern	13	1	9.1
Western	19	27	0.7
Total	**435**	**200**	**2.2**

The current utilization of cedar is uncertain since only 30% of the FIA measured removals are reported by the Maine Forest Service[9]. Removals have shown a steady decline over time, while annual growth and total inventory have also declined. In spite of the calculated growth to removals ratio, the weight of the evidence is that the cedar will continue a gradual decline.

Figure 3.35. Age Class Distribution of Cedar Stands



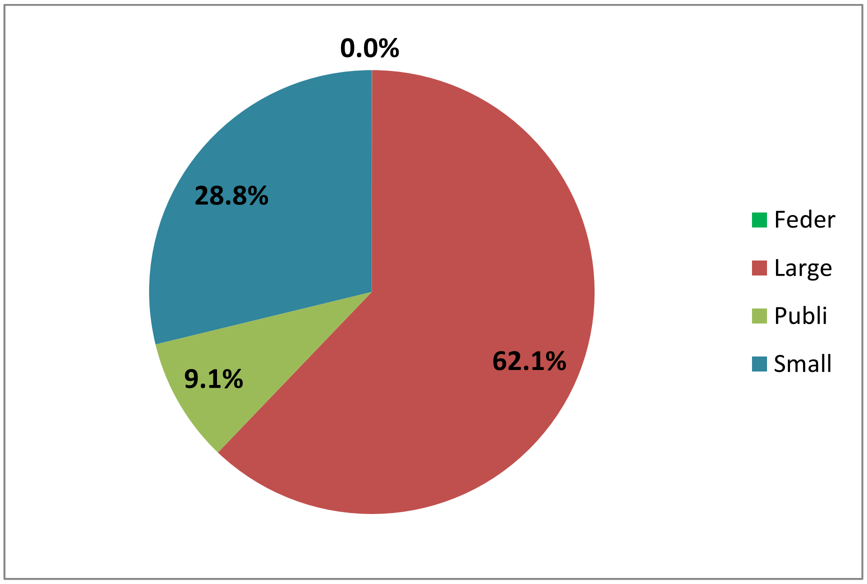
A majority (60%) of cedar volume is found in areas classified as cedar forest cover type. Nearly the entire acreage of cedar cover type has been classified as age 81 or older (Figure 3.35). No significant pipeline of younger stands exists.

[9] Figure 4.2

CEDAR - MODELED FORWARD

In the base scenario with harvest levels equal to the estimated 2017 harvest, the percentage of potential harvest of cedar over the five decade period is heavily weighted to the larger private timberlands at 62%, with 29% from Small Private landowners, 9% off Other Public lands and only 0.02% from Federal lands (Figure 3.36).

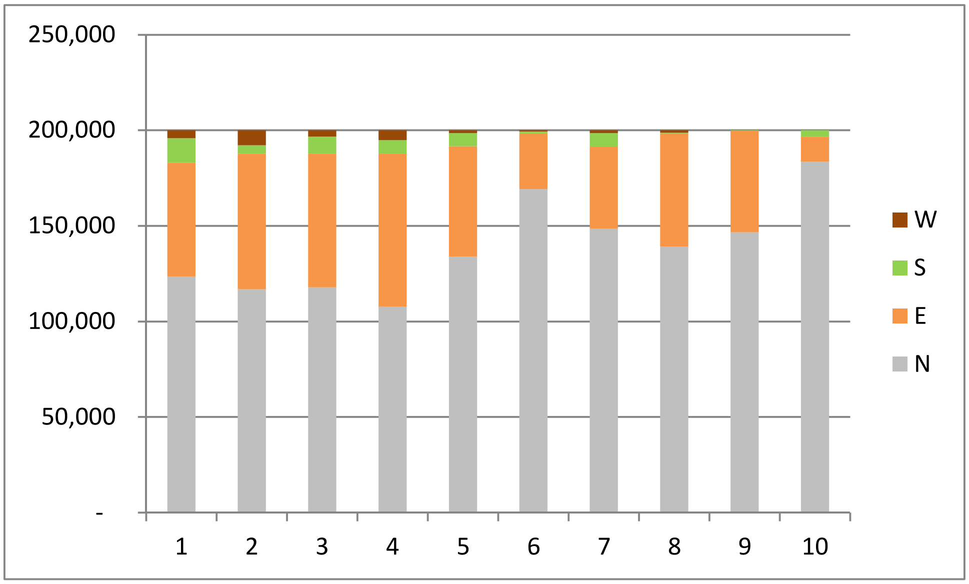
Figure 3.36. Run1, Distribution of Average 50-year Modeled Harvest of Cedar Across Landowner Types



In Runs 2 and 3, these percentages change more than any other species. Large landowner harvests fluctuate from 58% to 74%; Small Private from 19% to 36% and Other Public from 5% to 9%.

Average modeled distribution of harvest levels of 200,000 green tons are 69% in the Northern megaregion, 27% in the Eastern, 3% in the Southern and 1% in the Western (Figure 3.37).

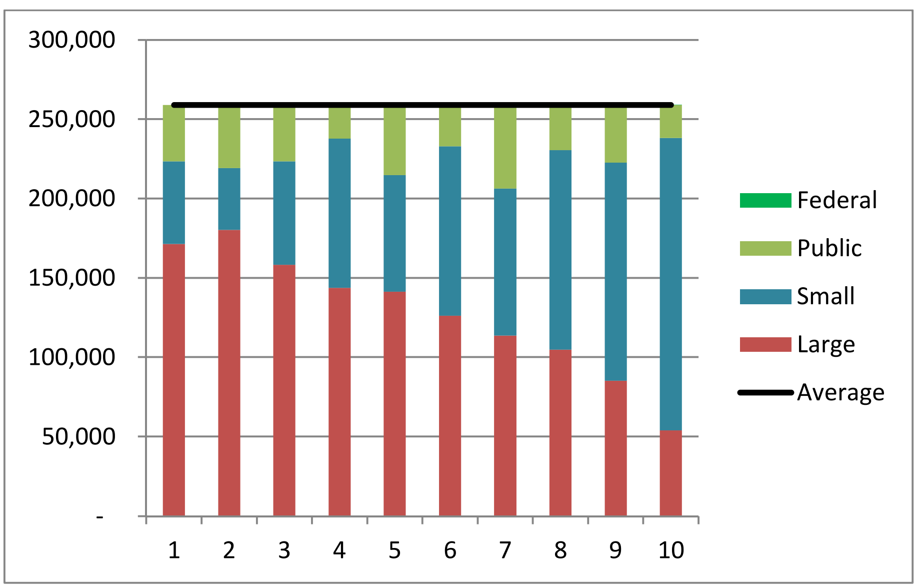
Figure 3.37. Run1, 50-year Distribution of Modeled Harvest of Cedar Across Megaregions



Inventory of cedar decreases by 5% under this base scenario.

As the model is programmed in Run3 to maximize harvest in a non-declining manner (Figure 3.38), it immediately selects an annual harvest level of 258,800 tons and holds that through the modeled study period. This biological capacity represents increases over estimated 2017 harvest levels but because of the statistical accuracy of the model we recommend thinking about it as sustainable at the present levels of harvest.

Figure 3.38. Run3, Modeled, Non-declining, 50-year Harvest of Cedar by Landowner Type



Utilizing the same discounting factors of Federal -100%, and Other Public - 30%, the model nets out to a harvest level of 250,000 tons/year. As with pine, any increase in cedar harvesting would have to involve a greater percentage of Small Private landowners over time.

4. DERIVATION OF ESTIMATED 2017 (BASE LEVEL) DEMAND

For most species groups, the Maine Forest Service Wood Processor Report (WPR) reported harvest is below the levels observed on FIA's 5-year revisited plots (table 4.1). The exception is pine; it is frankly puzzling why pine would be over-reported. It's possible that some of the survey respondents are submitting hemlock or mixed softwood purchases under the "White and Red Pine" column, or perhaps failing to distinguish volume from New Hampshire.

For aspen, WPR requests information only on pure loads. Apparently, about half of all aspen is delivered as a minor component of mixed hardwood.

Table 4.1. FIA vs. WPR[10] Harvest Levels and 2017 Harvest Estimate by Species Group

Species Group	Annual Average 2008-16		Ratio	WPR	Sewall	Notes
	FIA	WPR	WPR/FIA	2016	Estimate 2017	
Aspen	1,192	619	0.52	705	900	WPR covers only pure loads
Cedar	288	83	0.29	72	200	Both FIA and WPR are trending down
Hardwood	7,410	5,263	0.71	5,439	5,200	2017 harvest 6,200 with firewood
Other Softwood	1,093	861	0.79	612	750	Recent reductions
Pine	1,116	1,322	1.18	1,107	1,100	Not sure why greater in WPR than FIA
Spruce-fir	3,763	3,000	0.80	2,737	3,200	Recent reductions

Dense hardwood has the largest variance between FIA removals and WPR reported harvest. While there is scant data on the utilization of firewood/pellets in the State, the data points to it being somewhere between 1.0 and 1.3 million tons/year.[11] This indicates that the WPR may be under reporting firewood/pellet usage by as much as a million tons. For purposes of the modeling, Sewall utilized our best estimate of commercial usage, and made mention of the additional residential demand in the commentary.

Cedar is significantly under-reported. The difference may be smaller operators and individuals who are not included in the survey. Also, the FIA of removals estimate is weak due to sampling error on such a small resource.

With the general relationship between reported and "actual," and knowledge of very recent changes that were not fully apparent in the 2016 WPR, Sewall has proposed base level harvest rates that we believe reflect the state of the industry today. For modeling purposes, Sewall representatives made an estimate between the two data sources.

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[10] Wood Processor Report, compiled annually by the Maine Forest Service.

[11] A State Planning Office report in 1999 pegged the estimate at 1.2 million tons. Sewall estimates utilizing the 2016 US census report household data came up with between 1.0 and 1.3 million tons/year, depending on the severity of the winter.

The series of charts that follow show the history of the WPR reported harvest for each species group.

Figure 4.1. Aspen WPR Harvest Since 2000

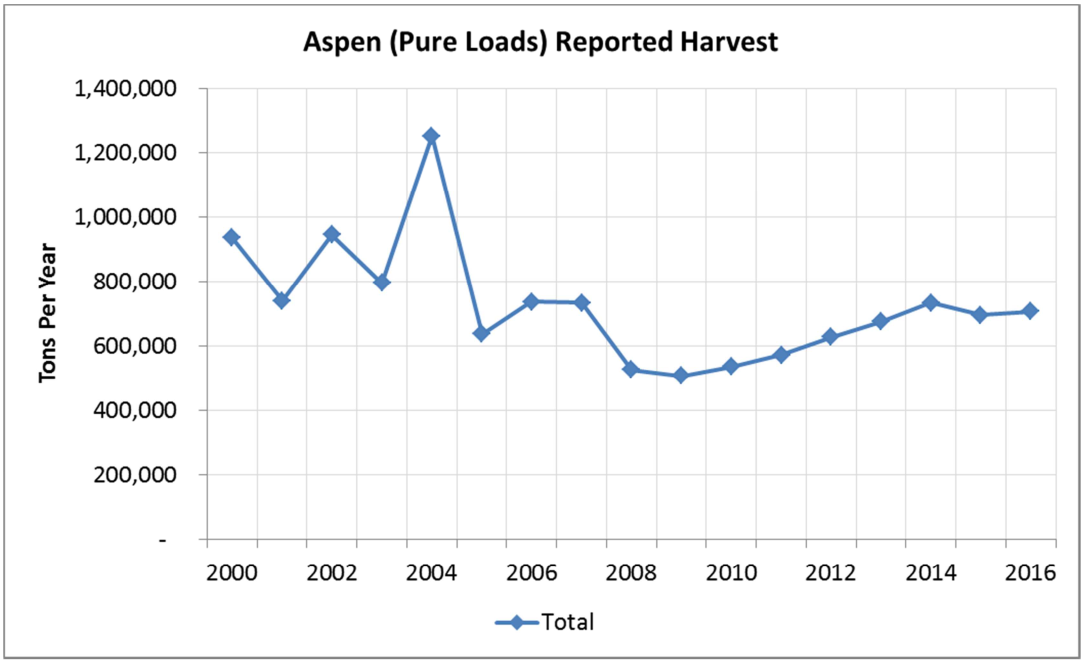


Figure 4.2. Cedar WPR Harvest Since 2000

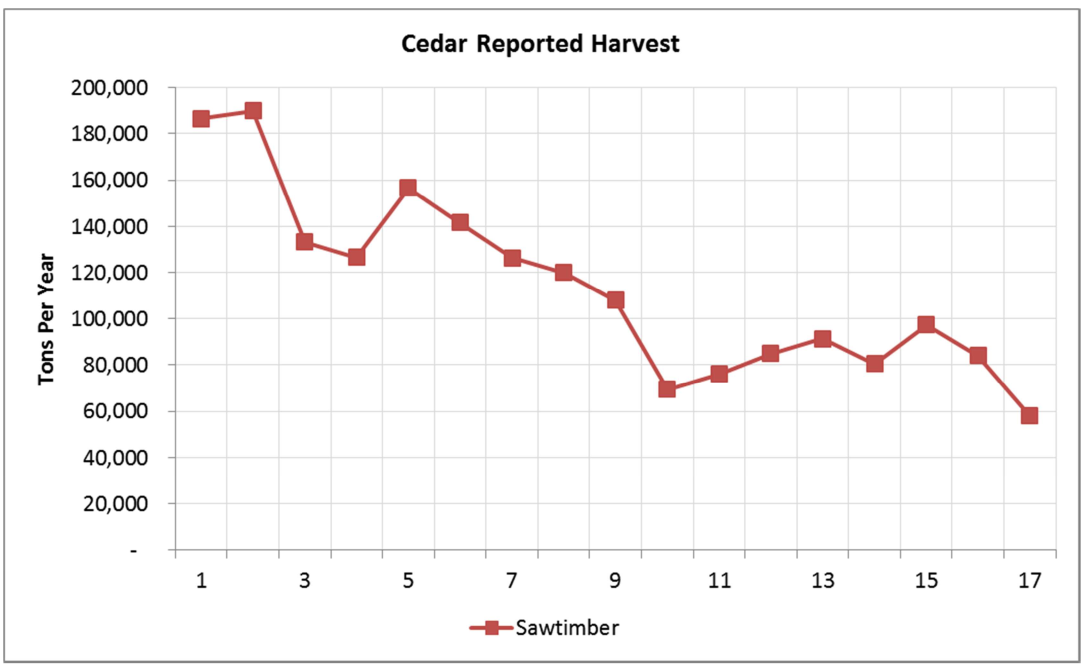


Figure 4.3. Mixed Hardwood WPR Harvest Since 2000

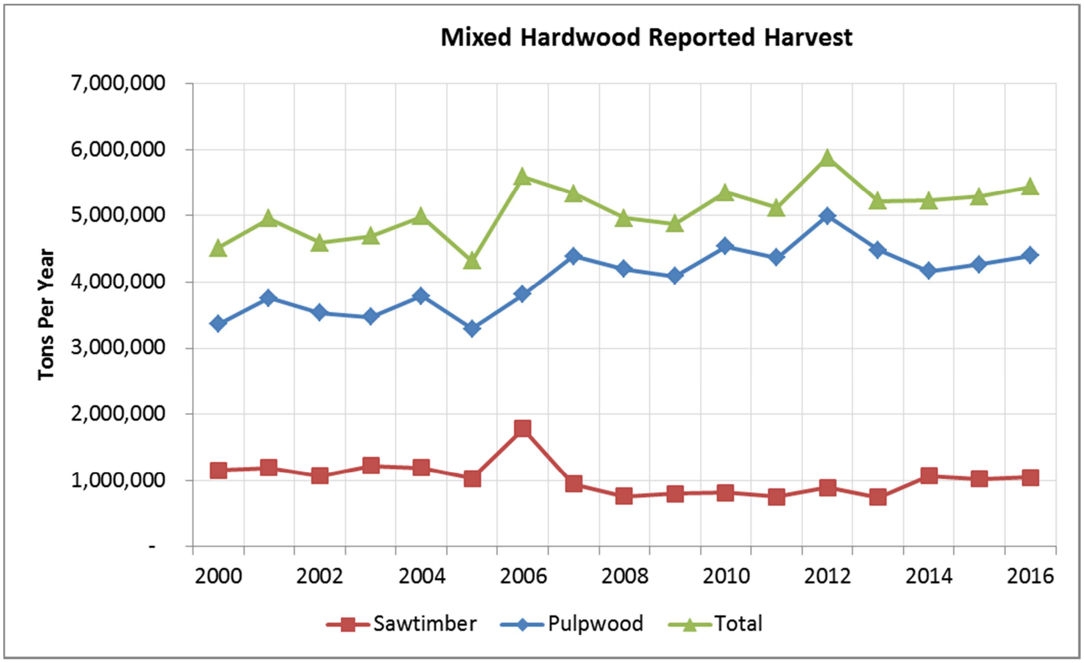


Figure 4.4. Other Softwood WPR Harvest Since 2000

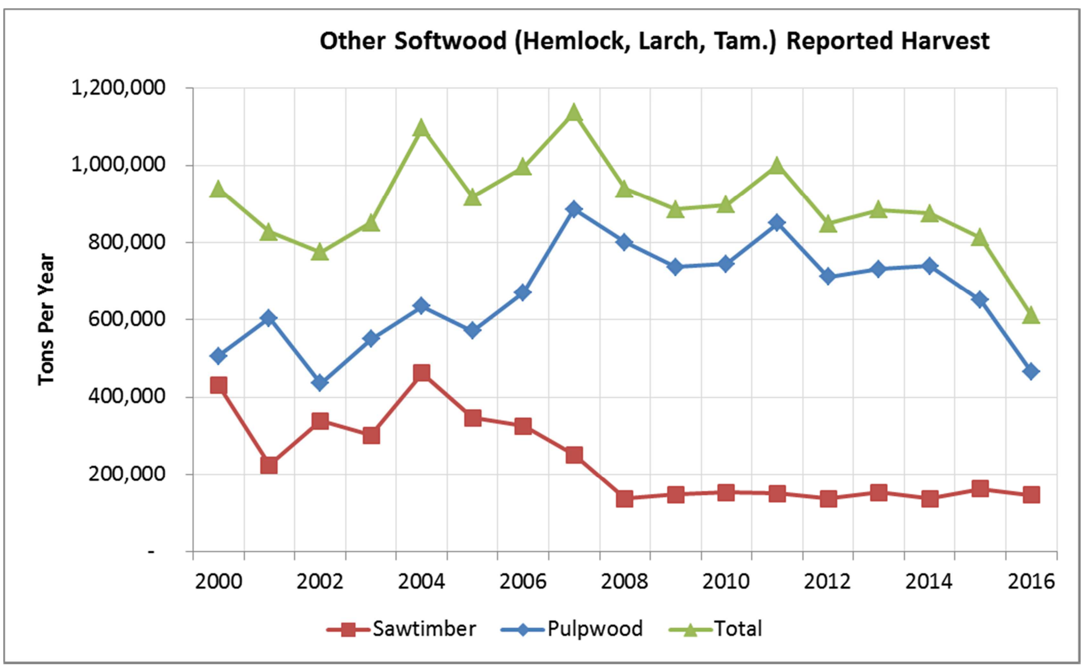


Figure 4.5. White and Red Pine WPR Harvest Since 2000

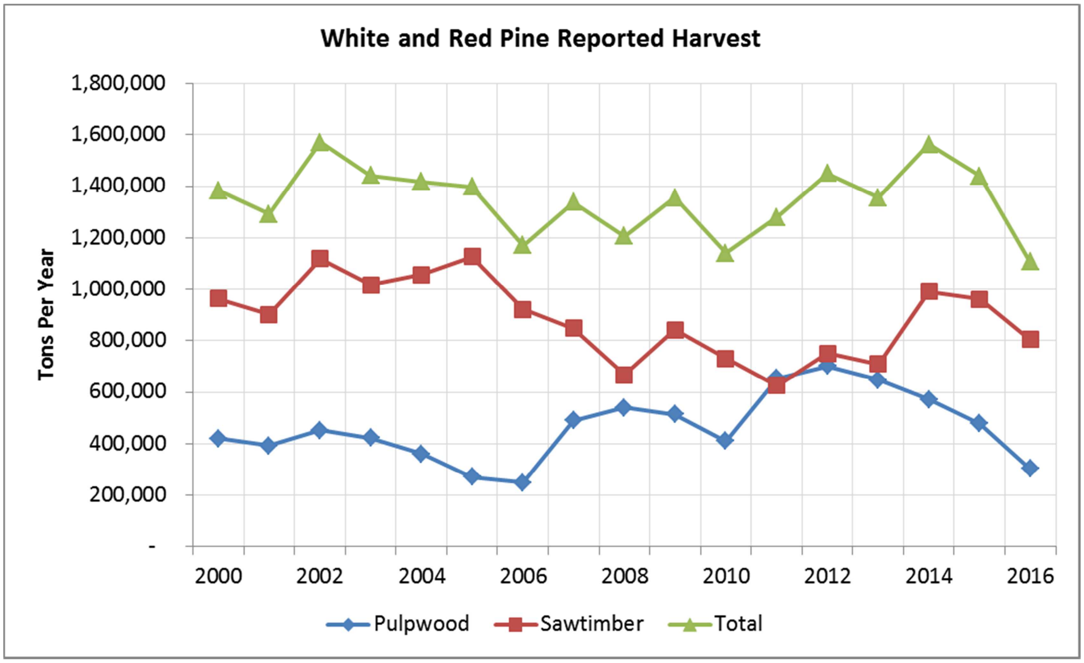
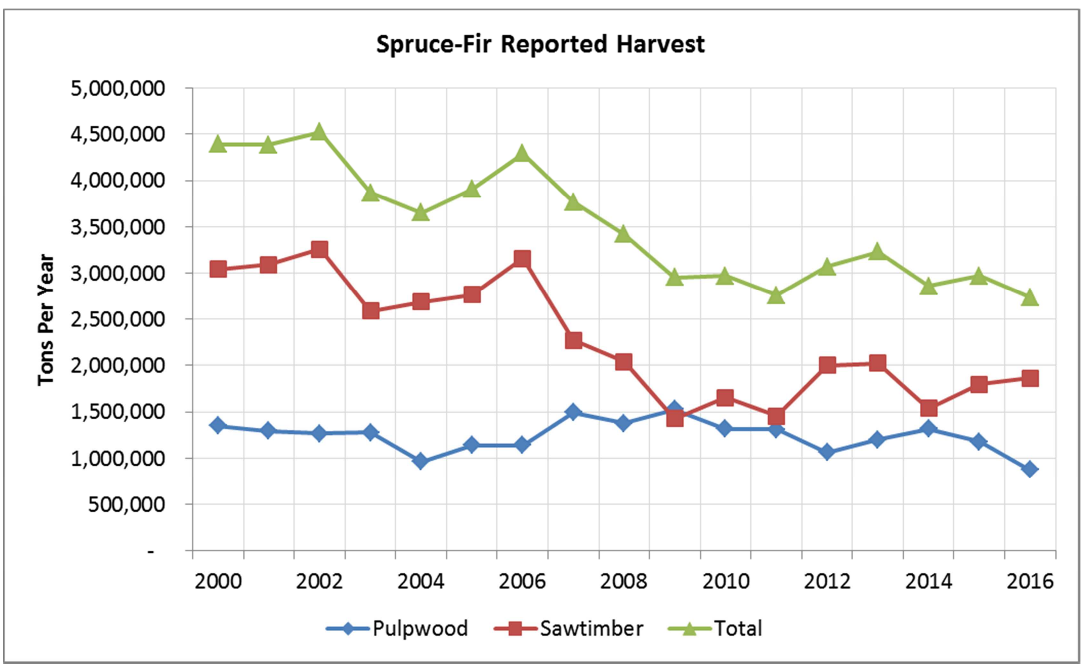


Figure 4.6. Spruce-fir WPR Harvest Since 2000



Appendix A
Modeling Assumptions

APPENDIX - MODELING ASSUMPTIONS

AREA FILE DEVELOPMENT (THEME ATTRIBUTE ASSIGNMENT)

Theme 1 – Plot/Condition. Concatenation of Plot and Condition codes to create a unique ID. 3,498 unique values.

Theme 2 – County Name.

Theme 3 – Forest type. Used FORTYPCD (algorithm based). If an assignment was not made based on FORTYPCD then FLDTYPCD was used in an effort to make an assignment.

Theme 3 Forest Type	Code	Forest type / type group
Cedar	126	Tamarack
	127	Northern white cedar
Hemlock	105	Hemlock
IntHdwd		Elm / ash / cottonwood group
	701	Black ash / American elm / red maple
	705	Sycamore / pecan / American elm
	706	Sugarberry / hackberry / elm / green ash
	707	Silver maple / American elm
	708	Red maple / lowland
		Aspen / birch group
	901	Aspen
	902	Paper birch
	903	Gray birch
	904	Balsam poplar
	905	Pin cherry
LAPlt	385	Introduced larch
NonStock	999	Nonstocked
NSPlt	384	Norway spruce
Oak		Oak / hickory group
	503	White oak / red oak / hickory
	505	Northern red oak
	514	Southern scrub oak
	516	Cherry / white ash / yellow-poplar
	517	Elm / ash / black locust
	519	Red maple / oak
OakPine		Oak / pine group
	401	Eastern white pine / northern red oak / white ash
	409	Other pine / hardwood
Pine		White / red / jack pine group
	102	Red pine
	103	Eastern white pine
	104	Eastern white pine / eastern hemlock
	167	Pitch pine
SF		Spruce / fir group
	121	Balsam fir
	122	White spruce
	123	Red spruce
	124	Red spruce / balsam fir
	125	Black spruce
TolHdwd		Maple / beech / birch group
	801	Sugar maple / beech / yellow birch
	805	Hard maple / basswood
	809	Red maple / upland

Code 962 Other Hardwoods assigned based on Field Type Code

Theme 4 – Owner Class – combination of owner code and owner size.

Owner Class	Owner Size (from Sewall)	Owner (from FIA)
Federal	Any	National Forest
Federal	Any	Dept of Defense
Federal	Any	National Forest
Federal	Any	Other Federal
LargePrivate	Large	Private
Other Public	Any	State
Other Public	Any	County and Municipal
Other Public	Any	Other local govt
SmallPrivate	Small	Private

Theme 5 – Basal area/acre class. Calculated from the plot data on all live stems 1.0"+ DBH.

Basal Area Class	Basal Area Range
VH	≥ 150
H	100 to < 150
M	60 to <100
L	30 to <60
VL	< 30

Theme 6 – Operability. If the slope code (on the plot header) was ≥ 40 then the Plot/Condition was assigned to "Inop." Else assigned to "Op." FIA plot/conditions with a slope code >= 40 were identified as inoperable. No harvest activity is allowed in inoperable. The area identified as inoperable is 229,014 acres.

Theme 7 – Status. If STORGCD = 1 then assigned to "Planted." Else "Natural."

Theme 8 – Harvest Status. Used by Woodstock to keep track of treatments. All plot/conditions assigned to "NA" at this point.

Woodstock age (5 year age class) was assigned as wk_age = INT(STDAGE/5) + 1.

Clean up items: If wk_age = 0 then wk_age = 1 (can't have age 0 in the Woodstock area file). Also if theme 3 = "NonStocked" and theme7 = "Natural" then theme 3 = "IntHdwd."

Next, excluding theme6 = "Inop," 5% of each plot/condition with theme7 = "Natural" was assigned a theme 6 value of "Zone." For zones 5% of the non-planted operable acres were assigned to zoned. In other words, none of the planted area was zoned and 5% of the remaining area were classified as zoned. This created 808,794 acres of zoned area. The zoned area could be harvested via the shelterwood system just like the operable non-zoned area, but we included a constraint that no more than 5% of the zoned area could be harvested in a 5-year period. So in the 10 period run (50 years), half of the zoned area gets harvested.
A DBF file was output for input to Woodstock.

Yield Curve Generation

We used 3 models. The models were FVS (northeast variant), Fiber, and GNY. All yield curve sets are 5-year periodic.

FVS was used for all plot/conditions where theme 5 values are not equal to"VL." Fiber was used for all plot/conditions where theme 5 = "VL" and theme 7 = "Natural." GNY was used for all plot/conditions where theme 5 = "VL" and theme 7 = "Planted."

Each plot/condition was grown separately in FVS. Data were input as 1 acre fixed radius plots with trees expanded to per acre values. Data input for the trees were trees/acre, species code, DBH, height, and tree class code (growing stock, rough cull, rotten cull). Site index and site index species were input on the plot header record. Not all plot/conditions have a site index. In the cases that site index was missing a substitution was made utilizing the weighted average site index by theme 3. The breakpoint between large and small trees was set at 5 inches.

FVS was run using 5 year reporting periods for 60 years.

Volume/basal area ratios (tons/square foot) were developed by individual species. These ratios were used to predict weight (using the predicted DBH and trees/acre) for each growing stock tree projected. Next, species were grouped into the Woodstock yield species groups and weights were summed by theme 1 (plot/condition), species group, and projection year. Yield projections were created by initializing the yield projection with the inventory value for the species group in the plot/condition, then incrementing the inventory value with the difference between predicted weights from one period to the next. This was repeated for each year of the projection. Woodstock formatted yield curve sets were created.

For the Fiber-based yield curves, individual yields by plot/condition were not made. Average weight by species group and forest type was calculated and used to initialize the yield projections. Fiber runs on file at Sewall were used to create the yield projections in the same manner as the FVS runs. That is, the difference in weight between projection years was applied to the initial weight by species group. There are 8 Fiber yield curve sets (Fiber yields were not made for theme 3 values "LAPlt,""NSPLT,",or "NonStock"). We arbitrarily assigned the beginning age of each yield set at 3 periods of age and reset the wk_age values in the area file for these classes to 3.

For the GNY projections we created 3 yield curve sets; Plant_SP (planted spruce), Plant_PI (planted pine), and Plant_LA (planted larch). The only difference between these sets is the conversion used from cubic feet to tons (we only used one GNY run to make the 3 yield sets). We used GNY projections that we had on file. We used Land Capability 7 projections.

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