PORT HAWKESBURY PAPER

STRATEGIC LONG-TERM PLAN

APPENDIX A

TIMBER SUPPLY ANALYSIS REPORT

December 2022

PREPARED BY:

ANDREA DOUCETTE, BAA, MES

SUPERINTENDENT, CERTIFICATION ENVIRONMENT OUTREACH

EXECUTIVE SUMMARY

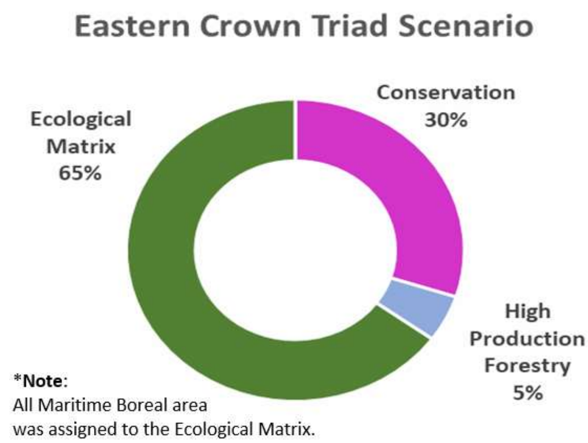
In December 2020, Port Hawkesbury Paper (PHP) and the Nova Scotia Department of Natural Resources & Renewables (NSDNRR) initiated a joint wood supply analysis for the eastern Crown land-base and PHP's Crown license area under the Forest Utilization License Agreement (FULA). The main goal of the study was to establish an updated sustainable harvest level that took new forest management guidelines from the 2018 Forestry Review (FR) process into account including a new TRIAD management model for Crown forests. The analysis' findings would also be in support of PHP's Forest Utilization License Agreement's impending renewal.

A 400,000 gmt/yr commitment to wood supply was included in the original FULA that was signed in 2012. An updated sustainable estimate of 331,000 gmt/yr was produced by the strategic forest analysis method (SFA) in 2016. Although the long-term is predicted to expand greatly in the future to over 400,000 gmt/yr, the short-term sustainable supply is projected to decline further to 275,000 gmt/yr in this latest analysis that aims to meet new forest policy. By the year 2066, the fibre supply is expected to return to approximately 400,000 gmt/yr. However, many factors could delay or hinder the projected fibre supply increases (e.g., fire, wind, area reductions, new government policy).

A portion of the short-term drop in wood supply might be attributed to changes in FULA boundary modifications that have reduced the working land-base as well as new regulations that decrease the clearcut harvest method. The new harvest limits within the operating land-base that reduce clearcutting are by far the main cause of the short-term decreases in wood supply. Most of the land-base would be maintained as ecological matrix (EM) through low, medium, or high retention harvests under the new TRIAD management strategy, with traditional clearcutting occurring only as part of high output forestry. It is important to state that the total area and locations of the high production forest lands were unknown at the time the plan was submitted to the Provincial Government. A strong commitment to each of the three TRIAD zones—Conservation, Ecological Matrix, and High Production Forestry—will be necessary for the entire concept to succeed

The initial base model was built on the NSDNRR 2016 Strategic Forest Analysis model. Six significant improvements to the functionality and structure of the base model were developed (herein called v6 base model). Numerous other alternate management scenarios were examined as part of the overall analysis, but only 15 were chosen to be reported as alternatives to the base model and sensitivity analysis for the final revision 6 model assumptions.

Given the information available at the time of the analysis, the v6 base model gradually shifted toward the group's desired strategic level forest modelling scenario. The range of policies under discussion were best addressed by the chosen scenario. Ultimately, run #1 Carbon of the Base v6 scenario, which included carbon in the objective function, was chosen as the preferred management scenario for PHP's eastern Crown lands license area.



Contents

1 INTRODUCTION

This Appendix outlines Port Hawkesbury Paper's (PHP) timber supply analysis for the forest management area (FMA) in Eastern Nova Scotia, Canada. The forest modelling component was implemented as a joint project between Port Hawkesbury Paper (PHP) and the Nova Scotia Department of Natural Resources & Renewables (NSDNRR) in 2021. A timber supply analysis in support of PHP's 100-year SFMLTP (2015-2115) was completed in 2014, which set the spruce/fir annual allowable cut (AAC) at approximately 394,000 tonnes/year. To support the renegotiation of the Crown license agreement between PHP and NSDNRR (FULA), which expired in 2022, the 2021 analysis was started to determine an updated sustainable harvest level for PHP FULA lands. This updated analysis will also feed into an updated Sustainable Forest Management Long-term Plan for PHP (100-year period from 2022 to 2122).

Additionally, new forest management strategies were created in response to the 2018 provincial forestry review process, and these strategies eventually affect sustainable harvest levels for Nova Scotia. In a perfect world, the new policies would already be in place, but many are still in the early stages with no firm release date. Given this, the analysis method will use interim guidance where available, and any results must be interpreted with consideration for the inherent uncertainty.

The idea of TRIAD management, which consists of three separate zones: Protected, Ecological Matrix (EM), and High Production Forestry (HPF), is a key component of the new strategy. The TRIAD model is a direct commitment of the Nova Scotia government for implementation on public land (Nova Scotia Government, February 2020). The protected zone for this analysis is the current status of existing and proposed protected areas. The analysis considers various zoning scenarios because the EM and HPF zones have not yet been established. The guidance from the December 2020 Draft Silvicultural Guide for the Ecological Matrix served as the basis for the EM management techniques (SGEM).

To identify a province-wide wood harvest that considers recent changes in forest policy, senior management within the Department of Natural Resources (DNR) launched the Nova Scotia Strategic Forest Analysis (SFA) in July 2016. A balanced approach that addresses wood harvest, forest wildlife habitat, and forest ecosystem objectives was the goal of the SFA. The base model with assumptions from the 2016 strategic forest analysis forms the basis for the base scenario used in this new timber supply analysis for PHP.

The team for the 2021 strategic analysis consisted of NSDNRR, PHP, and a consultant with Remsoft, the developer of the Woodstock Optimization Studio software used in this analysis:

- Joel Taylor, Forest Resources Superintendent – PHP
- Kari Easthouse, Consultant – Remsoft
- James Steenberg – Resource Analyst – NSDNRR

- Mark Hudson – Resource Analyst - NSDNRR
- Jamie Ring – Resource Analyst - NSDNRR
- Rob O'Keefe – Supervisor, Resource Analyst - NSDNRR

Existing FULA Agreement and FSC certification standards that the licensee is already required to follow were interspersed with the new management policies. A comparison of the spruce/fir harvest (000's gmt/yr) from the 2012 FULA agreement, the 2016 strategic forest analysis, and the 2021 eastern Crown area preferred scenario is shown in Figure 1 below.

Must of this summary analysis is based on NSDNRR's summary analysis report for the eastern Crown land-base (2021b), which was completed after the modeling work was finalized. This Appendix should be viewed in conjunction with the Data Package Appendix.

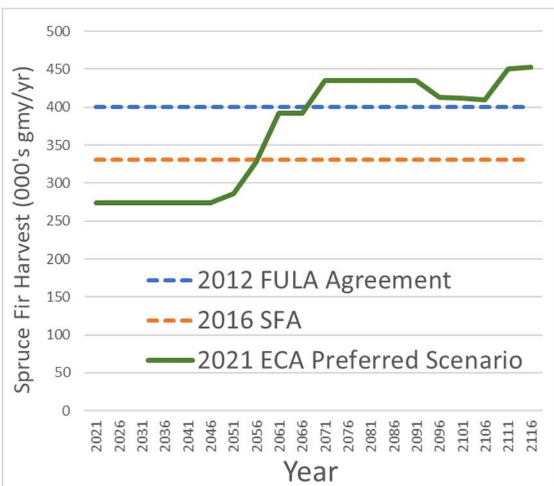


Figure 1. Comparison of Wood Supply Estimates for PHP FULA Lands

2 LAND BASE DESCRIPTION

2.1 Location

PHP's FMA is located in the seven eastern counties of Nova Scotia. The geographic extent of the FMA is shown in Figure 2. Currently, the company manages approximately 510,000 hectares of Crown land under FULA for the provincial government. The land-base classification (netdown) is shown in Table 1 below.

In addition to the Crown lands under forest management, the FMA also contains Crown wilderness areas that total approximately 108,000 ha. These lands are protected but contribute to non-timber values in the forest model. Contributing to the wood basket along with the Crown FULA lands are available unlicensed Crown in the Eastern region (as well as Pictou County) as approved by the Nova Scotia Department of Natural Resources & Renewables. Crown wood in central (excluding Pictou) and western Nova Scotia are not sources of wood for PHP. The company also relies on procuring sustainably managed fibre from small private woodlot owners through short-term stumpage leases or from private suppliers, and large industrial forest companies.

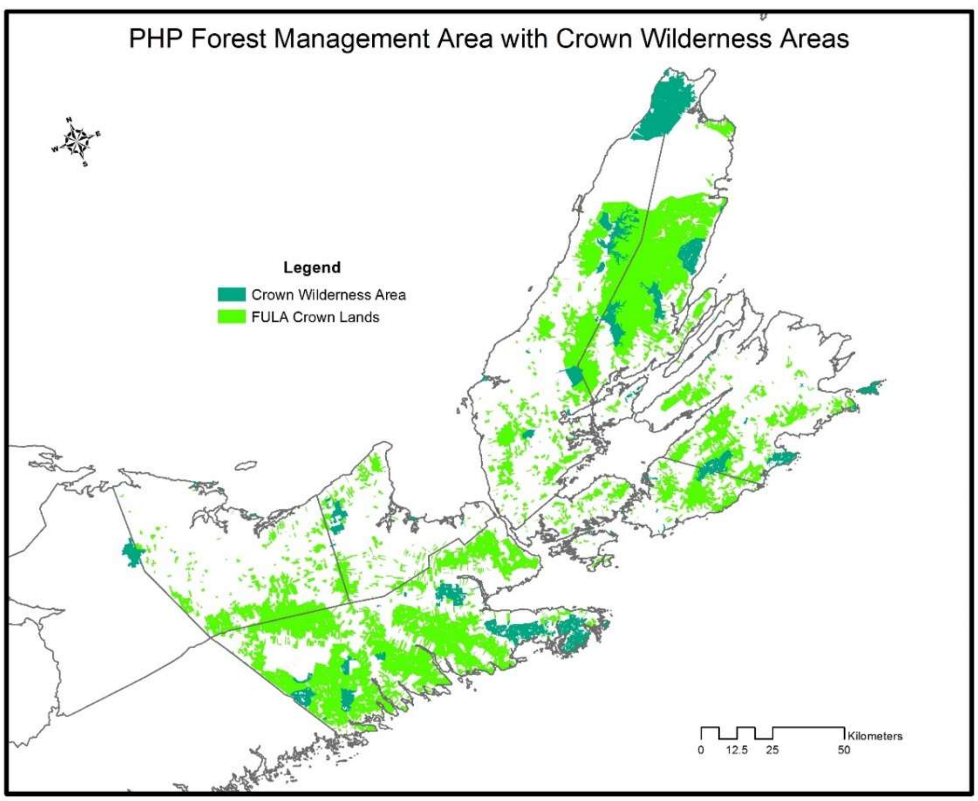


Figure 2. PHP Forest Management Area

2.2 Land-base Netdown Process

The land-base netdown process begins with the land base's gross area and gradually reduces it in accordance with certain classification criteria. The Appendix B: Data Package contains a detailed description of all the assumptions and data that were used in the analysis. Area is systematically eliminated by the netdown in order to create a base for a productive forest with timber harvesting. The area reduced under each netdown category, as well as the present and projected productive forest with timber harvesting, are shown in Table 1.

The land-base was assembled using the photo interpreted forest inventory flown in 2008 and 2009 as a base. Historic treatment shapefiles were incorporated from PHP and NSDNR databases to update the spatial boundaries and attributes of the forest inventory. Wildlife habitat, ecosystem data, special management layers, and hydrology and roads layers were compared, agreed upon and amalgamated where appropriate to create the most recent and accurate dataset possible (NSDNRR, 2021b).

As land-base layers are overlaid, attributes are coded to allow for partitioning of results based on forest and non-forest values. The total land area includes all area, crown wilderness area and non-forested land are removed to create the forested land-base. After removing permanent exclusions (off limits to forest management prescriptions), the remainder is the working land-base which contributes to wood supply. The working land-base is largely occupied by special management lands, which dictate treatment prescription details (NSDNRR, 2021b).

Table 1 – Land-base Netdown for PHP License Area

Analysis Unit: Eastern Crown: PHP License Area					
Land-base Category					**Area(ha)[1]**
1 Total Land Area					**510,342**
1.a Non-Forested Land	83,004				
2 Forested Land-base (FLB)	**[gTLB]**	**[gFLB]**	**[nFLB]**		**427,338**
2.a.1 Existing Protected Area	44,046	37,655	37,655		
2.a.2 Proposed Protected Area	28,440	22,672	22,672		
2.b.1 DNR Lynx Habitat Buffers	24,296	23,840	18,904		
2.b.2 DNR Moose Habitat Buffers	12,653	12,199	10,857		
2.b.3 Coastal Plains Flora Buffers	136	132	103		
2.b.4 Boreal Felt Lichen Buffers	6,809	5,157	3,966		
2.b.5 Other Special Site Habitat	1,166	858	562		
2.c DNR Old Growth Policy	40,707	40,587	9,207		
2.d Inoperable/Subjective Removals	36,777	34,260	19,545		
2.e Other Regional Harvest Exclusions	2,235	2,179	1,396		
2.f Aboriginal Offered Lands	100	99	6		
2.g.1 Regulation Watercourse Buffers (20m)	32,936	32,031	12,039		
2.g.2 Main River Watercourse Buffers (100m) (Crown)	103	102	64		

2.g.3 Non-Watercourse Open Bog Buffers (20m) (Crown)	1,932	1,897	522		
2.h Sensitive Forest Groups (Crown)	5,428	5,378	5,378		
2.i Draft IPCA (Crown)	6,655	5,917	2,986		
2 FLB Exclusions Sub-Total			***145,861***		
3 Working Land-base (WLB)	**[gTLB]**	**[gFLB]**	**[nFLB]**	**[nWLB]**	**281,477**
3.a.1 Non-Watercourse Treed Bog Buffers (20m) (Crown)	10,590	10,456	4,839	4,839	
3.b.1 Marten Patches	23,163	21,267	9,271	9,232	
3.b.2 Deer Wintering Areas	21,581	17,531	10,761	10,591	
3.b.3 Mainland Moose Concentration Areas	199,237	164,334	121,116	110,772	
3.b.4 Wood Turtle Habitat	4,418	3,892	2,332	295	
3.b.5 BFL Habitat buffers 200-500m	27,281	21,565	13,705	6,968	
3.b.6 BFL Bicknell's Thrush Habitat Areas	68,006	52,998	34,728	33,491	
3.c Rare Ecosections	25,156	17,812	10,962	3,430	
3.d Protected Areas 100m Buffer	12,573	10,862	8,373	2,403	
3.e Corridors	44,559	36,717	21,465	6,309	
3.f PHP Watershed (Margaree/St. Mary’s)	90,599	79,844	58,802	8,073	
3.g IRM - C2 Areas	267,547	224,939	129,115	40,934	
3 WLB Restrictions Sub-Total				***237,338***	
4 WLB No Restrictions					**44,139**
			NSCLFM Land-base2021v1a		

[1] All area statistics exclude water

[2] TLB, FLB and WLB were prefaced with 'g' indicating total intersect area and 'n' indicating intersect area after previous

The above table uses the following area statistics for exclusion category description (NSDNRR, 2021b):

- **gTLB: Gross Total Land-base:** This category reports the total land-base area contained inside the whole exclusion category, excluding any overlap with other exclusion categories. The gTLB statistic does not include any inland water body area.
- **gFLB: Gross Forested Land-base:** Only the forested area that falls within the exclusion category's boundaries is reported in this area statistic. What is or is not regarded to be forested is determined using data from the forest inventory. The [fornon] and [species] attributes from the photo-interpreted forest inventory are used to form the rules for classifying forested land-bases. A stand is regarded as being a part of the forested land-base if it has a valid [species] label or, in the absence of a [species] label, a [fornon] code indicating the potential to become a forest stand in the future. The loss of land for roads and trails that were not included in the main forest inventory is one exception.
- **nFLB: Net Forested Land-base:** The forested area inside the exclusion category's boundaries that hasn't already been taken into consideration by earlier exclusion categories is reported by this area statistic. Since there is no double counting in the nFLB area, these areas can be added to get accurate totals.

- **nWLB: Potential Working Land-base:** The forested area inside the exclusion category's boundaries that does not overlap with any other exclusion categories is reported by this area statistic. The nWLB offers a way to evaluate potential benefits to the working land-base that come with eliminating any particular exclusion category. Since they are category-specific, it is impossible to sum them up without first addressing any overlap between newly released categories.

Figure 3 shows the distribution of these categories within the forest management area by total land area available.

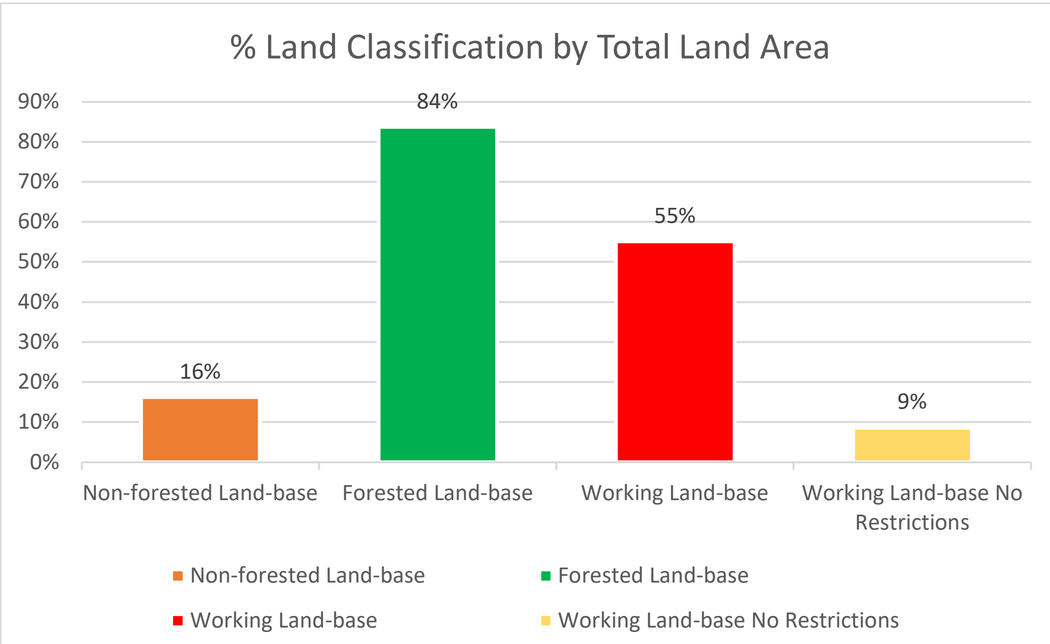


Figure 3. Percent Land Classification by Total Land Area

Even though the strategic forest model makes use of the complete forested land-base (FLB), only a fraction of this, known as the "working land-base," is available for scheduling forest management operations (WLB). The complete FLB is not included in the working land-base due to numerous operational and policy requirements (i.e., protected areas, old forest policy, wildlife habitat buffers, watercourse buffers, inoperable stands, etc.).

2.3 Base Forest Inventory

The Nova Scotia forest inventory serves as the main information layer describing the state of the forests. This is a continuous map of all the province's forest and non-forest stands. Aerial photography is flown, and the resulting photos are scaled down to 1:10,000 using a photo translator. The inventory is intended to be updated every ten years, with roughly 10% of the province being flown annually. The photo years for the forest inventory in PHP's forest management area range from 2007 to 2009 (NSDNRR, 2021b).

The photo year is utilised to age all of the forested stands to 2021 for strategic modelling. It's important to note that forest interpretation could be four to 26 years old. To make up for this, the ages are raised such that each stand now has a common year. The wider the age disparity, the more uncertainty this ageing process adds into the initial inventory (NSDNRR, 2021b).

Stand disturbance events like harvest, fire, or insect that significantly change stand development are the biggest risk associated with older inventory. Depletion updates are implemented in the land-base classification process to reduce this risk. To place forests on updated development trajectories, extra data is needed to overrule the data from picture interpretation. The following were some of the main sources of depletion data used to compile the 2021 PHP strategic model:

- Registry of Buyers Harvest and Silviculture Records
- Records of Crown Land Silviculture and Harvest
- Harvest Tracking System Data from FPDat
- Updated satellite data

In general, the highest level of assurance that harvest depletions are recorded would be found in the Crown land records. The Registry of Buyers records are the main source of updated information for private land. Clearcut harvest is not recorded in this dataset, even though it may be assumed from provided follow-up actions like planting and pre-commercial thinning. The actual harvest date would still be 7–15 years away. The holes on private are filled by satellite updates (NSDNRR, 2021b).

3 MODELING ASSUMPTIONS

The assumptions the analysis group decided were necessary to build a model under a TRIAD management system that handles as many of the new policies as was practicable given the timelines are discussed in more detail in the sections that follows. This is not a blueprint for new legislation; rather, it represents the analytic team's viewpoints considering their objective. Most of the policy direction the team was working with was in draft form. Some policy elements, such Environmental Assessment and Natural Disturbance Regime, were mentioned as secondary factors even though they weren't directly addressed in the analysis. The key pieces of policy that were considered in this research are listed below:

- High Production Forestry
- Ecological Matrix
- Forest Carbon
- Climate Change
- Ecosystem Based Management (EBM)
- Wildlife Habitats
- Silviculture Budgets (NSDNRR, 2021b)

3.1 High Production Forestry Assumptions

In the Triad system, High Production Forests (HPF) are a crucial zone. Many Nova Scotians depend on the production of primary and secondary forest products for their livelihood, and in some communities, it is a substantial economic driver that sustains a large number of direct and indirect jobs and services. The high yields anticipated from HPF will contribute to ensuring that there is a sufficient supply of timber to maintain the economy and jobs, and they will partially make up for the reduction in the supply of timber in the ecological matrix zone's lower management intensity (Nova Scotia Government, 2020).

There are currently two main DNRR assumptions associated with the HPF zone with long-term forest management planning:

1. The market demand for forest products is the subject of the first assumption. Spruce sawlogs and studwood are currently perceived as the top value softwood forest product markets in Nova Scotia (i.e. saw timber or sawables). To produce high yields of spruce saw wood products, HPF is being developed. Markets can change over time, and HPF species strategies may need to be modified to account for those changes if the market demand changes from spruce sawlogs and studwood to another species/product. Within the ecological matrix zone, it is anticipated that additional high-value goods will be generated, such as hardwood and pine logs.
2. The second assumption is that the use of non-native spruce species, fertilisers, and herbicides in the creation and upkeep of highly productive plantations will be included in the scope of permissible silvicultural equipment and activities on Crown land classified as HPF. (Nova Scotia Government, 2020).

The HPF zones have not yet been spatially identified, however, there is a set list of suitability criteria that would be removed from a potential HPF zone (NSDNRR, 2021b). These include:

- Rare/High landuse pressure ecosections
- Maritime boreal ecosites
- Biodiversity Sensitive Forest Groups
- Low (spruce) productivity ecosites
- Marginal productivity sites unsuitable for HPF
- Tolerant hardwood & mixedwood / Intolerant hardwood on rich sites
- Extreme wind exposure

With adequate tree development, nutrient management, and silviculture techniques, the targeted productivity levels in the HPF area are in the range of 7m3/ha/yr. The proposed suitable area for HPF is mostly ecosites AC10/11. The Nova Scotia Growth and Yield (NSGNY) model was used to forecast yields, and regional best practices served as prescriptions. The general activity sequencing for HPF from site preparation all the way through to final harvest is shown in the below table (NSDNRR, 2021b).

Table 2. HPF General Activity Sequencing

	Site Prep / Soil Amendment	Plant	Competition Control (Herbicide)	Cleaning (PCT)	CT 1 (*opt)	CT 2 (*opt)	Final Harvest
Timing (yr)	0	1	~3	~8	~25	~35	35-50
Costs Est. $/ha	300/500	600	125	400	550	550	--

Source: NSDNRR, 2021b.

The options for planted species are either red spruce, white spruce, or Norway spruce. The commercial thinning options were created to control final harvest piece-size objectives. Using the Nova Scotia Growth and Yield model, the assumptions used for base parameter plantation yields in HPF are:

- Site index gains based on 2nd generation tree improvement gains
- Planted spacing at 2.4 meter spacing (1736 stems/ha)
- 85% establishment stocking of planted species
- Commercial thinning is a 30% basal area removal – thinning from below with first entry removing an additional 10% for roads
- Merchantable volume segmented into pulpwood, studwood, and sawlog product estimates

Yields and activities in the HPF were modeled through a regime formulation with prescriptions to cover a range of species, commercial thinnings, and final harvest timings (NSDNRR, 2021b).

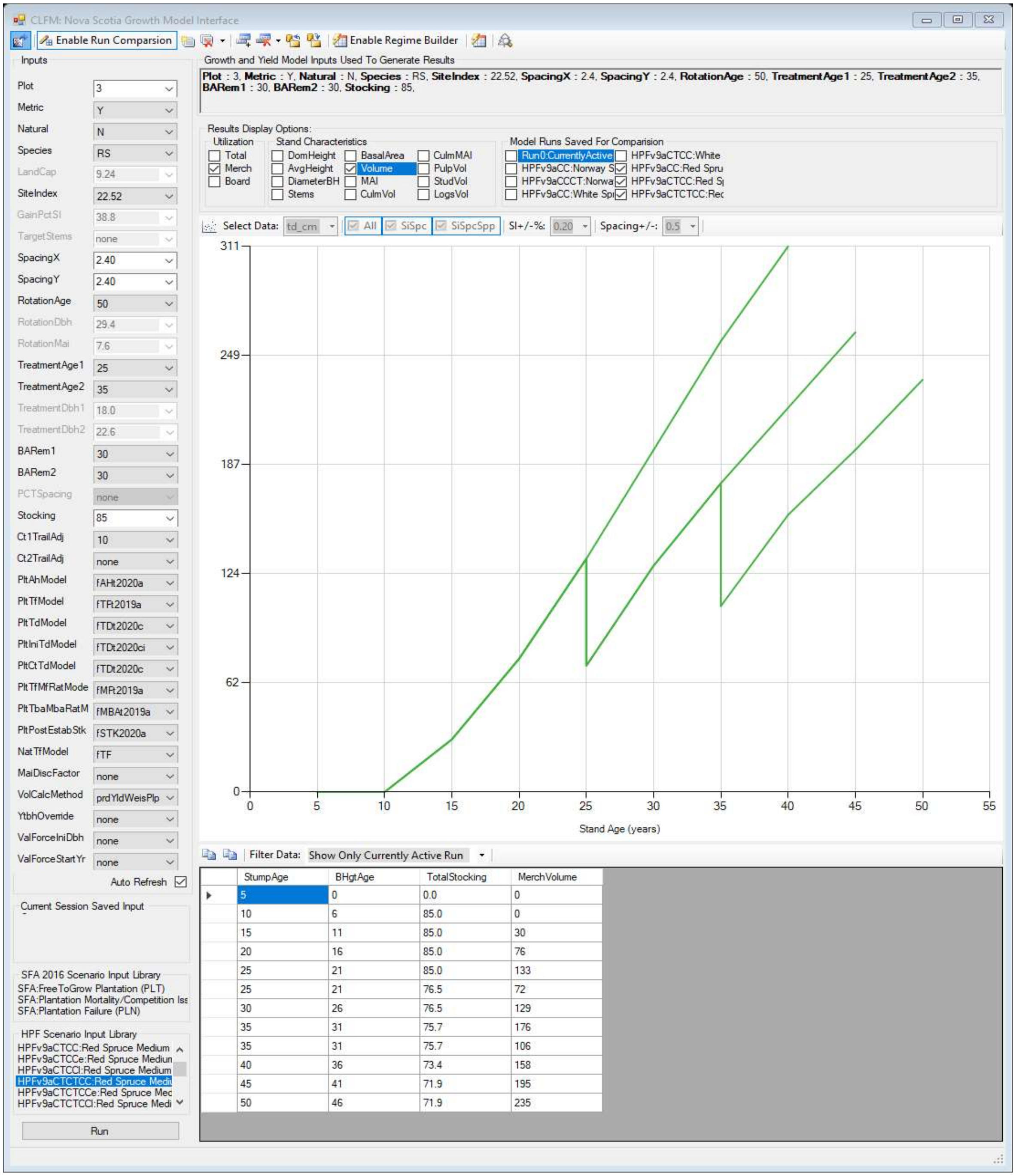


Figure 4. Sample HPF prescription merchantable volume yield (NS Growth & Yield Plantation Model (NSDNRR, 2021b).

A crucial choice in the overall TRIAD approach is how much area should be allotted to HPF. According to the *High Production Forestry Discussion Paper (2020)* at the time of this analysis, a suitable area on the eastern Crown land-base is projected to be 76,000 hectares, or around 10.5% of the eastern Crown land-base. It was determined to target a 5% or 35,000 ha HPF zone while taking some sensitivity into account for expanding or contracting the zone due to the lack of explicit policy limits at the time of the 2021 timber supply analysis.

3.2 Ecological Matrix Assumptions

Acadian and Maritime Boreal ecosite groups each make up a portion of the Ecological Matrix land-base. The recently released Silvicultural Guide for the Ecological Matrix (2021a) describes suitable silvicultural techniques for the ecological matrix inside the TRIAD, where conservation and production objectives are both applicable and combined in the context of sustainable forest management and ecological forestry (2021a).

Maritime Boreal ecosites are mostly distributed in ecodistricts 100, 210, 810, and 820 of the provincial Ecological Land Classification system. It is significant to note that Acadian ecosites might be included within the limits of these ecodistricts. Operationally, these ecosites are managed in accordance with the Acadian SGEM's recommendations, but in terms of long-term planning, the entire ecodistrict is categorised as Maritime Boreal. It is possible for Maritime Boreal to exist outside of these ecodistricts (near the ecodistrict boundaries). Once more, these locations are handled operationally as if they were Maritime Boreal. When it comes to strategic planning, these additions are considered Acadian ecosites (NSDNR, 2017).

At the time of this analysis, the final SGEM's (2021a) had not been released. Therefore, NSNDRR's draft SGEM's were incorporated into the analysis which included a range of harvest treatments within the Acadian and Maritime Boreal ecosite groups. The table below summarizes the treatment prescriptions used in the analysis as they were described at that time.

Table 3. Draft SGEM Treatments Incorporated into Timber Supply Analysis (NSDNRR, 2021b)

ACADIAN ECOSITE GROUP	
Treatment Prescription	**Description**
Low Retention Harvests - Zonal Shelterwood - Zonal Overstory Removal - Edaphic Overstory Removal	Where low concentrations of LIT (long-lived, intermediate to shade tolerant) species (below 30%) are present, low retention harvests are advised. The retention that was left over from the final harvest is what sets these treatments apart from earlier shelterwood/overstory removal methods. The single-entry final harvest treatments of edaphic overstory removal and zonal overstory removal are comparable to clearcut harvests with 30% and 20% retention, respectively.

	Zonal shelterwood is comparable to classic shelterwood, with the establishing cut retention rate being 67% (up from 50% earlier). Ten years following the initial entry, the overstory is removed with 30% retention.
Medium Retention Irregular Shelterwood	In areas where LIT species are prevalent in moderate concentrations (20–60%), medium retention irregular shelterwood is recommended. This treatment has four entry cycles totaling 120 years: 0, 30, 90 and 120. At each entry, 50% of the stand is removed. To allow the cohort generated in the first entry to reach the age of 90 before it is harvested, there is a 60-year gap between the second and third entries. When the second entry's cohort is 90 years old, it is harvested (at 120 years since the first entry). The suggested medium retention irregular shelterwood timeframes from the draft SGEM were used to model the timing of this regime.
High Retention Irregular Shelterwood/Selection	Where LIT species are abundant (>60%), high retention irregular shelterwood and selection are advised. High retention irregular shelterwood and selection retention values are comparable (67% vs. 70%, respectively). Re-entry cycles for high retention irregular shelterwoods will be 25–30 years whereas those for selected harvests will likely be 15–25 years. The key differences between the two treatments in the SGEM are the windthrow hazard and the current age class structure. Prescribed selection will often be made from existing multi-aged stands with little risk of windthrow. The use of high retention irregular shelterwood will be advised for stands that are even-aged or multi-aged with a moderate-high windthrow hazard. At the strategic planning level, windthrow risk and age class structure of stands are unreliable inventory features. Since re-entry cycles and retention levels are comparable, they were merged. For selection treatments and high retention irregular shelterwood, a 20-year re-entry cycle with a 30% removal was applied.
MARITIME BOREAL ECOSITE GROUP	
Treatment Prescription	**Description**
Variable Retention	In Maritime Boreal zones, harvest guidelines adhere to the current framework (clearcut, traditional shelterwood, selection and commercial thinning). Following the Interim Retention Guidelines, final harvests (clearcut, shelterwood overstory removals, now referred to as variable retention) leave 10, 20, or 30% permanent retention depending on the amount of LIT present in the stand. The matching retention in

	the regimes section was used to reduce yields. Retention is left at 10% when the LIT is less than 10%, 20% where the LIT is between 10% and 30%, and 30% where the LIT is greater than 30%. Retention was measured as stock growth over 20 years (10/20% retention) and over 30 years (30%).
Traditional Silviculture (PCT and Planting)	PCT and planting are choices that are available in shelterwood with variable retention, low retention harvests, and irregular medium retention. In high retention irregular shelterwood/selection, PCT is an alternative. Except for 10% variable retention, PCT expenses for all prescriptions were decreased proportionately by the retention amount. For instance, it was expected that 50% of an area will be eligible for PCT when a cohort is 10 years old in a medium retention irregular shelterwood with 50% retention. $400 per hectare was charged instead of $800. Retention levels did not result in lower planting costs.

Source: NSDNRR, 2021b

Prescription Decision Points

For determining prescription eligibility, three factors must be taken into consideration: the ecosite group, the forest community, and the percentage of long-lived, intermediate-to-shade-tolerant (LIT) species.

The Tend key in the instructions was never used because it was always presumed that existing regeneration was more than 60%. Commercial thinning is still a choice, and it operates similarly to the 2016 Crown Land Forest Management framework.

To determine whether the prescription set will be based on the SGEM (Acadian) or Interim Retention Guidelines (Maritime Boreal), Ecosite Group is employed. Softwood forest communities with more than 50% black spruce were referred to as edaphic locations.

Forest communities were linked to an FEC forest group for the Acadian ecosites. LIT% was used to evaluate prescription eligibility (for non-tending treatments) in each forest community/forest group pair. In the Spruce Hemlock forest group, for instance, LIT% is utilised to determine if retention is low (20% LIT), medium (>20-60% LIT), or high (>60% LIT). At a strategic planning scale, treatment variables (continuous cover vs. gap) are unimportant. All softwood forest communities, with the exception of the Spruce/Pine dominating community, were subject to the Spruce Hemlock forest group key (SPiDom) (NSDNRR, 2021b).

3.3 Forest Carbon Assumptions

To investigate the potential for forests and forest management to mitigate climate change, the dynamics of forest carbon were modelled for the eastern Crown analysis using a mix of techniques. The ability of forest ecosystems to lower net greenhouse gas emissions is due to the atmospheric CO2 sequestration and long-term storage of forest biomass and dead organic matter (Smyth et al., 2014). The potential of forests to reduce greenhouse gas emissions can be further improved by increasing the carbon storage in goods made from harvested wood or by using biomass from forests as an alternative to fossil fuels.

In this analysis, three main types of forest carbon (i.e. carbon pools) were taken into account. These include carbon in Dead Organic Matter (DOM), carbon in living biomass of trees, and carbon in harvested wood products.

The biomass carbon pool consists of both aboveground biomass, such as wood, bark, and leaves as well as belowground biomass, such as fine and coarse roots. The Canadian national tree aboveground biomass equations were used to determine the aboveground biomass of individual trees for the high productivity forestry (HPF) regimes using the diameter at breast height (cm) and average height (m) as inputs (Lambert et al., 2005). The Lambert et al. (2005) diameter-height equations were used to better reflect the taper of trees produced in plantations as opposed to those in natural stands. The Nova Scotia Growth and Yield Model's diameters and heights were used to get the biomass estimates for individual trees, which were then scaled up to the stand level using total frequency (stems/ha) to calculate the biomass and carbon estimations (t/ha). The carbon budget model of the Canadian forest sector's belowground biomass equations were used to derive estimates of belowground biomass and carbon in fine and coarse roots (CBM-CFS3; Li et al., 2003; Kurz et al., 2009). The CBM-CFS3 model, which uses merchantable volume (m3) yield curves as input, was used to simulate the living forest biomass for all other managed stands and all natural stands.

Snags, fine and coarse woody material, litter, dead roots, the forest floor, and mineral soil all contain carbon, as does the second carbon pool, DOM. These were estimated using the above-mentioned carbon estimates in live biomass using the CBM-CFS3 equations (Kurz et al., 2009). These equations consider the breakdown of dead organic matter in the Nova Scotian environment as well as biomass turnover (such as litterfall). Harvested wood products (HWP) is the third carbon pool. The Intergovernmental Panel on Climate Change (IPCC) recommendations for emissions accounting (IPCC, 2006) are used to calculate the decomposition rates for carbon storage in HWP. Products are divided into three pools: solid wood products, pulp and paper products, and residues/bioenergy. Products made of solid wood have a half-life of 35 years, two years for pulp and paper products, and an immediate release of carbon from residues/bioenergy (NSDNRR, 2021b).

3.4 Climate Change Assumptions

A preliminary set of vulnerability indicators was created and incorporated into the model and subsequent research to provide a baseline understanding of forest vulnerability to long-term climate change. Vulnerability to climate change has many intricate facets, including shifting average temperatures and precipitation, climatic extremes including drought and freeze/thaw events, and increasingly frequent and severe disruptions. This particular analysis concentrated on the lengthening of the growing season, its effects on the environment, and the consequent appropriateness of Nova Scotian tree species in light of their current climatic range. Growing Degree Days (GDD) with a base of 5°C are used to measure the length of the growing season. In the past, Nova Scotia forest modelling research has used the GDD variable to predict climate impacts on forest composition and species range shifts. Major Nova Scotia tree species' minimum and maximum GDD values (Table 5) were taken from the literature (Steenberg et al., 2011), and GDD was calculated using predicted climatic data at a 1-km resolution under various Representative Concentration Pathway (RCP) scenarios (Bush & Lemmen, 2019 Table 4; Figure 5) (NSDNRR, 2021b).

Table 4. Growing Degree Days (base 5° C) for the Current Climate and Representative Concentration Pathways (NSDNR, 2017)

Ecoregion	Current (1981-2010)	GDD, RCP 2.6 (2071-2100)	GDD, RCP 8.5 (2071-2100)
1 & 2	1,375	1,900	2,860
3	1,559	2,117	3,121
4	1,596	2,121	3,115
5	1,631	2,204	3,252
8	1,569	2,054	3,027

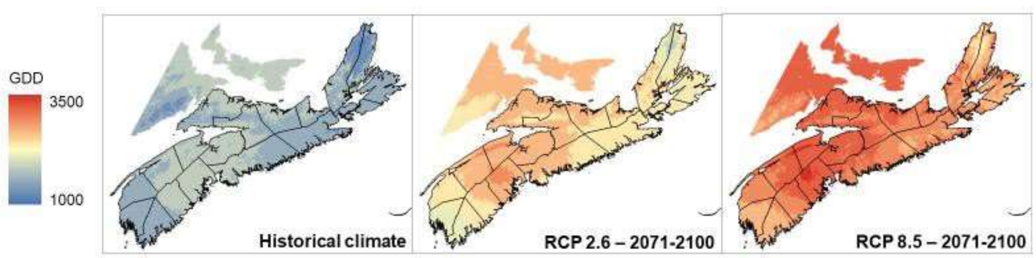


Figure 5. Mapped Growing Degree Days for Nova Scotia under Representative Concentration Pathways

Source: NSDNRR, 2021b

Table 5. Minimum and maximum growing degree day (GDD; base 5° C) values for Nova Scotia tree species' climatic range and the corresponding vulnerability indicators for Representative Concentration Pathways (RCPs) 2.6 and 8.5 in Ecoregion 4 only.

Species	Minimum GDD	Maximum GDD	Vulnerability – RCP 2.6	Vulnerability – RCP 8.5
RS	800	2,900	0.826	1.062
BS	300	2,200	0.982	1.263

WS	280	1,911	1.047	1.345
BF	563	2,011	1.025	1.317
WP	1,100	3,400	0.714	0.918
RP	1,400	2,300	0.960	1.234
EH	1,222	3,800	0.625	0.803
TL	560	2,386	0.941	1.209
RM1	1,260	6,600	0.100	0.100
WB	484	2,036	1.019	1.310
XA	800	3,000	0.804	1.033
SM	1,222	3,100	0.781	1.004
BE	1,300	3,500	0.692	0.890
YB	1,100	2,900	0.826	1.062
RO	1,525	3,878	0.608	0.781

1 The red maple indicator value of 0 was replaced with 0.1 to have all non-zero values for the optimization in Woodstock.

The optimization was parametrized to investigate the effects of lowering the total vulnerability indicator values for the research area in the climate change scenario contained in the Eastern Crown analysis. Two additional constraints were introduced to the optimization, requiring a 10% reduction in the overall aggregated vulnerability for LIT and non-LIT species throughout the simulation on the working land-base of the ecological matrix. To avoid drastically lowering LIT species in the research area in favour of non-LIT species with low sensitivity, LIT and non-LIT species were specified as separate limitations (i.e., red maple). This was an attempt to strike a compromise between ecological goals related to preserving or increasing the number of LIT species and those related to vulnerability (NSDNRR, 2021b).

3.5 Ecosystem Based Management Assumptions

Ecosystem Based Management (EBM) was incorporated into the analysis using the same methodology as the 2016 Strategic Forest Analysis (SFA) Process. The Ecodistrict, Element, and Natural Disturbance Regime (NDR) targets for forest composition indicators are set by the EBM technique. The goals for the frequent, infrequent, and gap NDRs for the mature development class indicator (i.e., stands > 40 years of age) were 40%, 60%, and 70%, respectively. For frequent, infrequent, and gap NDRs, the objectives for the late seral species composition were 33%, 40%, and 50%. Finally, the old forest/multi-aged objectives for frequent, infrequent, and gap NDRs were 8%, 16%, and 24% respectively. Beginning in year 50 of the forecast, this target lasts until year 100.

The distinction between stands that are or are not deemed mature in terms of structure has become less distinct with the introduction of new multi-aged / multi-cohort management prescriptions at varying retention levels within the ecological matrix. The analysis committee engaged with numerous departmental specialists to develop the rule-set for this study in the absence of any policy direction on maturity in these new prescriptions. This is not policy; rather, it is the team's projection of the policy's future course. According to the table below, the retention level of the prescription changed the age base maturity:

Table 6. EBM Mature Forest Persistence by Retention Level Assumptions

	Harvest Retention %					
	70%	50%	30%	20%	10%	0%
Remain Mature Post Harvest	YES	YES	NO?	NO	NO	NO

Whether the 30% retention would continue to operate as mature was a topic of discussion. In the end, it was decided, out of caution, not to count it as mature (NSDNRR, 2021b).

3.6 Wildlife Habitats Assumptions

Wildlife habitats and modeling assumptions for this analysis are summarized in the below table.

Table 7. Eastern Crown Wildlife Management Assumptions

Pine Marten Patch Management	Existing Pine Marten habitat patches were excluded from harvest except for commercial thinning treatments in pre-existing plantation and precommercial thinned areas.
Deer Wintering Area Management	Deer wintering habitat areas were available for harvest scheduling under the condition that 50% of the initial softwood forest area remains in a mature condition throughout the 100-year planning horizon by ecoregion. This is only applied on Crown land.
Moose Concentration Area Management	Harvest estimates within moose concentration areas are reduced by 16%. This reduction approximates the anticipated volume impact of applying the moose special management practices within these zones. This policy only applies on Crown land. It was discussed whether the 16% was still relevant given the shift to TRIAD management. Initial thinking was the medium/high retentions may have less planning restrictions yet after discussion with the PHP planners and their experience with the interim policy they recommended keeping the 16% planning volume adjustment.
Specific Wildlife Habitat Protection	Specific habitat areas that were removed from the working land-base included: • 100m lynx habitat buffers, • 20m watercourse and wetland buffers in moose zones, • 100m coastal plains flora buffers, • 200m buffers on known and predicted boreal felt lichen locations. • 200m buffers on known raptor nest locations: goshawk
Wood Turtle	Wood turtle buffers were incorporated into the land-base yet no specific harvest exclusion or modelling objective were set for these areas. It was treated as a seasonal scheduling issue that would be handled at the tactical/operational planning levels.
Bicknell's Thrust Critical Habitat	Bicknell's thrust critical habitat layer was incorporated into the land-base. Though there was no specific strategic-level management direction it was incorporated for sensitivity analysis of not being able to precommercial thin stands within this area.
Bank Swallow Critical Habitat	The bank swallow critical habitat layer was not merged into the land-base for this analysis. A high-level assessment of the size and location of the areas indicated they were primarily coastal and overlapped very little with working land-base. It was decided it would be handled at the tactical/operational planning levels.

Other 'In-Progress' Wildlife Habitat Policies that may affect Analysis	It was known these policies were under development, yet no specific planning direction existed that could be incorporated into this analysis: • Moose Critical Habitat • Lynx Recovery Plan

Source: NSDNRR, 2021b

To aid PHP's FSC certification process, particular species habitat indicators were also included along with previous indicator species in PHP's 2015 SFM Long-term Plan. Although not set up as concrete targets, the indicators were considered when evaluating the outcomes of management scenarios. Indicators of species habitats included:

Table 8. Species Habitat Indicators

2015 SFMLTP Indicator Species	FSC Indicator Species
Pileated Woodpecker	Canada Warbler
Barred Owl	Chimney Swift
Bicknell's Thrush	Nighthawk
Blacked Back Woodpecker	Eastern Wood Peewee
White Wing Cross Billed	Eastern Whip Poor Will
	Evening Grosbeak
	Olive-sided Flycatcher
	Rusty Blackbird
	Wood Thrush

3.7 Silviculture Budgets Assumptions

The Eastern Crown License's traditional silviculture budget was $5 million per year. The budget would specify maximum annual investment levels for partial harvest financing initiatives. These expenses would have been based on the Silviculture Credit Limits for Wood Acquisition Plans in earlier analyses. The transition to TRIAD resulted in novel treatments necessitates consideration of how to incorporate the new HPF and EM management recommendations into overall silviculture budgets. The costs that were modelled in this analysis are summarised below.

<u>High Production Forestry</u>

The below table was based on the High Production Forestry Phase 1 Discussion Paper directives.

Table 9. High Production Forestry Silviculture Costs.

	Site Prep	Plant	Herbicide	Cleaning	CT	Soil Amendment
Costs Est. $/ha	300	600	125	400	550	500

Ecological Matrix

The silviculture budget assumptions under the ecological matrix were based on discussions with PHP on current rates and expected potential funding needs for new SGEM treatments.

The predicted funding for harvest treatments are:

- $550/ha for high retention (> 2/3)
- $275/ha for low retention (1/3). This is approximately $9 per % of retention. This ratio was then used to approximate funding for other retention levels.

Table 10. Ecological Matrix Partial Harvest Funding Costs

	Harvest Retention %					
	70%	50%	30%	20%	10%	0%
Harvest Funding Cost Estimate $/ha	550	460	275	185	90	0

Silviculture treatment funding were identified as follows:

- Pre-commercial thinning (PCT), which is based on utilising natural regeneration, was considered to be the dominating silviculture activity for the ecological matrix. Cost for traditional PCT is $800/ha. It was chosen to discount this full rate based on the percentage of retention remaining when planning the role that PCT will play in fresh retention harvests. Although fictitious, it was a quick and easy approach to gauge the effects of novel EM harvest on conventional PCT. In a gap NDR where fixed areas or patches are harvested, the strategy makes more sense than in a continuous cover.
- In the Acadian ecological matrix zone, PCT was the only silviculture option assumed.
- Plantations are often not an EM treatment. PCT was the only silviculture option that was studied for the Acadian ecological matrix zone. However, a choice to plant highland White Spruce was preserved for the Maritime Boreal zone to be consistent with present management techniques in this zone that might alter under Maritime Boreal ecological matrix management. The key distinction between these and HPF plantations is the change in species composition, which results in yields that are comparable to those of natural PCTs. This has historically been seen as advantageous for decreasing overall budworm risk and expanding management options in the forest of the Cape Breton Highlands that is dominated by balsam fir (NSDNRR, 2021b).

4 OTHER POLICY CONSIDERATIONS

4.1 Environmental Assessment / Forest Stewardship Planning Process

The team acknowledged that a process called "Forest Stewardship Planning" is in progress and will probably have an impact on the creation of future forest management plans. The identification of values-objectives-indicators-targets (VOITs) to direct management would be a crucial component of the Forest Stewardship Planning Process.

What potential VOITs might or might not be necessary in the future as part of a Forest Stewardship Planning procedure was unknown for this analysis of the eastern Crown. The group used information about VOITS from a variety of sources, including:

- NS Code of Forest Practices
- NS Ecological Landscape Analysis Guide
- Wildlife special management practices
- PHP Certification Experience (with FSC and CSA)

Source: NSDNRR, 2021b

4.2 Natural Disturbance Regimes

According to the Independent Review of Forest Practices, emulating natural disturbance regimes in forest planning and management is a proven strategy for preserving biodiversity and a cornerstone of ecological forestry (Seymour & Hunter, 1999). (i.e., Lahey Report). Furthermore, the Lahey Report made the explicit suggestion that research on natural disturbance regimes (NDR) be done in Nova Scotia and that NDR be incorporated into the Department's planning. Landscape-level maturity targets are one such planning area that might incorporate recent NDR research. Age-related compositional goals within ecoregions or ecodistricts, as well as their NDR class under the previous framework (i.e., frequent, infrequent, or gap NDR in the Woodstock model optimization), are defined by the current planning and subsequent modelling technique. For instance, it is planned to preserve 40%, 60%, and 70%, respectively, of the mature development class's forested land-base in the frequent, infrequent, and gap NDR classes.

The joint NDR research that was conducted in response to the Lahey Report included research that focuses on integrating NDR into ecological forestry in the province and research that characterises and quantifies the various NDR in the province (Taylor et al., 2020). (MacLean et al., 2021). Through the development of new potential natural vegetation (PNV) forest communities, the latter connects NDR to the provincial ELC. In the absence of anthropogenic disturbance, the PNV classes describe the predominant forest characteristics that would be anticipated at a location given its environmental and climatic parameters. Each PNV class in Nova Scotia's dominant NDR was connected to it, providing, among other things, mean annual disturbance rates that are both mapped and connected to. The previous landscape-level maturity targets should be improved upon and updated in light of this new research using the mean yearly disturbance rates and mapped PNV from MacLean et al. (2021). The project team considered this strategy and agreed that it would be a useful tool for incorporating ecological forestry into the planning process for the Eastern Crown. It was decided to designate this as an area of interest for upcoming planning and modelling projects, despite the fact that this research was still being peer reviewed and hadn't been published at the time of the analysis (NSDNRR, 2021b).

Table 10. Total Area in Each PNV Forest Community in the Eastern Crown Land-base

Potential Natural Vegetation	Area (ha)
Acadian Zonal Forests	
Tolerant Hardwood	227,148
Tolerant Softwood	35,780
Tolerant Mixedwood	38,990
Maritime Boreal Zonal Forests	
Coastal Spruce-Fir	53,706
Coastal Hardwood	6,203
Highland Fir	112,249
Azonal Forests	
Spruce-Pine	152,693
Acadian Wet Coniferous	6,785
Floodplain	1,229
Maritime Boreal Wet Coniferous	30,944

Source: NSDNRR, 2021b

5 CHANGES IMPACTING LICENSE AREA LAND-BASE

The impacts of change to the overall boundary of the license area land-base are expected to reduce the total management area of ~ 522,000 ha (~511,000 ha excluding inland waterbodies) defined under the 2012 Forest License Utilization Agreement.

Boundary changes that will impact the future license area land-base are:

1. Removal of Mi'kmaq Forestry Initiative Eastern Lands – ~10,000 ha
2. Removal of Indigenous Protected & Conservation Area Lands – ~7,700 ha
3. Potential removal of designated protected areas. Given that some designated protected areas were included in the 2012 license area, it was unclear if any would be eliminated at the time of this analysis. Approximately 16,000 ha would be removed if all designated protected areas were to be left out of the license area.

The above removals would change the total FULA land-base from ~511,000 to ~423,000 ha (-9.3%).

The working land-base as contrasted to the 2016 SFA is further impacted by new and/or modified Crown management rules in addition to the boundary issues listed above. Table 12 below lists the key effects on the PHP FULA working land-base (NSDNRR, 2021b).

Table 12. PHP FULA Working Land-base Impacts

Category	Area (ha)
Potential Boundary Removals:	
MFI Eastern Lands	600
IPCA Lands	3,000
Protected Area Buffers	400
Other Major Policy Updates:	
Old Growth Policy	2,100
200m BFL Buffers	3,000
SGEM Sensitive Forest Groups	5,400
Total Working Land-base Impact	**14,500ha**

Source: NSDNRR, 2021b

The working land-base for the FULA lands in the 2016 SFA was 296,000 ha, however the working land-base in this analysis is 281,000 ha, representing a 5% reduction in the amount of land that may be used for harvest planning.

In the 2016 SFA process or when the FULA was originally signed, areas of the 281,000 ha working land-base are now subject to more restrictive management policies. These new and/or revised policies are summarised in Table 12 below.

Table 13. PHP FULA Working Land-base Restriction Impacts

Category	Area (ha)	
Specific Policies:		
200-500m BFL management buffer	14,000	Only medium-high retention harvests
Rare Ecosections	11,000	Only medium-high retention harvests
100m Protected Areas Buffer	8,000	Only medium-high retention harvests
General Triad Zoning Impacts:		
Acadian Ecozone: SGEM Retention	200,000	Minimum Retention based in SGEM minus any lands that get allocated to HPF
Maritime Boreal Zone: Interim Guidelines	81000	Minimum Retention based in LIT

Source: NSDNRR, 2021b

6 MODELING SCENARIOS

Six significant improvements to the functionality and structure of the base model were developed and reviewed by the group during the analytical effort. The initial base model was built on the NSDNRR 2016 Strategic Forest Analysis model, with revisions progressing through the gradual adoption and improvement of the new management policies as shown in the preceding sections. The group's comfort level with the setup was reached after many iterations of the setup.

Six indications are provided here for high-level summary and scenario comparison, while there are many others that might be utilised to evaluate management scenarios.

1. **Wood Supply (Spruce-Fir gmt/yr)**: This indicator is influenced by a non-declining flow constraint over the 100-year planning horizon.

2. **Wood Supply (Hardwood gmt/yr)**: This indicator is influenced by a sequential flow constraint within the HPF zone and a standard non declining policy in the EM zone.

3. **Inventory of Late Seral Mature Forest (ha)**: This indicator is the average area of mature forest over the modelled 100yr planning horizon.

4. **Cumulative Area of HPF Establishment (ha/yr)**: Sites being transitioned to HPF management are all assumed to get the full suite of management activities including site preparation, planting, herbicide, soil amendments, weeding, and commercial thinning wherenecessary.

5. **Management Costs ($/yr) by Triad Zone**: This indicator is a combination of estimated EM and HPF zones silviculture and harvest funding costs. HPF includes establishment costs plus

commercial thinning costs when needed. The EM costs will cover the partial harvest funding model as well as any silviculture costs (precommercial thinning/planting).

6. **Cumulative Net Carbon Emissions (tC)**: Net atmospheric carbon emissions across all forest and product pools, where negative emissions indicate a net removal of carbon from the atmosphere.

Numerous other scenarios were examined as part of the overall analysis, but only 15 were chosen to be reported as alternatives to the base model and sensitivity analysis for the final revision 6 model assumptions. According to the table below, these scenarios cover a variety of policy alternatives of interest to the analytic team (NSDNRR, 2021b).

6.1 Base Model Scenario

This hypothetical scenario was created to mimic current forest management planning, which has prioritised maximising a sustainable short-term even-flow of spruce-fir fibre supply under the current NS policy environment. This algorithm comes close to the conventional method for estimating the prospective supply of wood in Nova Scotia. In this case, there is no set goal for the percentage of the land that must be partially harvested.

Woodstock Formulation Parameters (Optimize Section)

Table 14. Woodstock Parameters (NSDNRR, 2021b)

Objective Function	Maximize spruce-fir harvest with a priority on conventional spruce/fir.
Fiber Flow Constraints	Control by Management Unit, Species Group and Harvest Class - Even-flow softwood and hardwood - Conventional spruce/fir +/- 5% tolerance - Tier 2 spruce/fir +/- 5% tolerance
Sustainability Constraints	Non-declining operable growing stock Targeted at last 25 years of planning horizon Targeted at the spruce/fir inventory component
Silviculture Budget Constraints	With no allocation goals unique to management units, a dynamic budget was established using an annual investment of $3.00/m3 of softwood volume harvested and $0.60/m3 of hardwood volume.

Source: NSDNRR, 2021b

6.2 Alternate Scenarios

The additional 15 scenarios described in the table below all assume the above parameter constraints

Table 15. Modeling Scenarios

Theme	Index	Description
0: Base		
	0	Revision six base model assumptions
1: Carbon		
	1	Effects of adding Carbon into the objective function while maintaining base short-term harvest.
2: Climate Change		
	2a	Effects of adding objective around reducing long-term climate change vulnerability index while maintaining base short term harvest levels.
	2b	Combining the carbon and climate change objectives [1,2a]
3: HPF Allocation		
	3a	Increase HPF allocation to 53,000ha (~7.4% of total eastern crown)
	3b	Lower allocation to 18,000ha (~2.5% of total eastern crown)
	3c	No HPF Allocation
4: Maritime Boreal Low Retention		
	4	Effects of removing 10% retention option in the Maritime Boreal zone effectively raising the minimum retention level to 20% on all harvests.
5: Ecosystem Based Management		
	5	Effects or removing all ecosystem-based management - indicator targets
6: Harvest Flow by Triad Zone		
	6	Effect of having each zone have a non-declining spruce-fir harvest flow policy
7: Hardwood Harvest Limits		
	7a	Base has no upper limits on hardwood harvest in the model. This scenario looks at effect on limiting hardwood harvest to less than 75,000 gmt/yr
	7b	Effect on limiting hardwood harvest to less than 50,000 gmt/yr
8: Silviculture Budget		
	8a	The base model uses a budget of $6million/yr. This scenario looks all removing all budget constraints.
	8b	Effect of lowering it to $5million/yr
9: Moose Adjustment		

	9a	Base model apply 16% volume adjustment to all harvests within MCA areas. This scenario looks at removing the adjustment completely.
	9b	Effect of removing adjustment from any medium or high retention harvests

Source: NSDNRR, 2021b

7 SCENARIO RESULTS

The following aims to summarize key findings from the analysis. Table 16 provides specific results for each scenario.

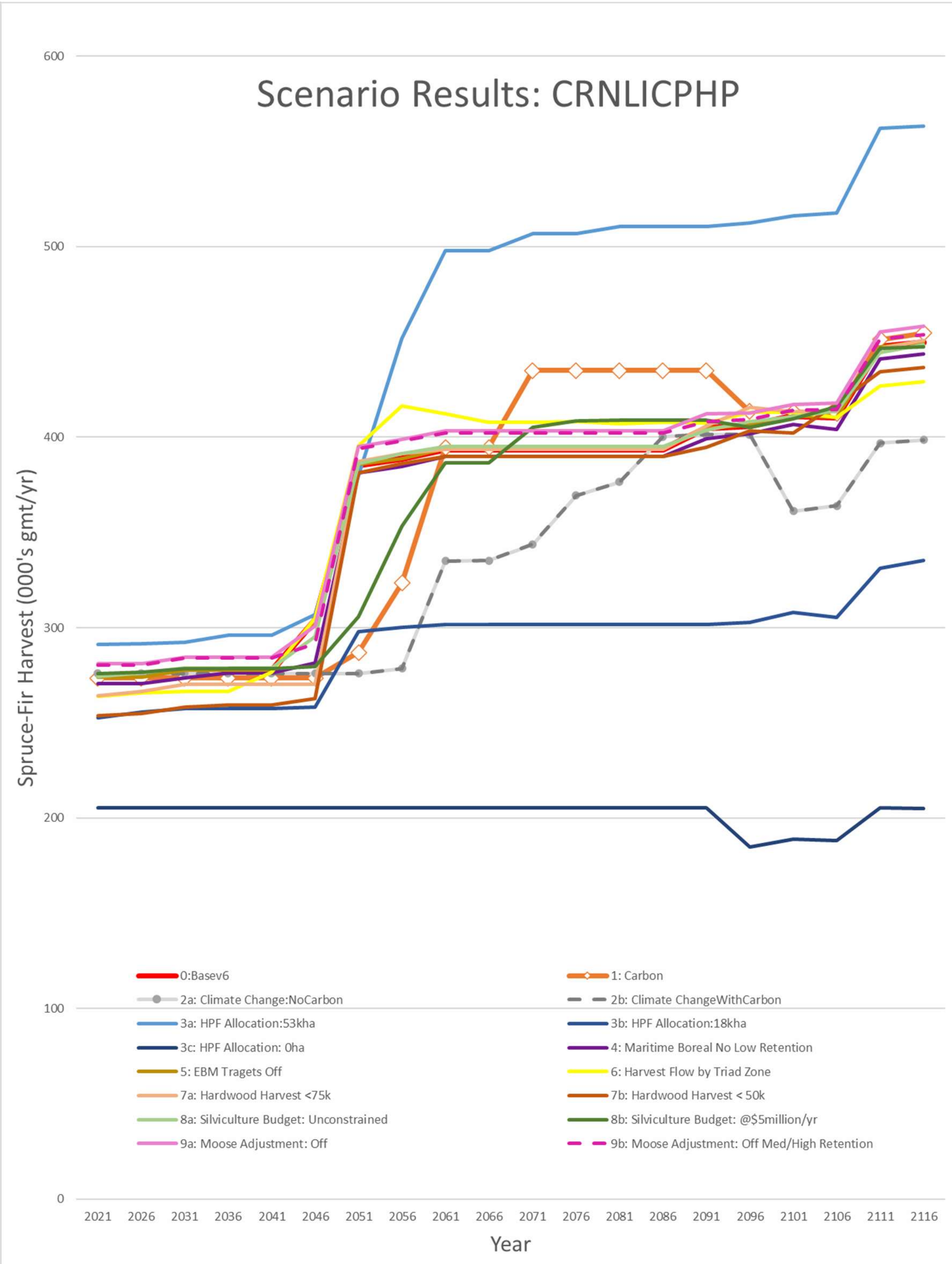
Table 16. Modeling Scenario Results for PHP Crown License Area

Scenario Theme	Id#	Spruce-Fir Harvest (000's gmt/yr) 20yrAvg	50+yrAvg	Hardwood Harvest (000's gmt/yr)	Av. Mature Forest Area (ha)	Cumulative Net Carbon Emissions (tC)	HPF Estab Av. Rate (ha/yr)	Management Cost (000's $/yr) EM	HPF
0: Base	**0**	276	390	108	471	-17,871	1,008	3,049	1,964
1: Carbon	**1**	274	392	101	480	-21,756	1,008	3,444	1,912
2: Climate Change									
	2a	276	349	87	480	-16,294	1,008	2,890	2,034
	2b	276	349	87	480	-16,296	1,008	2,891	2,034
3: HPF Allocation									
	3a	293	478	119	461	-16,868	1,502	2,703	2,783
	3b	256	300	103	482	-18,990	513	3,415	1,002
	3c	205	202	100	495	-19,654	0	3,494	0
4: MB Low Retention	**4**	273	385	107	471	-17,950	1,008	3,080	1,958
5: EBM	**5**	276	391	108	471	-17,835	1,008	3,053	1,964
6: Harv Flow by Zone	**6**	266	397	109	472	-18,571	1,008	3,045	1,978
7: Hw Harvest Limits									
	7a	268	389	66	476	-17,033	1,008	2,761	1,975
	7b	257	382	44	480	-16,217	1,008	2,474	1,975

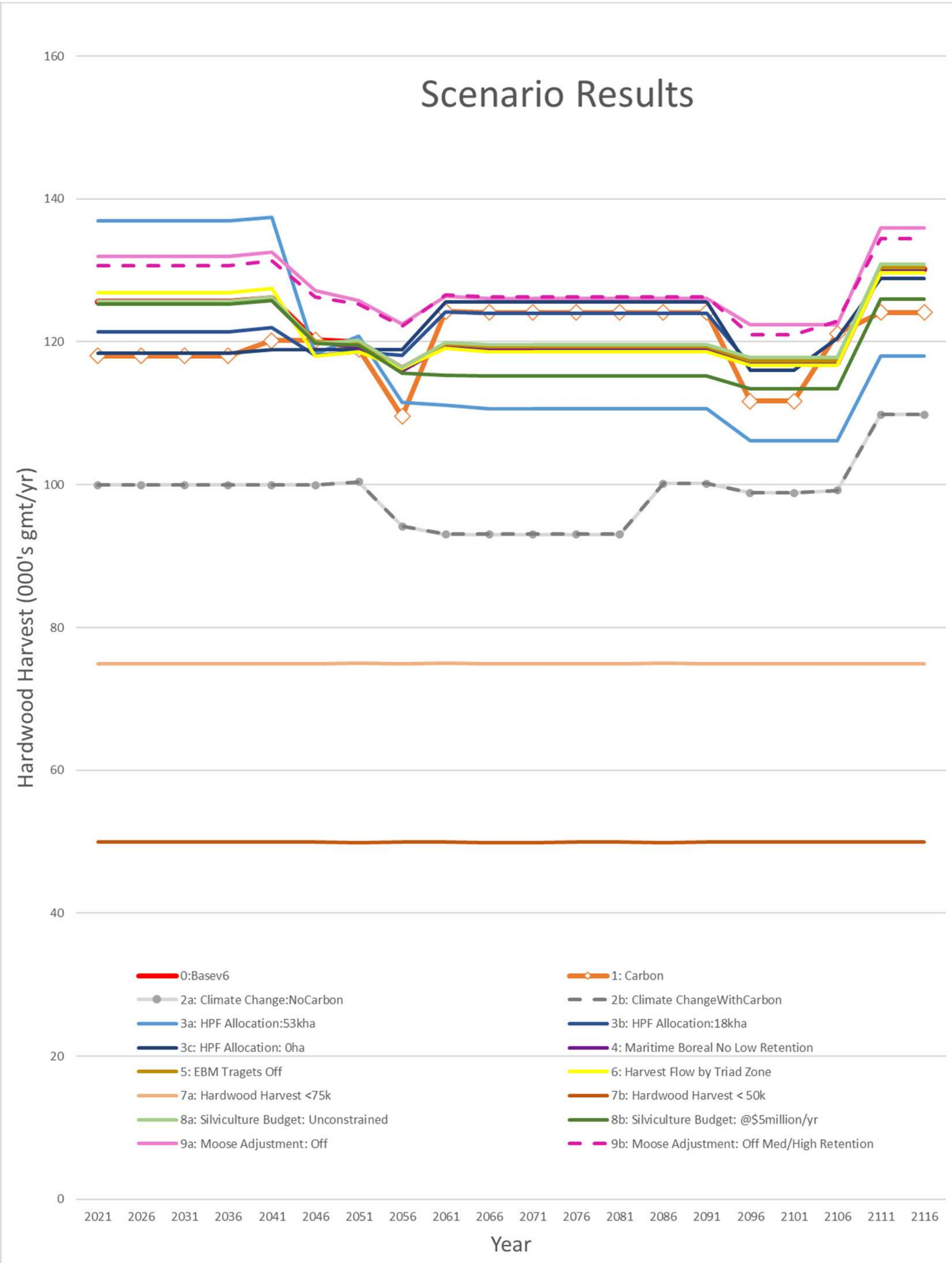
8: Silviculture Budget								
8a	277	391	108	471	-17,852	1,008	3,306	1,982
8b	278	385	107	471	-17,448	1,008	2,734	1,816
9: Moose Adjustment								
9a	283	398	113	470	-17,685	1,008	3,145	1,949
9b	282	396	112	471	-17,744	1,008	3,101	1,954

Scenario 1: Carbon is the preferred scenario for strategic level forest management as it best represents and addresses the range of policies under consideration. The following graphs show model results across all 16 management scenarios for PHP's Crown License Area (CRNLICPHP) (NSDNRR, 2021b).

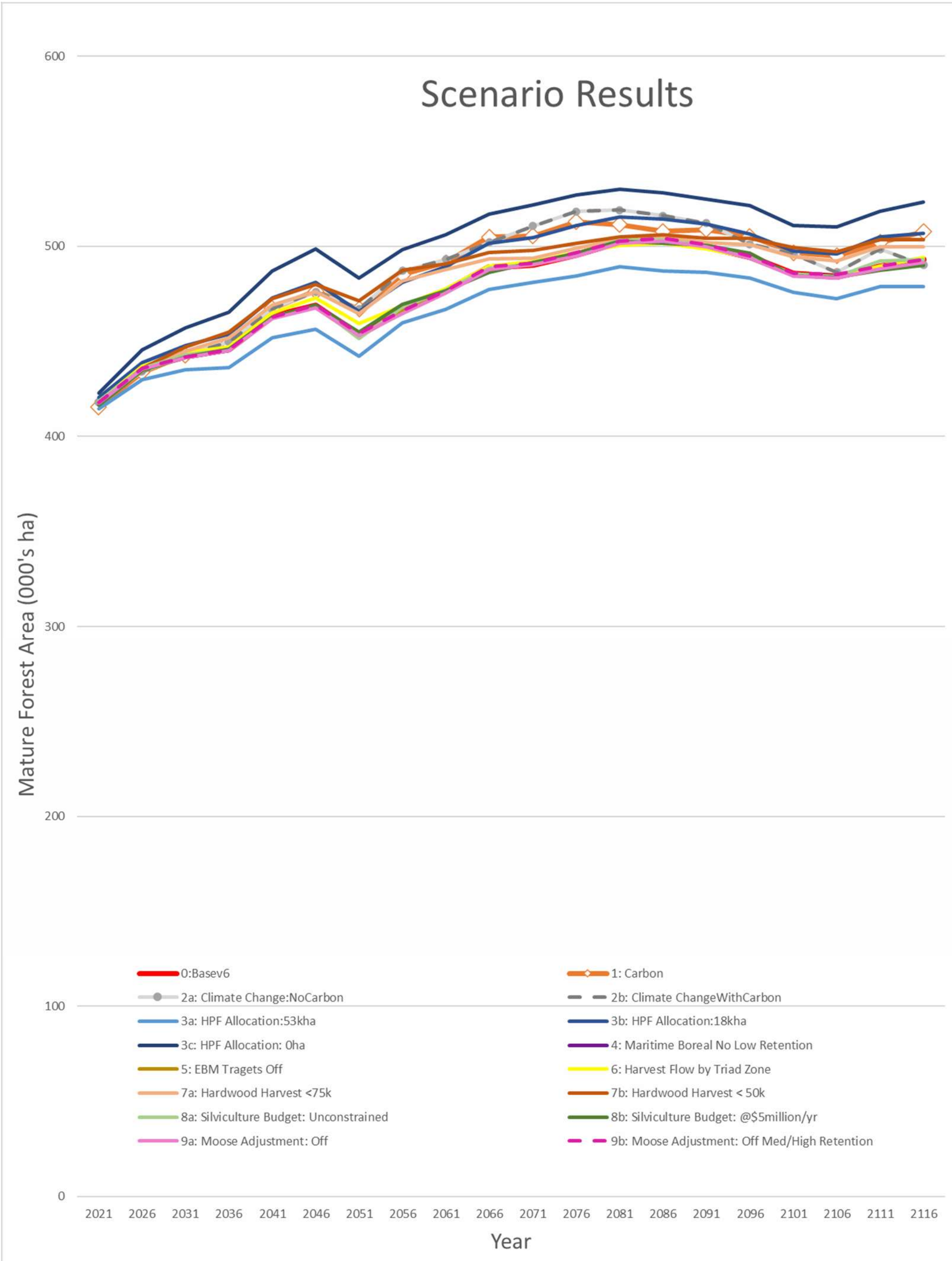
7.1 Wood Supply: Spruce-Fir



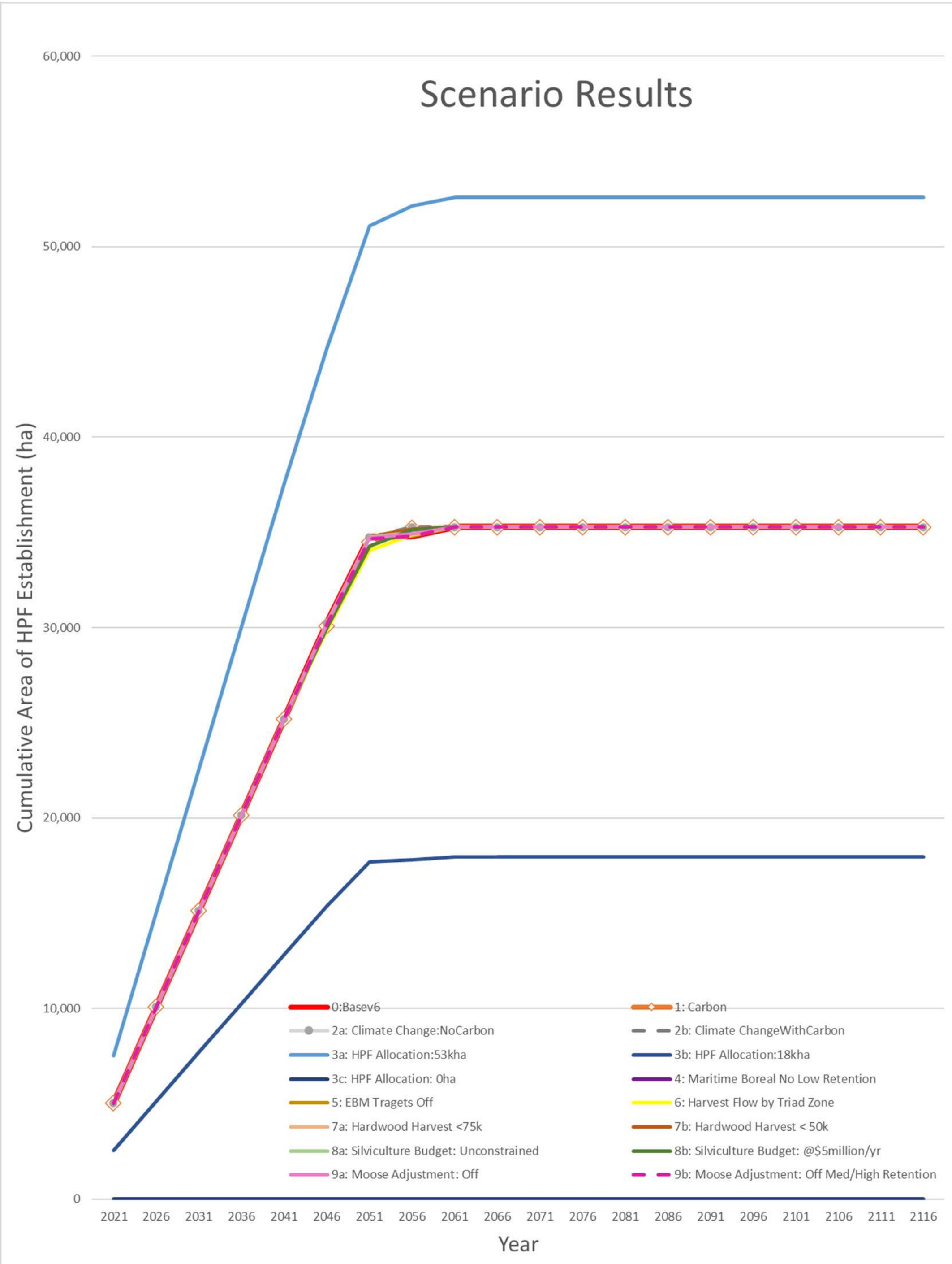
7.2 Wood Supply: Hardwood



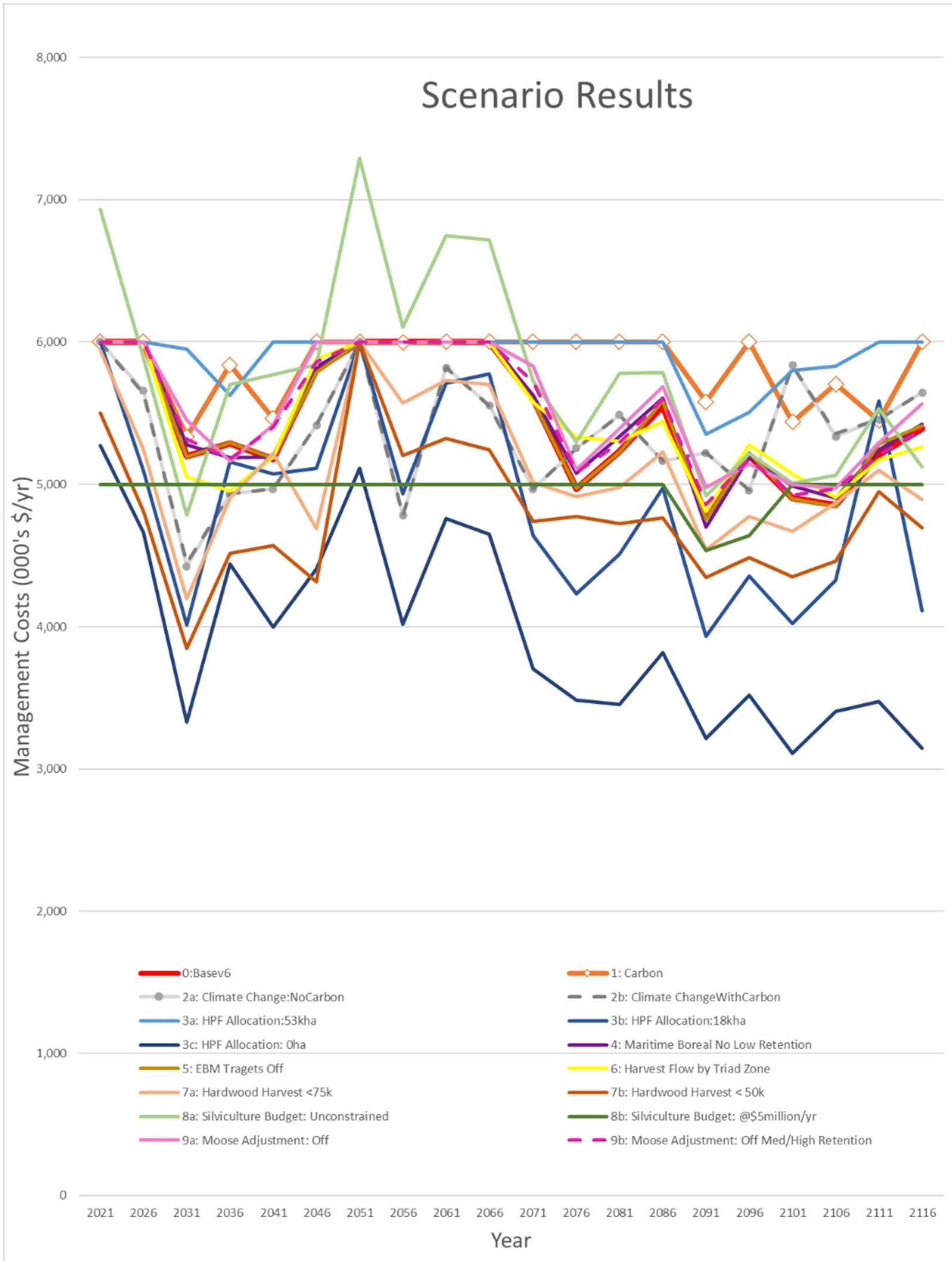
7.3 Mature Forest



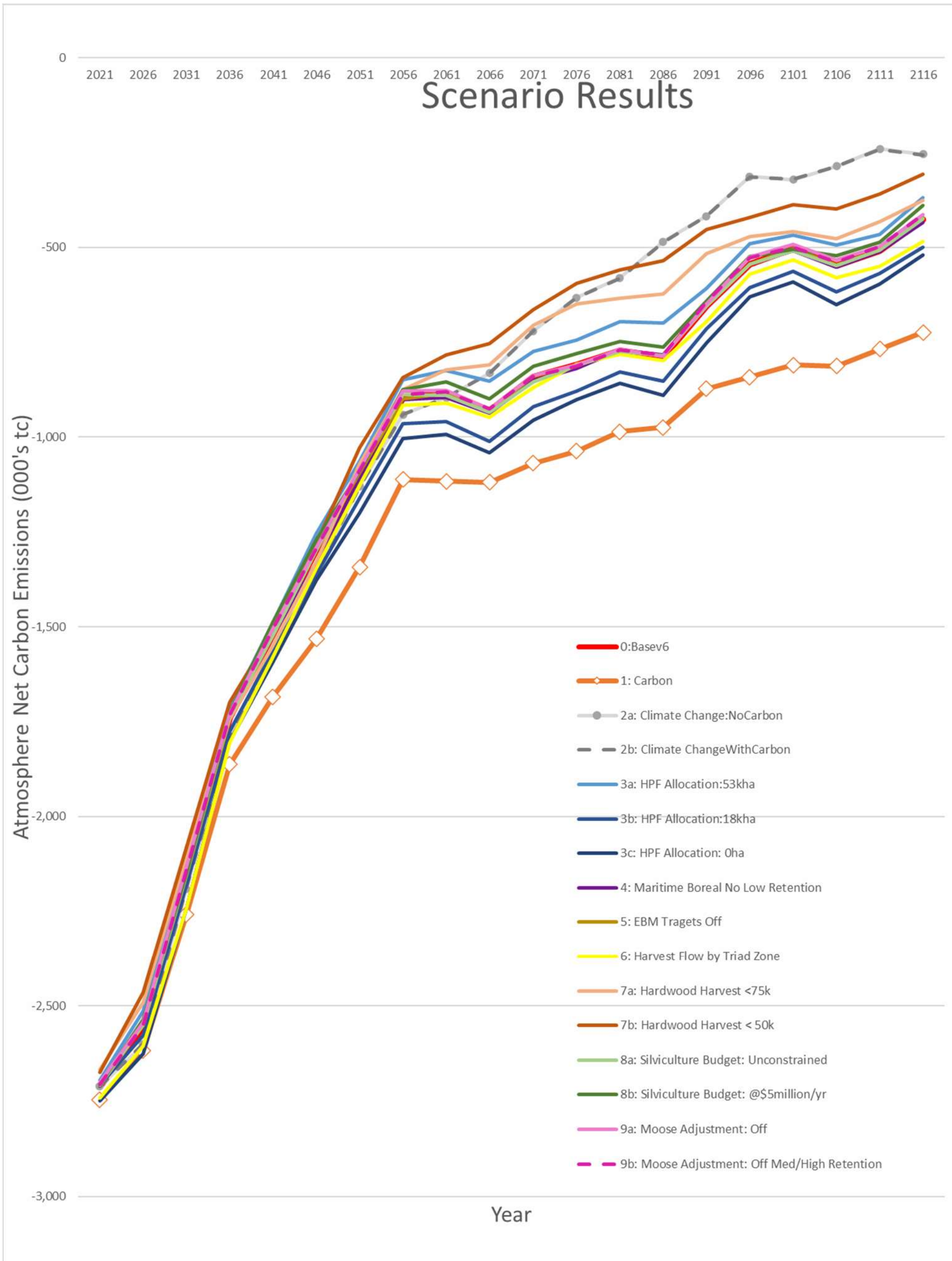
7.4 High Production Forestry Establishment Rate



7.5 Management Costs



7.6 Atmosphere Net Carbon Emissions



8 DISCUSSION

8.1 Carbon

When all forest and forest product carbon is considered, the results demonstrate that the Eastern Crown study region was a net sink of atmospheric carbon for the duration of the simulation (Figure 6). Between the start and end of the 100-year simulation, the emissions levels varied from - 548 kt/yr to - 146 kt/yr, respectively. While demonstrating some rise in the HPF zone and some reduction in the conservation zone, carbon in living forest biomass grew significantly in the ecological matrix (Figure 7). With the exception of soils, dead organic matter carbon storage rose in all three Triad zones, with a rapid increase in the conservation zone and a minor decline toward the simulation's conclusion (Figure 8).

Last but not least, soil carbon storage was the greatest of the forest carbon pools. It showed minor increases in all three Triad zones, with an early simulated decline in the ecological matrix (Figure 9). The carbon transfers to various HWP types reveal that softwood pulp and paper products were the largest carbon sinks in terms of harvested volume (Figure 10). Softwood solid wood products accumulated the most carbon storage by the end of the simulation when taking into account the decomposition and combustion of those products at the end of their useful lives (NSDNRR, 2021b).

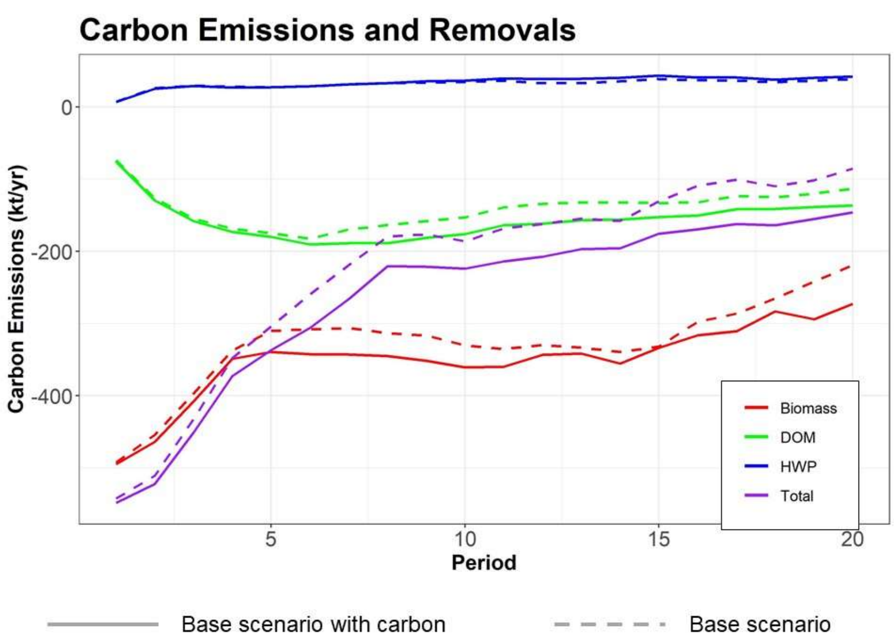


Figure 6. Total carbon emissions and removals from living forest biomass, dead organic matter (including soils, DOM), and harvested wood products (HWP) for the entire eastern Crown land-base.

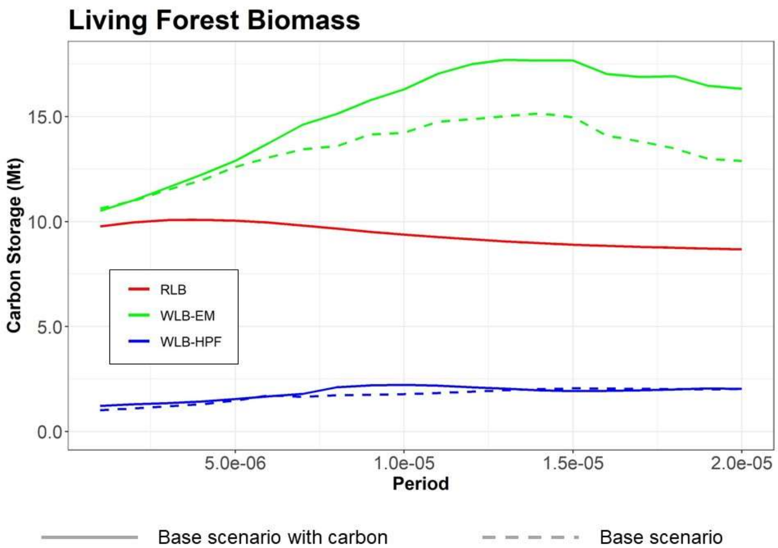


Figure 7. Carbon storage in living forest biomass in the conservation zone (i.e., restricted land-base (RLB), working land-base of the ecological matrix (WLB-EM), and working land-base of the HPF zone (WLB-HPF)).

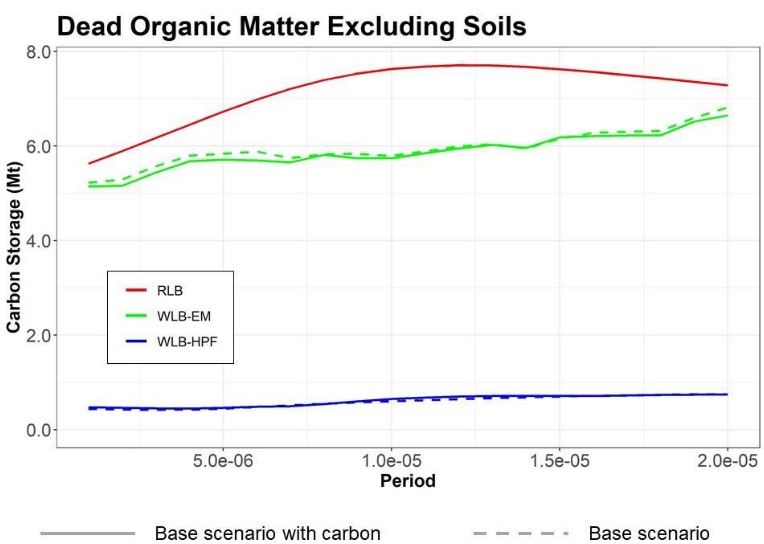


Figure 8. Carbon storage in dead organic matter (excluding soils) in the conservation zone (i.e., restricted land-base (RLB), working land-base of the ecological matrix (WLB-EM), and working land-base of the HPF zone (WLB-HPF)).

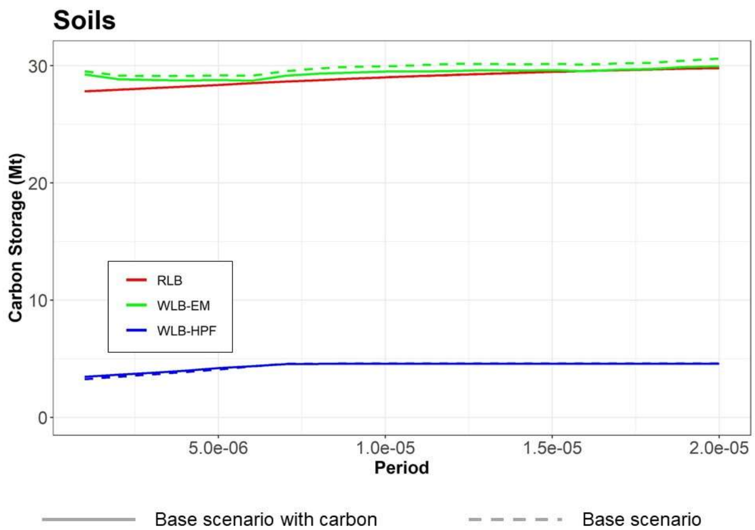


Figure 9. Carbon storage in soils in the conservation zone (i.e., restricted land-base (RLB), working land-base of the ecological matrix (WLB-EM), and working land-base of the HPF zone (WLB-HPF)).

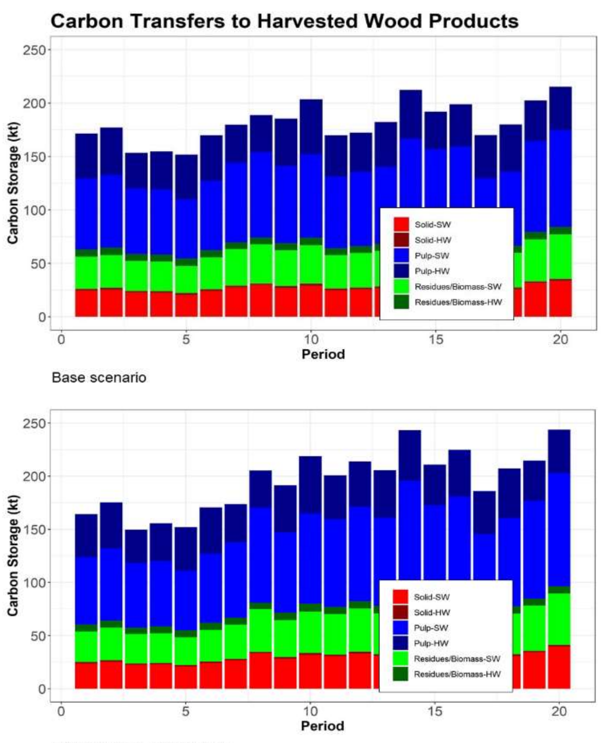


Figure 10. Carbon transfers to harvested wood products at time of harvest by softwood (SW) and hardwood (HW) species groups, including solid wood products (Solid-SW/HW), pulp and paper products (Pulp-SW/HW), and residues/biomass products (Residues/Biomass-SW/HW).

8.2 Climate Change

With a little decrease in the climate change scenario compared to the base scenario, the overall vulnerability of the eastern Crown land-base remained mostly unchanged (Figure 11). There was a rising abundance of LIT species and a falling abundance of non-LIT species in both the climate change and base scenarios. The climate change scenario saw an increase in these same tendencies, however it fell short of the 10% goal objective for LIT species. By period 20, the vulnerability of LIT species had decreased by 2% while that of non-LIT species had decreased by 11%. All ecoregions experienced a decrease in vulnerability at the ecoregional level. Additionally, a comparison of ecoregions reveals that the Cape Breton Highlands and Atlantic Coastal ecoregions, which are characterised by Maritime Boreal ecosystems, are more vulnerable (Figure 12) (NSDNRR, 2021b).

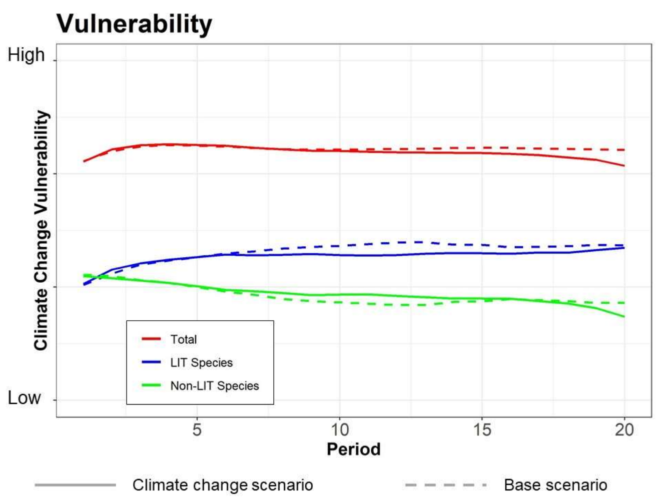


Figure 11. Vulnerability indicator values for LIT species, non-LIT species, and all species combined in the working land-base of the ecological matrix.

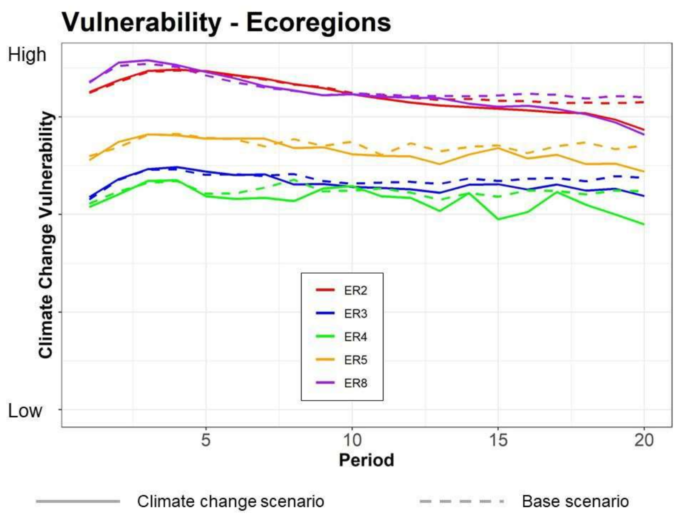


Figure 12. Vulnerability indicator values at the ecoregion level for all species combined. The values were standardized by the total area of each ecoregion for the sake of comparison, so that differences between ecoregions are due to species composition/vulnerability only.

The shift in the ecological matrix's forest species composition explains the patterns of vulnerability (Figure 13 & Figure 14). The volume of red spruce significantly increased in both the climate change and base scenarios, and balsam fir volume decreased. With the exception of white pine and to a much lesser extent red oak, all LIT species saw volume reductions as a result of the climate change scenario. Because balsam fir and white spruce are more climate-vulnerable, their decline and an increase in red maple's sensitivity can be substantially attributed to the non-LIT species' general decrease in vulnerability. Red maple and white spruce showed the most noticeable differences between the base scenario and the climate change scenario. It should be noted that the modelling of red maple and white spruce took into account the forest groupings and ecoregions where these species are either deemed LIT or not (NSDNRR, 2021b).

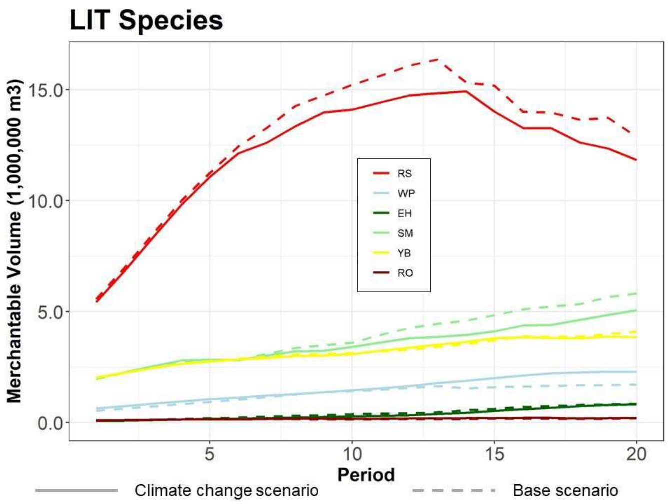


Figure 13. Forest species composition by volume for LIT species in the working land-base of the ecological matrix.

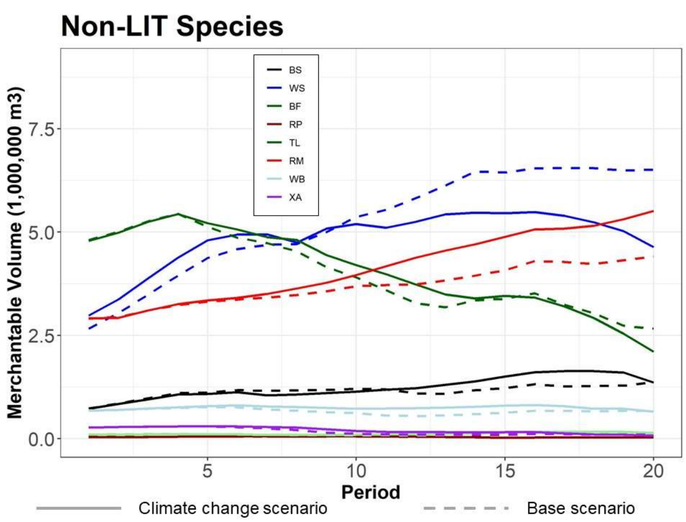


Figure 14. Forest species composition by volume for non-LIT species in the working land-base of the ecological matrix. Note that red maple is considered a LIT species occurring in the tolerant hardwood forest group and white spruce is considered a LIT species when not occurring in coastal, highland, or old field forest groups.

Finally, the softwood harvest volumes decreased under the climate change scenario compared to the base scenario starting in period 9, although the flow of spruce-fir harvest was controlled by a minimal constraint and a non-declining yield. The total amount of hardwood harvested from the working land-base was lower in the climate change scenario. However, in the climatic change scenario compared to the base, the hardwood harvest from land being converted to HPF was higher. Less pre-commercial thinning, less commercial thinning, and fewer selection harvests were used to accomplish most of the changes in species composition and, consequently, susceptibility, in the climate change scenario. Interestingly, when carbon was included in the optimization, similar management techniques were preferred, showing that trade-offs between climate mitigation and adaptation are conceivable (NSDNRR, 2021b).

9 PREFERRED MANAGEMENT SCENARIO

Given the information available at the time of the analysis, the v6 base model gradually shifted toward the group's desired strategic level forest modelling scenario. The range of policies under discussion were best addressed by the chosen scenario. Ultimately, run #1 Carbon of the Base v6 scenario, which included carbon in the objective function, was chosen as the preferred scenario (see table 15 above).

According to the recommended scenario, 430,000 gmt/yr is the short-term (20-year average) total sustainable harvest level for the eastern Crown. Approximately 73% (312,000 gmt/yr) is made up of softwood. Short-term softwood harvest in the PHP licence area is 284,000 gmt/yr, or 91% of the overall softwood supply on eastern Crown.

The harvest estimates for each of the three distinct management units (PHP Crown license, MFI East lands (preliminary) and unlicensed eastern Crown land) are compiled in Tables 17 and 18, respectively, for the short-term and long-term projections (NSDNRR, 2021b).

Table 17. Eastern Crown short-term (20-year average) harvest estimates by management unit and species group.

Management Unit	Short-Term Sustainable Harvest Estimate[1] (000's gmt/yr)							
	Softwood		Hardwood		Spruce-Fir		Total	
PHP License	*284*	*91%*	*101*	*86%*	*274*	*91%*	***385***	***90%***
MFI East(preliminary)	*5*	*2%*	*2*	*2%*	*5*	*2%*	***7***	***2%***
Unlicensed Eastern Crown	*23*	*7%*	*15*	*12%*	*22*	*7%*	***38***	***8%***
Total	**312**		**118**		**301**		**430**	
Percent of Total	**73%**		**27%**		**70%**		**100%**	

Table 18. Eastern Crown long–term (50+ year average) harvest estimates by management unit and species group.

Management Unit	**Long-Term Sustainable Harvest Estimate[1] (000's gmt/yr)**							
	Softwood		**Hardwood**		**Spruce-Fir**		**Total**	
PHP License	*447*	*94%*	*103*	*84%*	*429*	*94%*	***550***	***92%***
MFI East(preliminary)	*6*	*1%*	*3*	*2%*	*5*	*1%*	***9***	***2%***
Unlicensed Eastern Crown	*24*	*5%*	*16*	*13%*	*21*	*5%*	***40***	***7%***
Total	**477**		**122**		**455**		**599**	
Percent of Total	**111%**		**28%**		**106%**		**100%**	

Table 19. Final preferred scenario overview by management unit.

	PHP License Area		
	EM	HF	Total
Working Landbase	246	35	281
Harvest Area (ha/yr): Short-Term (20yr Avg)			
Clear Cut	0	1,008	1,008
Patrial Cut:	4,802	246	5,048
Commercial Thin	363	246	609
Low Retention	1,357	0	1,357
Medium Retention	1,467	0	1,467
High Retention	1,615	0	1,615
Sub-Total	4,802	1,254	6,056
Silviculture Area (ha/yr): Short-Term (20yr Avg)			
Plantation	398	1,008	1,405
Natural PCT	1,663	12	1,675
Sub-Total	2,061	1,019	3,080
Treatment Funding (000's $/yr): Short-Term (20yr Avg)			
Silviculture (plantation/pct)	1,821	1,348	3,169
Partial Harvest:	2,021	135	2,156
Commercial Thin	200	135	335
Low Retention	258	0	258
Medium Retention	675	0	675
High Retention	888	0	888
Sub-Total	3,842	1,483	5,325
Harvest (000's gmt/yr): Short-Term (20yr Avg)			
Hardwood	89	12	101
Softwood:	180	105	284
Other Softwood (Pine/eH/tL)	6	4	11
Spruce-Fir	173	100	274
Total	269	117	386
Harvest (000's gmt/yr): Long-Term (50 Yrs+)			
Hardwood	103	0	103
Softwood:	199	248	447
Other Softwood (Pine/eH/tL)	18	0	18
Spruce-Fir	181	248	429
Total	302	248	550

10 CONCLUSIONS

About the numerous new policies being taken into consideration as part of the 2018 Forestry Review process, our research significantly advanced our understanding of what a new sustainable harvest level for the eastern Crown land-base may be. As of December 2020, this research considered all fresh regulations important to long-term planning. These policies were in varying stages of development; thus, some might not have been considered for the analysis.

The primary policies relating to the Forestry Review addressed the crucial issue of TRIAD zoning on Crown land. The analysis used the draft Silviculture Guide for the Ecological Matrix and the HPF Phase 1 Discussion Paper for guidance. The modelling of acceptable management procedures in the EM and HPF zones was aided by these draft policy guidelines.

The analysis was updated in addition to the 2018 Forestry Review to include:

1. The most recent forest inventory and management practices that have an impact on the working forests that can be used for harvest planning, as described in the land-base section. Since the 2016 SFA process, the eastern Crown working land-base has decreased by about 3%, or 11,000ha.

2. Management of forest carbon and climate change at the strategic level.

3. New wildlife special management procedures and wildlife habitat indicators for PHP's certification systems.

A short-term spruce-fir wood supply estimate of 301,000 gmt/yr, of which 274,000 gmt/yr comes from the PHP licence area, was produced by the analytical team's chosen preferred scenario. From the 331,000 gmt/yr estimate in the 2016 SFA, the PHP number is down 17%. As HPF zones start to contribute to the supply of wood over the long term (30-35 years), it is anticipated that the spruce-fir harvest on the PHP Crown lands would increase by 18% over the 2016 SFA to 392,000 gmt/yr.

The HPF zone is given 35,000 ha, or 5% of the entire eastern Crown land-base, under the ideal scenario. As a result, 1,000 ha/yr of HPF are treated annually. About 30% of the remaining 95% of the land is in the EM zone and 65% is in the conservation zone. Traditional clearcutting was not practised under the EM's management; instead, all harvests were some variation of retention cuts, as per the SGEM. Balance for low, medium, and high retention was 28, 31, and 41%, respectively. The clearcutting rate predicted by the 2016 SFA is 3,300 ha/yr, which is more than 3 times the rate predicted under the current regulations (NSDNRR, 2021b).

11 FUTURE IMPROVEMENTS

During the analysis, it was found that the following strategic modelling framework components may be modified to better depict the many new policy directions:

1. The yields of ecological matrix stand development: Even older strata-level yields were stitched together as part of the analysis's methodology to predict a variety of multi-cohort management recommendations. To improve growth and yield projections for these novel prescriptions, more study is required.

2. Include the most recent NDR policy: According to the study, the new policy was not yet in a position where it could be analysed.

3. Include new species at risk policies: Habitat layers and new species at risk policies under development were not accessible at the time of this analysis. Mainland Moose, Lynx, Marten, etc. were included in this.

4. Forest Stewardship Planning: A better comprehension of the VOITS requirements for the upcoming new Forest Stewardship Planning process.

5. Include guidance for the conservation zone: The mission of the new administration calls for increasing protected land to 20% by 2030. These estimates of the sustainable harvest level would be significantly impacted if Crown were to provide the majority of this.

Source: NSDNRR, 2021b

APPENDIX 1: LAND-BASE SUMMARY TABLES

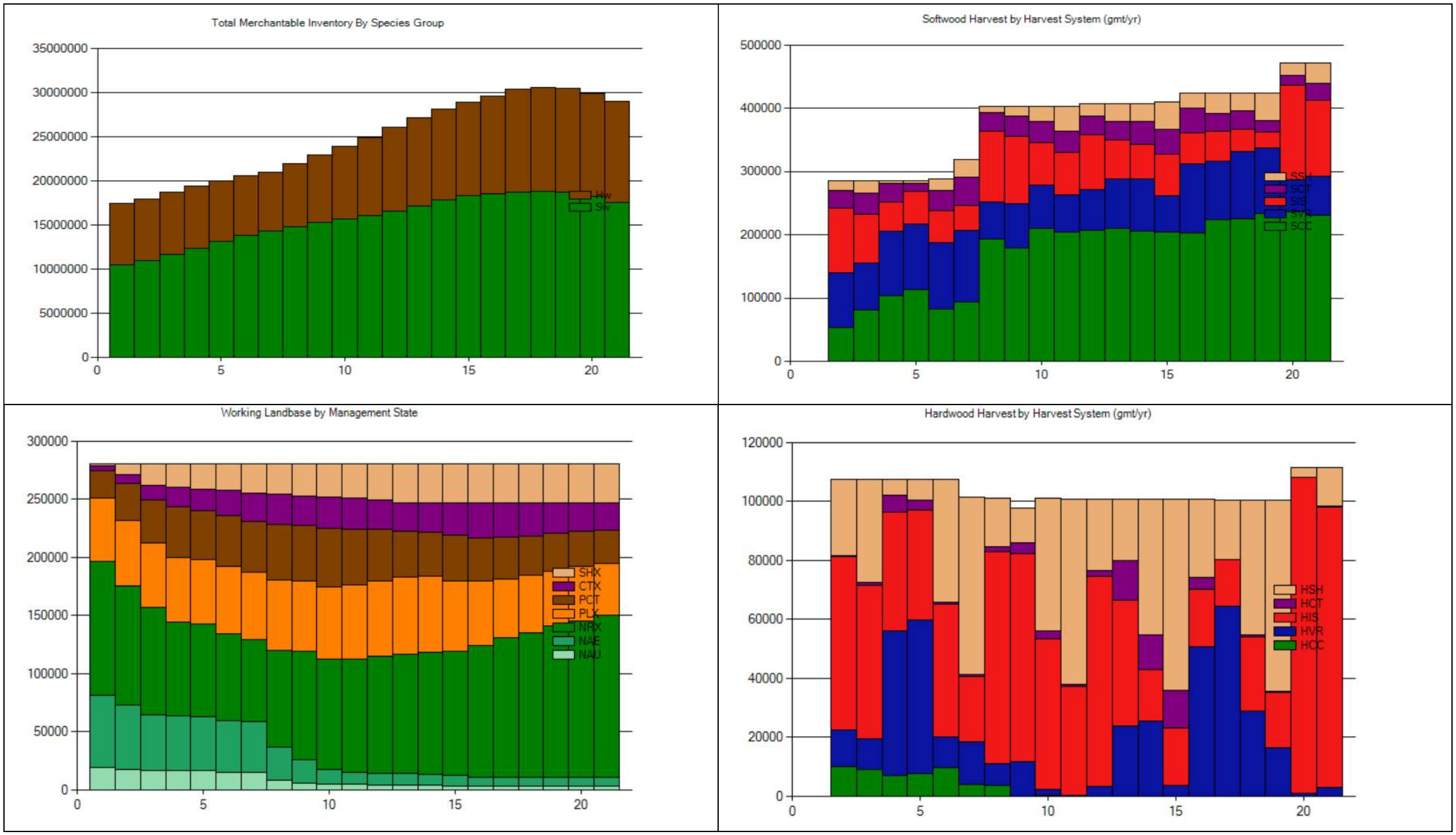
Land-base Changes Since 2016 Strategic Forest Analysis for Eastern Crown

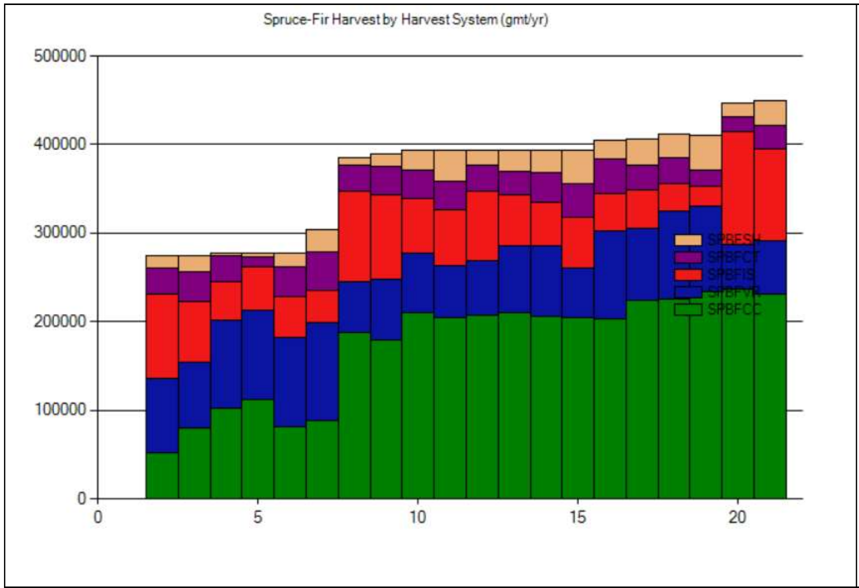
Feb 19, 2020	**Crown Land-base Version**				**Analysis Unit: CRNLICPHP**
	2016v2		**2021v1a**		
		(diff)			
WLB For Analysis	296,076	5,601	290,475	WLB For Analysis	
1.a Non-Forested Land	75,788	1,223	77,012		1.a Non-Forested Land
1.b Non-Forested Roads	6,107	79	6,028		1.b Non-Forested Roads
2.a.1 Designated Protected Area	33,867	3,788	37,655		2.a.1 Designated Protected Area
2.a.2 Protected Area Proposed	26,115	3,443	22,672		2.a.2 Protected Area Proposed
2.b.1 DNR Lynx Habitat Buffers	19,108	198	18,910		2.b.1 DNR Lynx Habitat Buffers
2.b.2 DNR Moose Habitat Buffers	10,889	32	10,857		2.b.2 DNR Moose Habitat Buffers
2.b.3 Costal Plains Flora Buffers	85	18	103		2.b.3 Costal Plains Flora Buffers
2.b.4 Boreal Felt Lichen Buffers	1,001	2,965	3,966		2.b.4 Boreal Felt Lichen Buffers
2.b.5 Other Special Site Habitat	41	521	562		2.b.5 Other Special Site Habitat
2.c DNR Oldgrowth Policy	7,060	2,147	9,207		2.c DNR Oldgrowth Policy
2.d Inoperable/Subjective Removals	20,498	949	19,549		2.d Inoperable/Subjective Removals
2.e Other Regional Harvest Exclusions	1,516	120	1,396		2.e Other Regional Harvest Exclusions
		6	6		2.f Aborigional Offered Lands
3.a.1 Regulation Watercourse Buffers (20	12,322	248	12,074		3.a.1 Regulation Watercourse Buffers (20
3.a.2 Main River Buffers (100m)(Crown O	65	1	64		3.a.2 Main River Buffers (100m)(Crown O
3.a.3 Non-Watercourse Open Bog Buffers	543	21	522		3.a.3 Non-Watercourse Open Bog Buffers
3.a.4 Non-Watercourse Treed Bog Buffers	5,839	173	5,666		3.a.4 Non-Watercourse Treed Bog Buffers
3.b.1 Marten Patches	9,215	53	9,269		3.b.1 Marten Patches
3.b.2 Deer Wintering Areas	11,483	251	11,232		3.b.2 Deer Wintering Areas
3.b.3 Mainland Moose Concentration Are	114,790	2,468	112,322		3.b.3 Mainland Moose Concentration Are
3.b.4 Wood Turtle Habitat Areas	275	33	308		3.b.4 Wood Turtle Habitat Areas
		n/a	7,842		3.b.5 BFL Habitat buffers 200-500m
		n/a	33,508		3.b.6 Bicknells Thrush Habiata Areas
		n/a	3,581		3.c Rare Ecosections
		n/a	2,428		3.d Protected Areas 100m Buffer
3.c IRM - C2 Areas	92,093	n/a	52,414		3.e IRM - C2 Areas
4.a WLB No Restrictions	62,380	n/a	51,904		4.a WLB No Restrictions

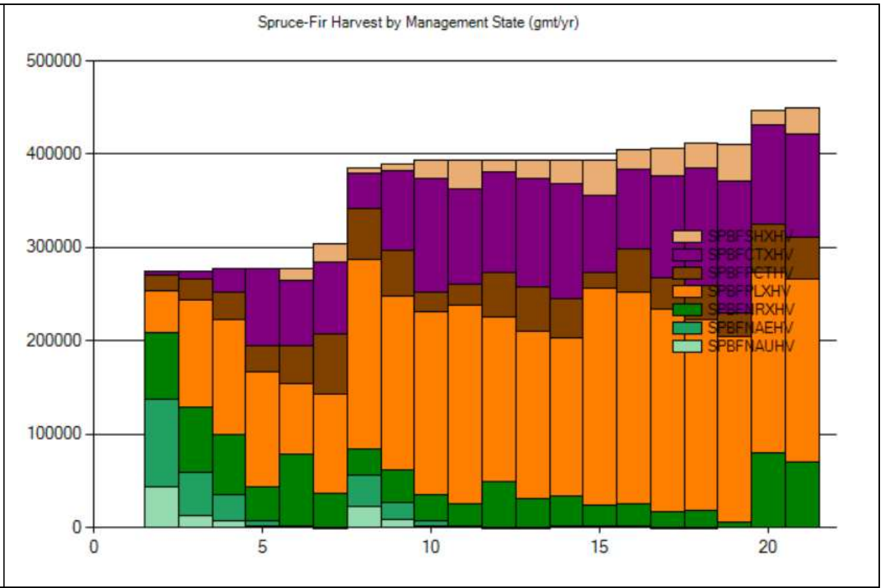
Source: NSDNRR, 2021b

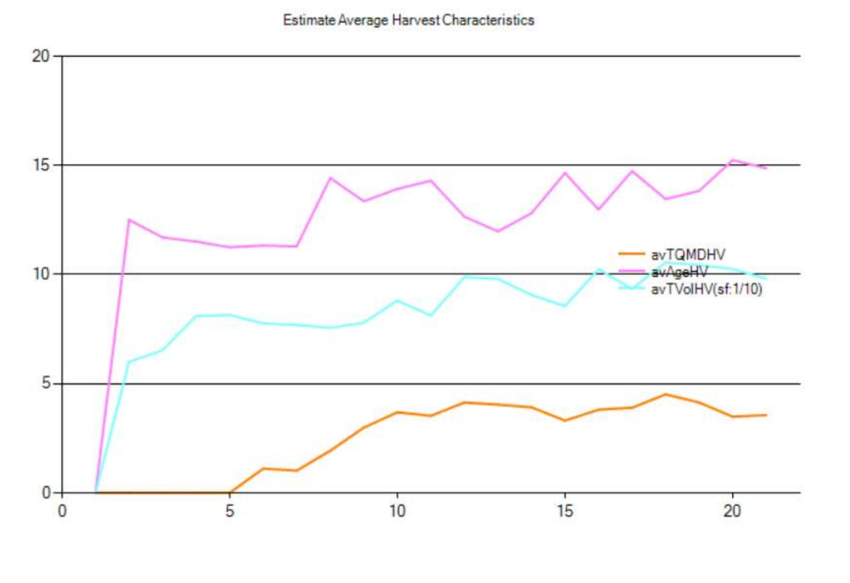
APPENDIX 2: PREFERRED SCENARIO CHARTS

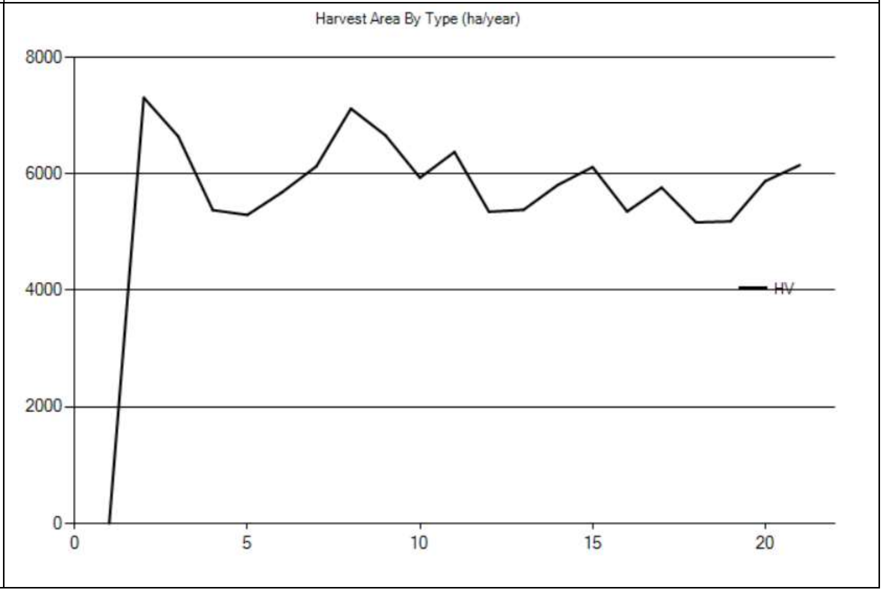
Harvest

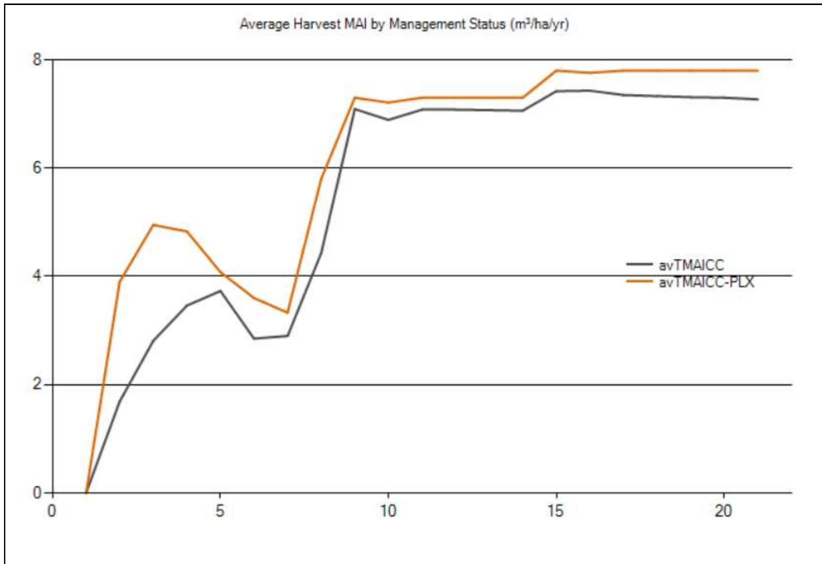


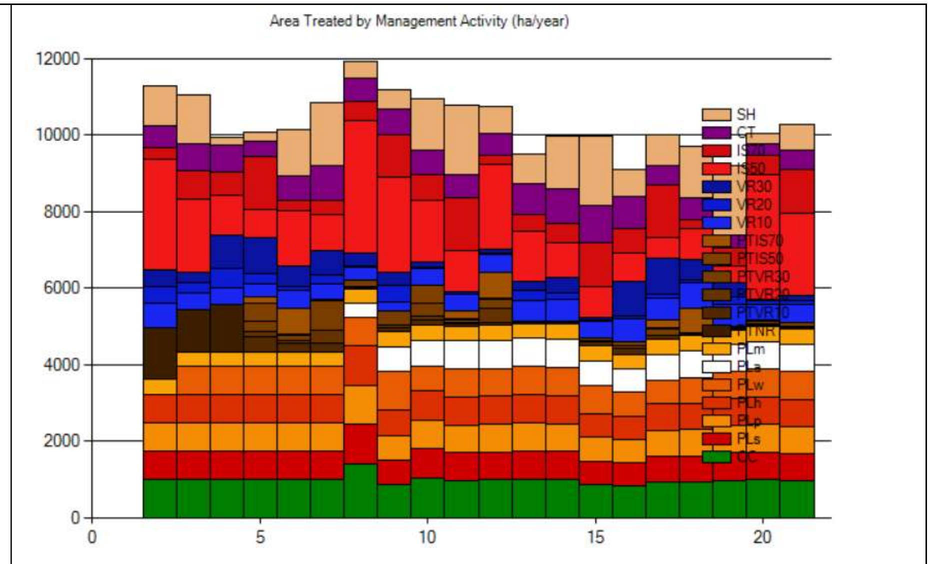

Spruce-Fir Harvest by Harvest System (gmt/yr)
500000
400000
300000
200000
100000
0
0
5
10
15
20
SPBFSH
SPBFCT
SPBFIS
SPBFCC

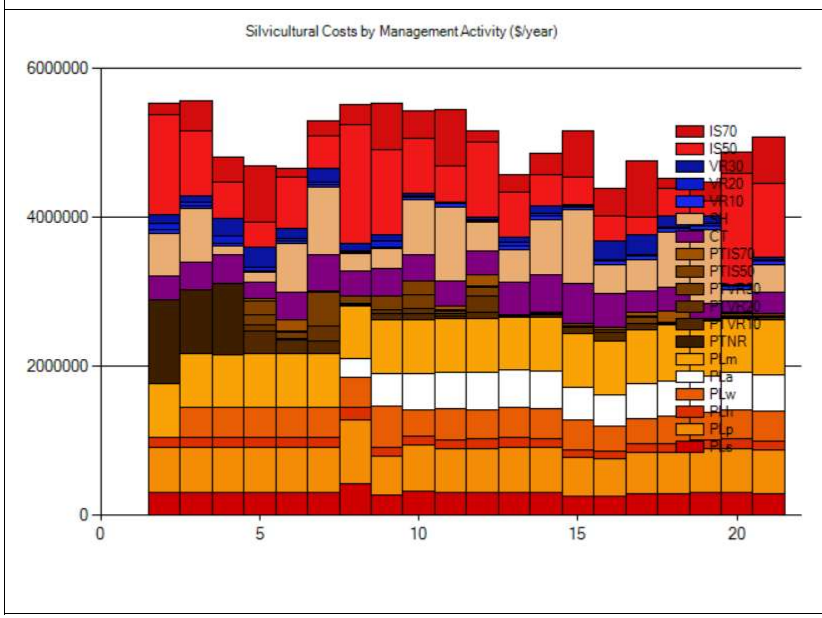

Spruce-Fir Harvest by Management State (gmt/yr)
500000
400000
300000
200000
100000
0
0
5
10
15
20
SPBFSHXHV
SPBFCTXHV
SPBFPLXHV
SPBFNAEHV
SPBFNAUHV

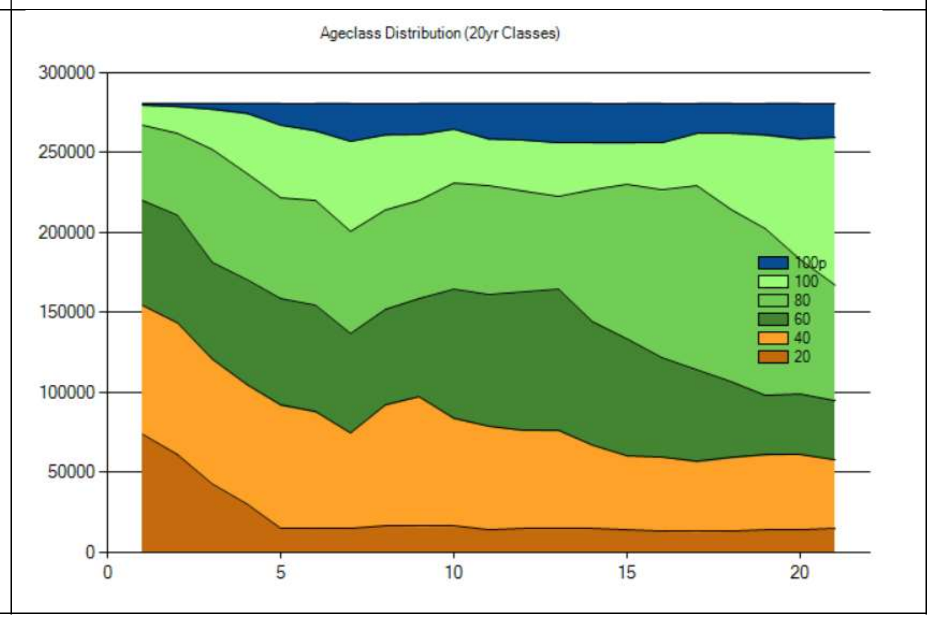

Estimate Average Harvest Characteristics
20
15
10
5
0
0
5
10
15
20
avTQMDHV
avAgeHV
avTVolHV(sf:1/10)


Harvest Area By Type (ha/year)
8000
6000
4000
2000
0
0
5
10
15
20
HV

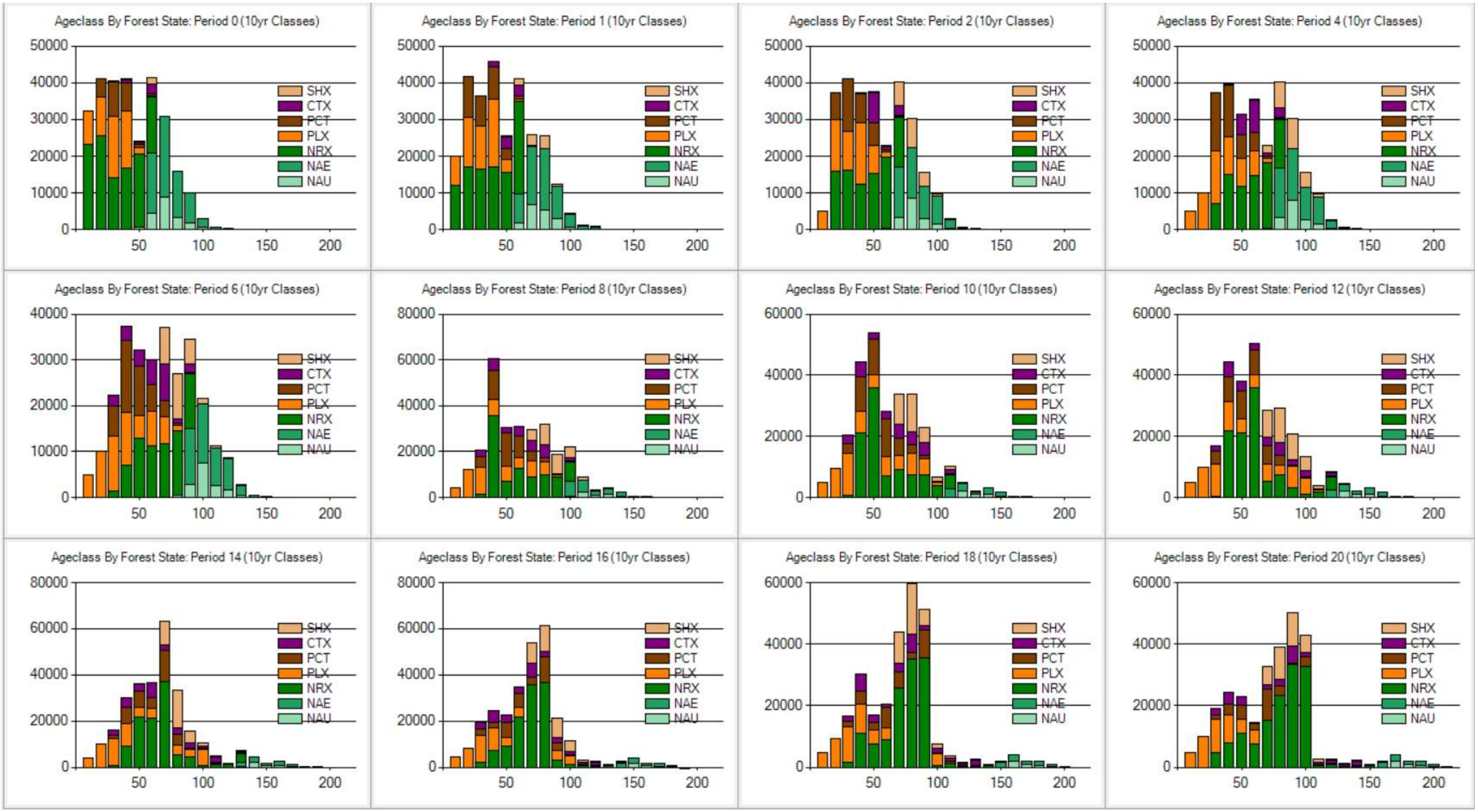

Average Harvest MAI by Management Status (m³/ha/yr)
avTMAICC
avTMAICC-PLX
0
2
4
6
8
0
5
10
15
20


Area Treated by Management Activity (ha/year)
SH
IS50
VR30
VR20
VR10
PTIS50
PTVR30
PLm
PLw
PLs
0
2000
4000
6000
8000
10000
12000
0
5
10
15
20

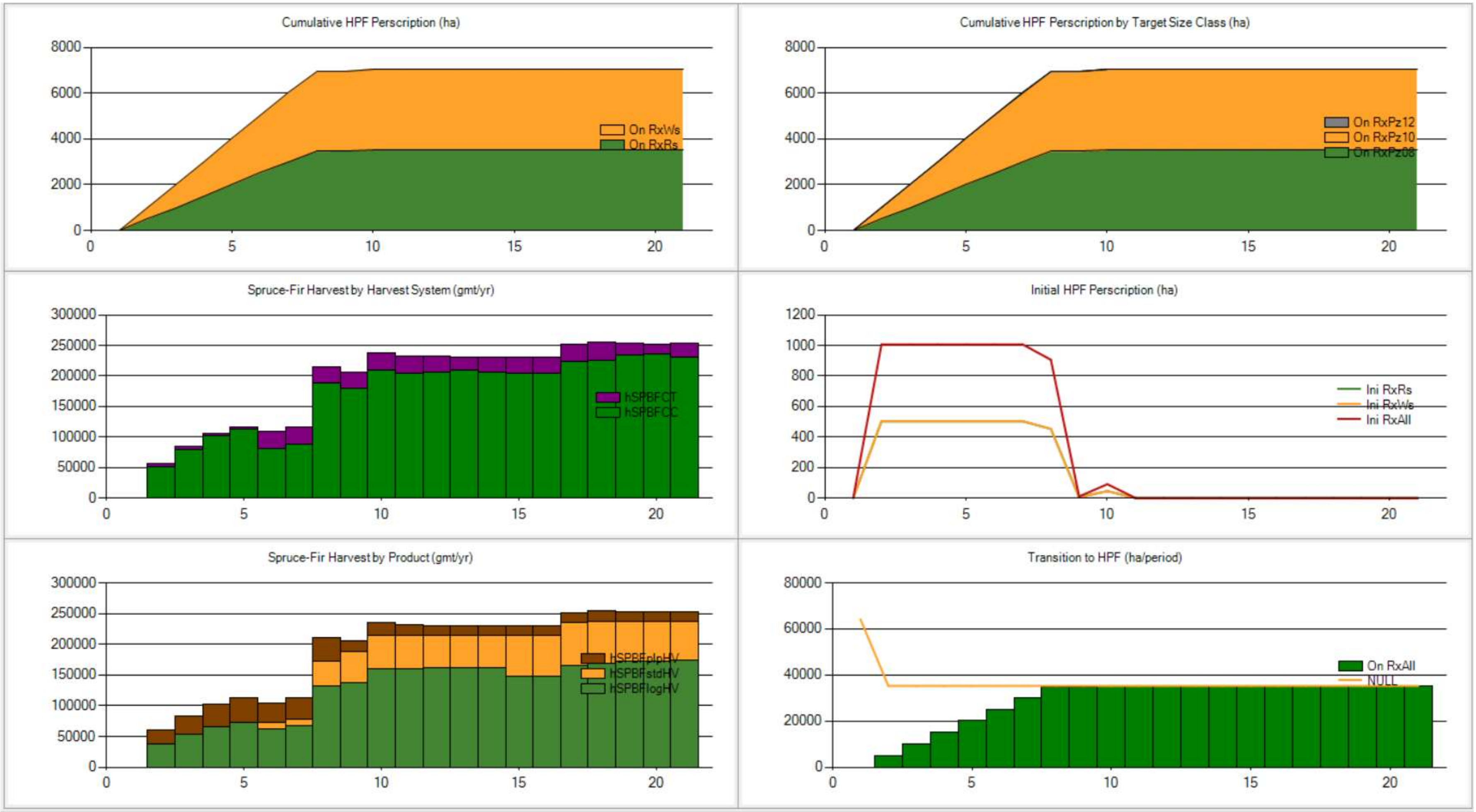

Silvicultural Costs by Management Activity ($/year)
IS70
IS50
PTNR
PLm
PLw
0
2000000
4000000
6000000
0
5
10
15
20


Ageclass Distribution (20yr Classes)
100p
100
80
60
40
20
0
50000
100000
150000
200000
250000
300000
0
5
10
15
20

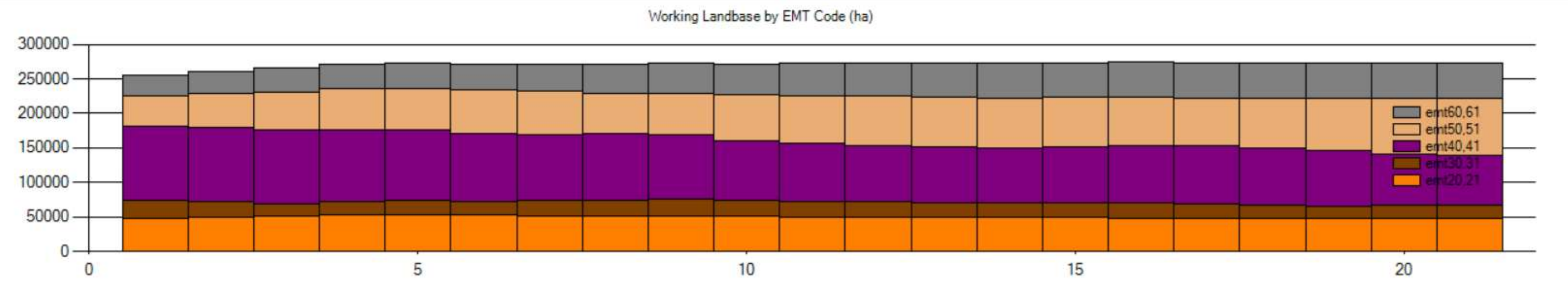
Working Land-base Ageclass

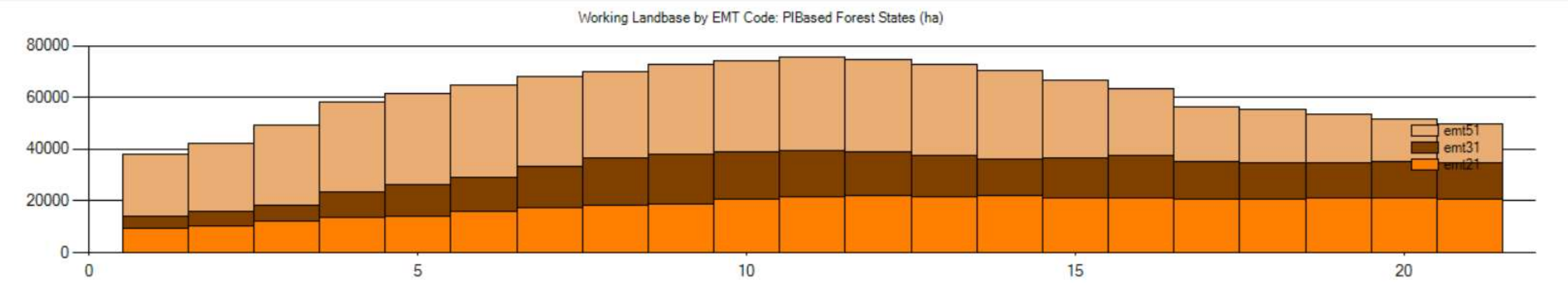


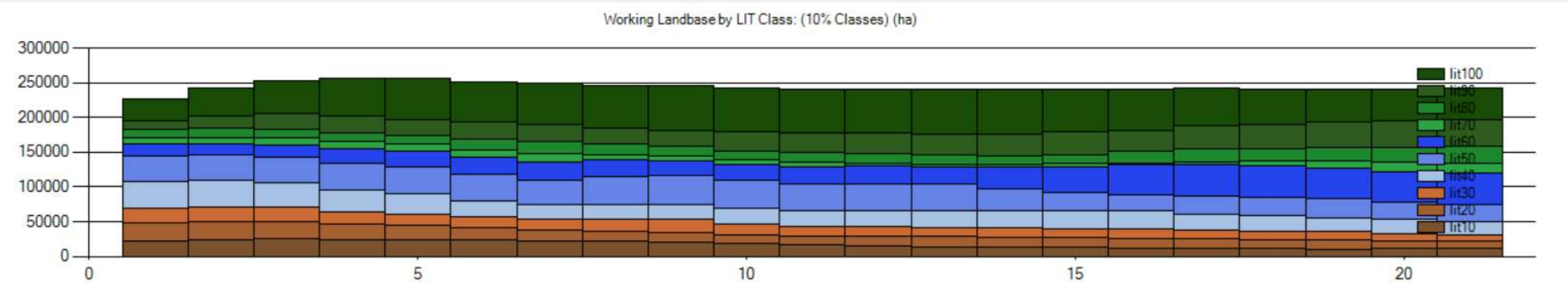
High Production Forestry



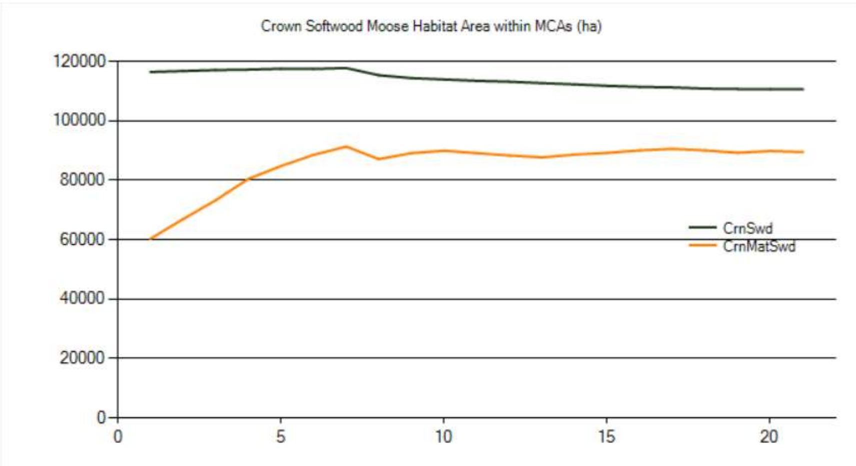
Ecological Matrix

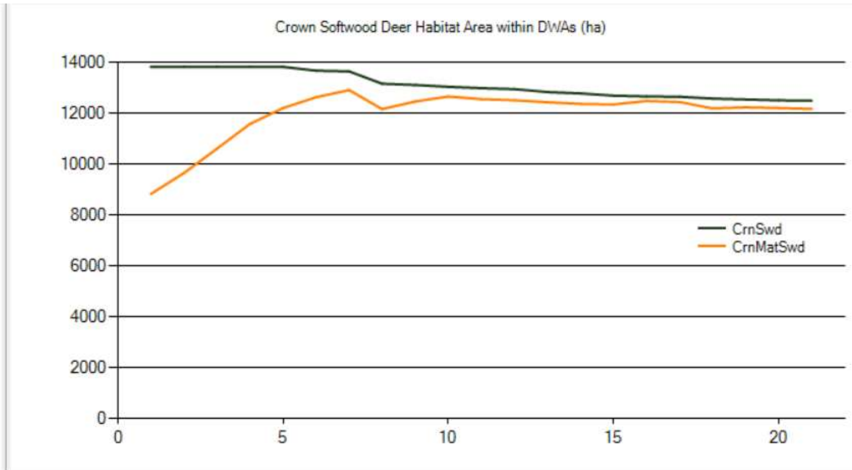


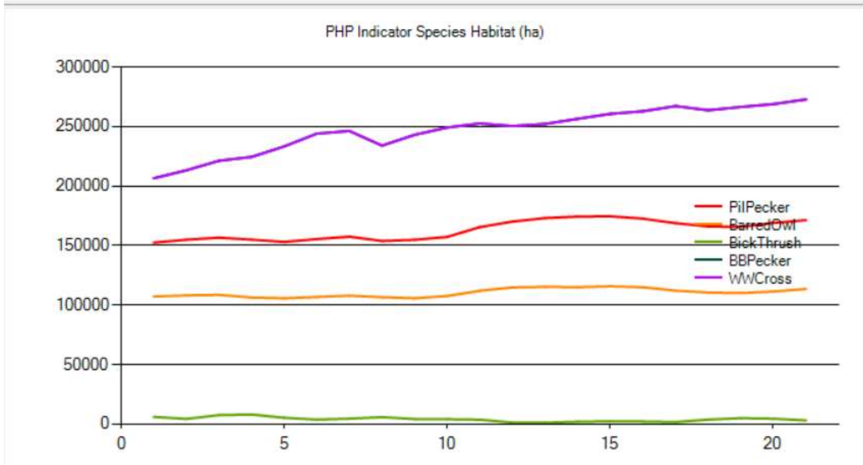


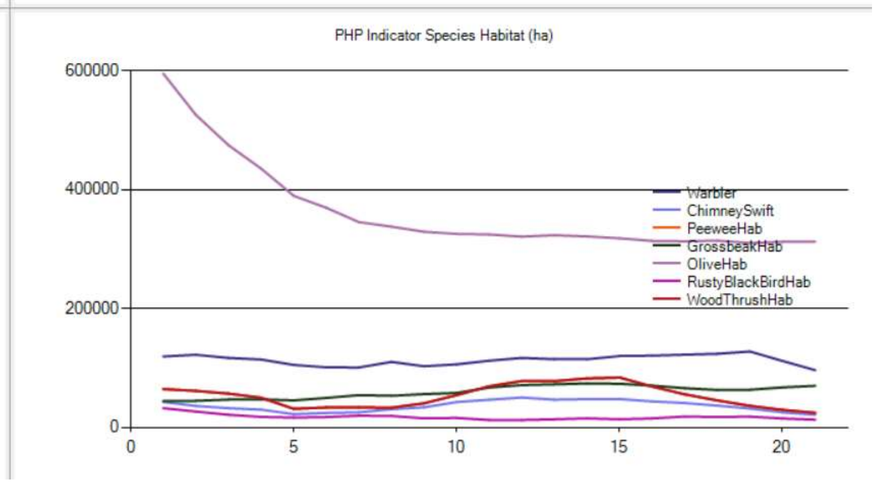


Wildlife Habitat

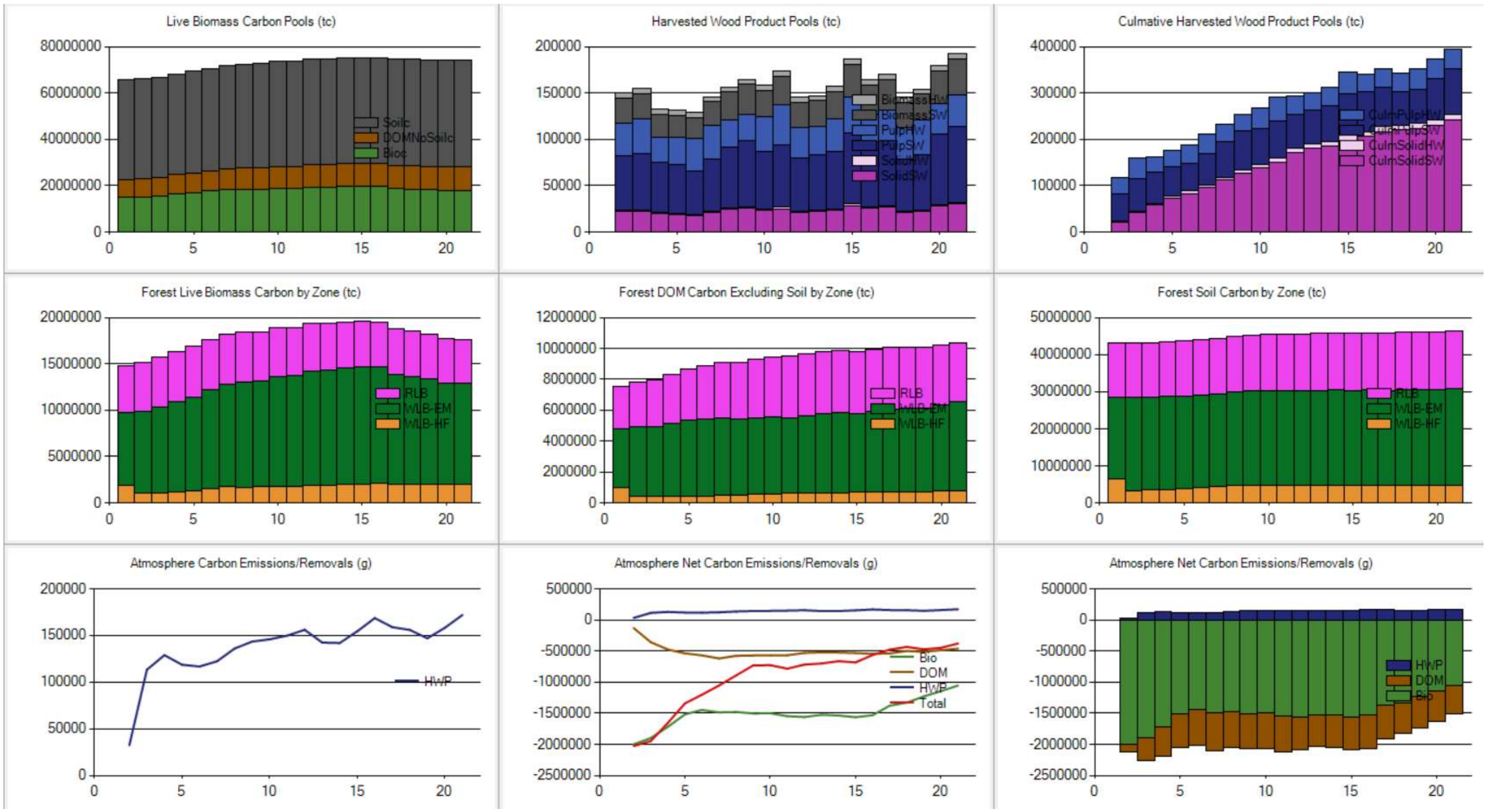






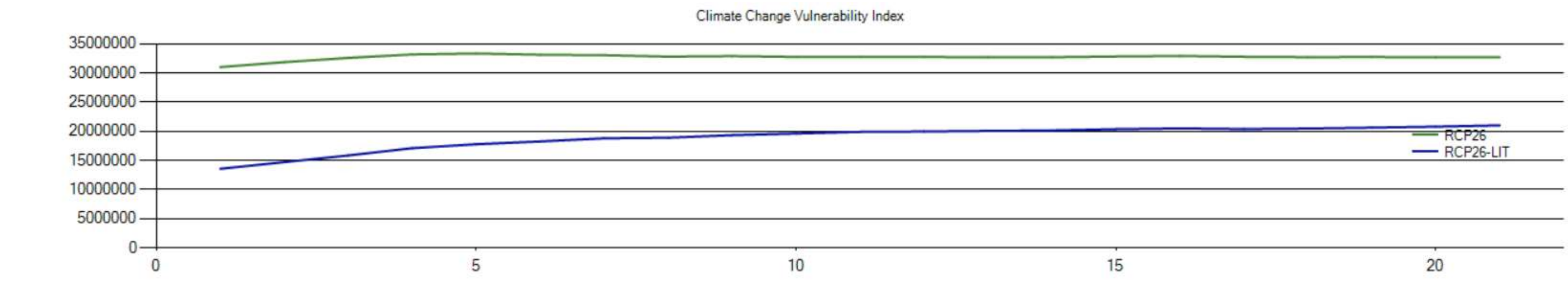


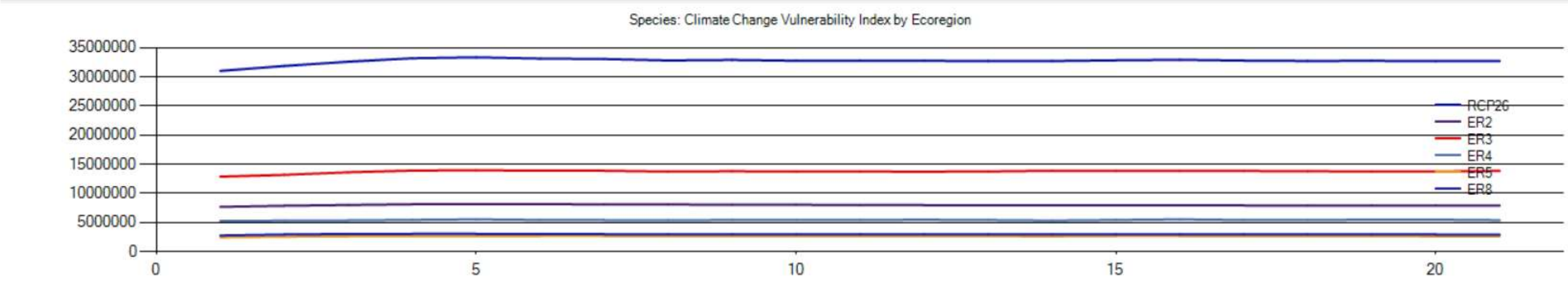
Carbon

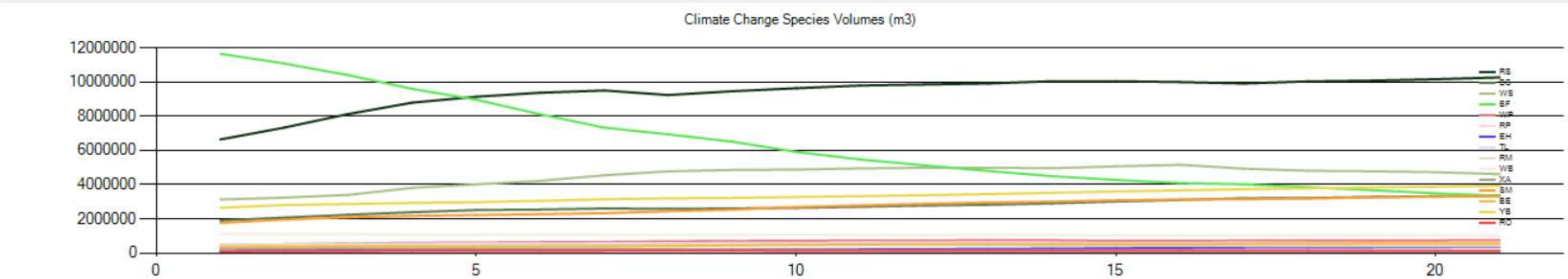


Live Biomass Carbon Pools (tc)
Soilc
DOMNoSoilc
Bioc
Harvested Wood Product Pools (tc)
BiomassHW
BiomassSW
PulpHW
PulpSW
SolidHW
SolidSW
Culmative Harvested Wood Product Pools (tc)
CulmPulpHW
CulmSolidHW
CulmSolidSW
Forest Live Biomass Carbon by Zone (tc)
RLB
WLB-EM
WLB-HF
Forest DOM Carbon Excluding Soil by Zone (tc)
RLB
WLB-EM
WLB-HF
Forest Soil Carbon by Zone (tc)
RLB
WLB-EM
WLB-HF
Atmosphere Carbon Emissions/Removals (g)
HWP
Atmosphere Net Carbon Emissions/Removals (g)
Bio
DOM
HWP
Total
Atmosphere Net Carbon Emissions/Removals (g)
HWP
DOM
Bio

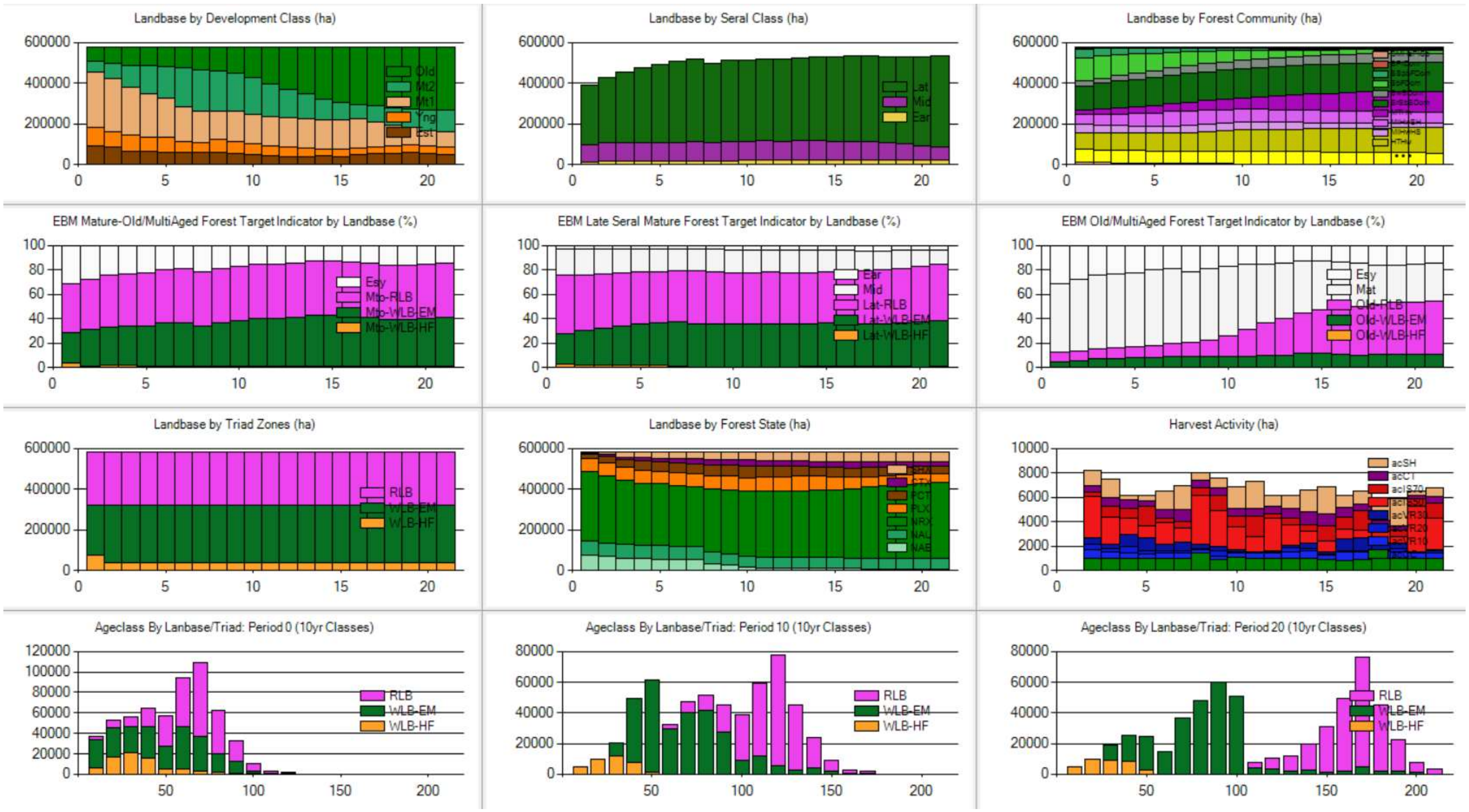
Climate Change





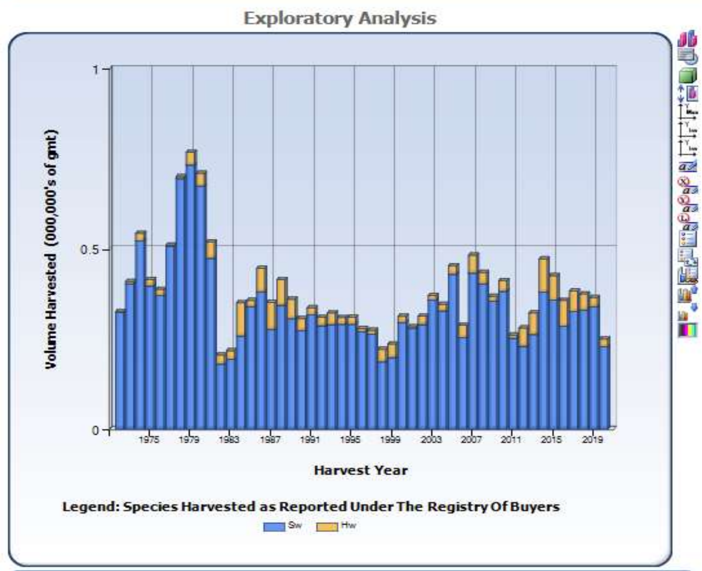


Ecosystem Based Management



APPENDIX 3: HARVEST REGISTRY DATA FOR EASTERN CROWN

Summary Chart...



Data Options (Scope:Filtered to 10% of the Province or 21,222,563m3)...

Current Scope is 10% of the Province or 21,222,563m3. Filters Included:
[County('Group(Cape,Inve,Rich,Vict,Anti,Guys,Pict)'), Land Tenure('Provincial Crown'),]

Select Data:

X-Axis Data: Harvest Year
Y-Axis Data: Volume Harvested (gmt)
Group Data: Harvest Species
Data Scale: by 1,000,000

Summary Table...

Exploratory Analysis

GroupBy	Sw	Hw	Total
2020	228,213	22,063	250,276
2019	340,064	25,159	365,223
2018	330,537	44,511	375,048
2017	326,585	56,788	383,373
2016	285,809	71,333	357,142
2015	358,298	67,683	425,982
2014	380,418	92,117	472,536
2013	262,357	60,411	322,769
2012	229,937	50,849	280,786
2011	252,519	8,803	261,322
2010	382,740	29,488	412,228
2009	355,197	13,509	368,706
2008	403,136	31,774	434,910
2007	433,251	49,747	482,998
2006	254,213	34,005	288,219
2005	429,777	23,444	453,222
2004	327,708	18,518	346,226
2003	358,316	12,340	370,656
2002	290,255	23,237	313,492
2001	278,910	5,006	283,916

REFERENCES

Bush, E. and Lemmen, D.S., editors (2019). Canada's Changing Climate Report. Government of Canada, Ottawa, ON. 444 pp.

IPCC 2006, 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Published: IGES, Japan

Kurz, W.A. et al. (2009). Carbon Budget of Canada's Managed Forest Derived from a Combined Inventory and Modelling Approach. Natural Resources Canada, Canadian Forest Service.

Lambert, M.-C.; Ung, C.-H.; Raulier, F. 2005. Canadian national tree aboveground biomass equations. Can. J. For. Res. 35: 1996-2018.

MacLean, D. A. et al. (2021). Natural disturbance regimes for implementation of ecological forestry: a review and case study from Nova Scotia, Canada. *Environmental Reviews*. **30**(1): 128-158.

Nova Scotia Department of Natural Resources (2017). Crown Lands Forest Model, Nova Scotia 2016 Strategic Forest Analysis (SFA) Technical Report. Forest Resource Analyst Group, Forestry Division. 160 pp.

Nova Scotia Department of Natural Resources & Renewables (2020). High Production Forestry Phase 1 – Discussion Paper. 26 pp.

Nova Scotia Department of Natural Resources & Renewables (2021). High Production Forestry in Nova Scotia Phase 1 – Final Report. 50 pp.

Nova Scotia Department of Natural Resources & Renewables (2021a). Nova Scotia Silvicultural Guide for the Ecological Matrix. 194 pp.

Nova Scotia Department of Natural Resources & Renewables (2021b). Eastern Crown Analysis Summary Report. Forest Resource Analyst Group, Forestry Division. 60 pp.

Smyth et al. (2014). Quantifying the Biophysical Climate Change Mitigation Potential of Canada's Forest Sector. Biogeosciences Discuss. 11, 441-480.

Taylor, Anthony & MacLean, David & Neily, Peter & Stewart, Bruce & Quigley, Eugene & Basquill, Sean & Boone, Celia & Gilby, Derek & Pulsifer, Mark. (2020). A review of natural disturbances to inform implementation of ecological forestry in Nova Scotia, Canada. Environmental Reviews. 10.1139/er-2020-0015.