Type 4 Silviculture Strategy

Modelling and Analysis Report – 100 Mile House TSA

Version 2.6

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1 Introduction

1.1 Context

This document is the third of four documents that make up a type IV Silviculture Strategy, the documents are:

1. Situational Analysis – describes in general terms the situation for the unit – this could be in the form of a PowerPoint presentation with associated notes or a compendium document.
2. Data Package - describes the information that is material to the analysis including the model used, data inputs and assumptions.
3. **Modeling and Analysis report –provides modeling outputs and rationale for choosing a preferred scenario.**
4. Silviculture Strategy –provides treatment options, associated targets, timeframes and benefits.

1.2 Analysis Assumptions

The following key assumptions are employed in this analysis:

- Silviculture opportunity evaluation is not limited by factors such as the availability of funding, funding source, or the ability to deliver a program. However, the final preferred strategy will be plausible.
- “Normal” market conditions will prevail in terms of demand and prices for timber and fibre.
- Mountain pine beetle populations have moved from epidemic to endemic levels, and no additional large scale mortality will occur.

A Type 4 analysis is not timber supply review (TSR). This is an important point when interpreting any of the analysis results. The Type 4 analysis, while projecting timber supply, establishes a base line against which silviculture investment scenarios are compared. Analysis assumptions used in this analysis are detailed in the Data Package (FESL, 2013), one of the documents that make up the Type 4 Silviculture Strategy.

While we attempted to ensure that most of the analysis assumptions in this analysis are consistent with those used in a formal TSR, differences exist. Most notable are the mountain pine beetle related assumptions dealing with the merchantability of beetle killed timber, i.e. shelf life. The shelf life assumptions are discussed in detail in the data package with some discussion also included in this document (Section 2.2.1).

2 Base Case

2.1 Model Output

2.1.1 Harvest Forecast

Figure 1 illustrates the base case harvest forecast. The initial harvest level of 2 million m^3 per year is maintained for 5 years. The mid term is predicted to drop to approximately 757,000 m^3 per year then increase to 840,000 m^3 at year 41. Another two steps – one at year 51 to 1,228,600 m^3 per year and another at year 71 - are required until the long-term harvest level of 1,662,900 m^3 per year is reached.

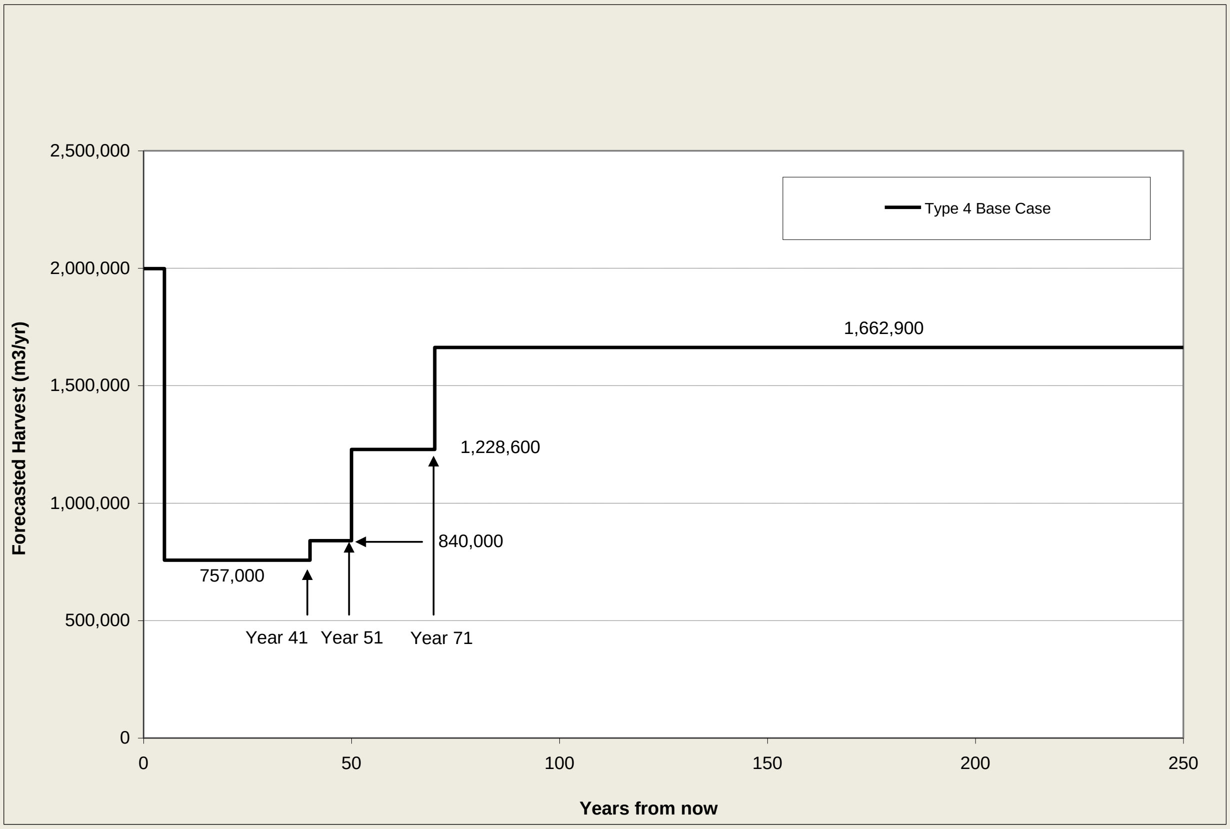


Figure 1: Base case harvest forecast

2.1.2 Unharvested Dead Pine Stands

In the base case approximately 65,000 ha of severely attacked dead pine stands are predicted to remain unharvested. While some of these stands do not get harvested in the model due to biodiversity constraints, most of them are already relatively low volume stands at the beginning of the planning horizon as shown in (Table 1); in 2013 20.1% of these stands are predicted to contain less than 61 m^3 per ha while 51.3% are predicted to have a merchantable volume between 61 and 100 m^3 per ha. The shelf life assumptions in the analysis reduce the merchantable volume of these stands further. By 2033 92% of these stands are predicted to have per ha volume less than 61 m^3 per ha (Table 1). These stands are set to break up in the model and continue growing as a combination of younger stands and the residual stands left from the MPB infestation. Figure 2 illustrates the spatial location of the stands that are predicted to remain unharvested in the base case.

Note that the predicted unharvested area of 65,000 ha is subject to a great deal of uncertainty. It is a model generated estimate; it is not possible to accurately predict whether the area licensees will in fact utilize some or most of these stands regardless of their low predicted volume per ha.

Table 1: Estimated volume of unharvestedMPB killed stands

Volume per ha (m3)	Year 2013	Year 2033
< 61	20.1%	92.0%
61 to 100	51.3%	3.5%
101 to 200	23.9%	4.4%
201 to 300	4.1%	0.1%
301 to 400	0.4%	
>400	0.2%	
Total	**100.0%**	**100.0%**

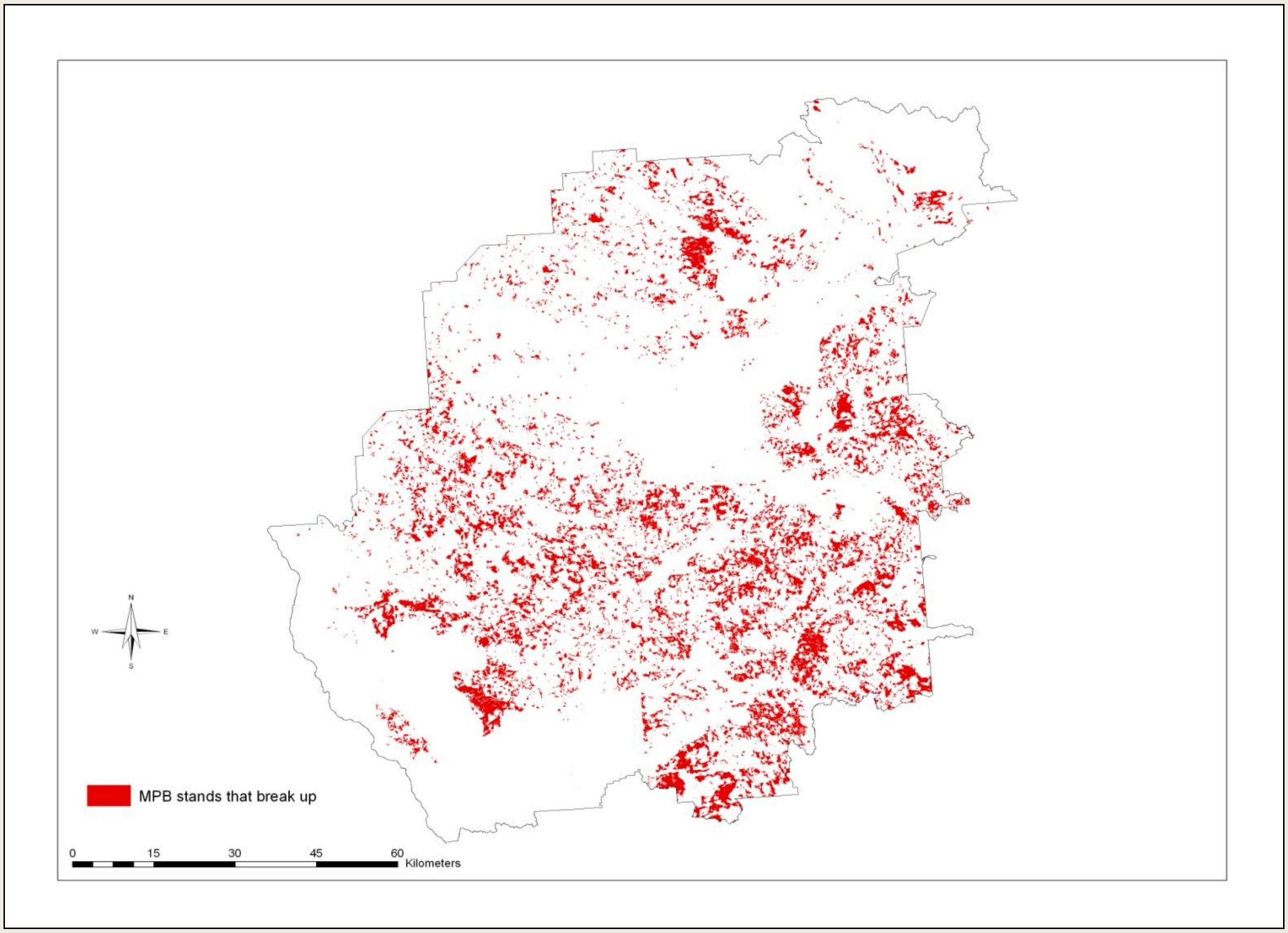


Figure 2: Dead pine stands that remain unharvested in the base case

2.1.3 Growing Stock

Figure 3 and Figure 4 depict the predicted growing stock development for the base case. Note that the presented growing stock development pertains to the model THLB of 523,524 ha, net of the WTP reduction of 138,676 ha. The stability of the growing stock in the long run is an indicator of sustainable harvest. The merchantable growing stock decreases from 47 million m^3 at year 0 to 12 million m^3 at year 30 before recovering. This rapid decrease is caused by the volume lost to the MPB attack and the high harvest level to facilitate salvage of the attacked stands. Assuming that the current management practices continue, pine is predicted to constitute approximately 50 % of the total THLB volume in the 100 Mile TSA in the long term (Figure 4).

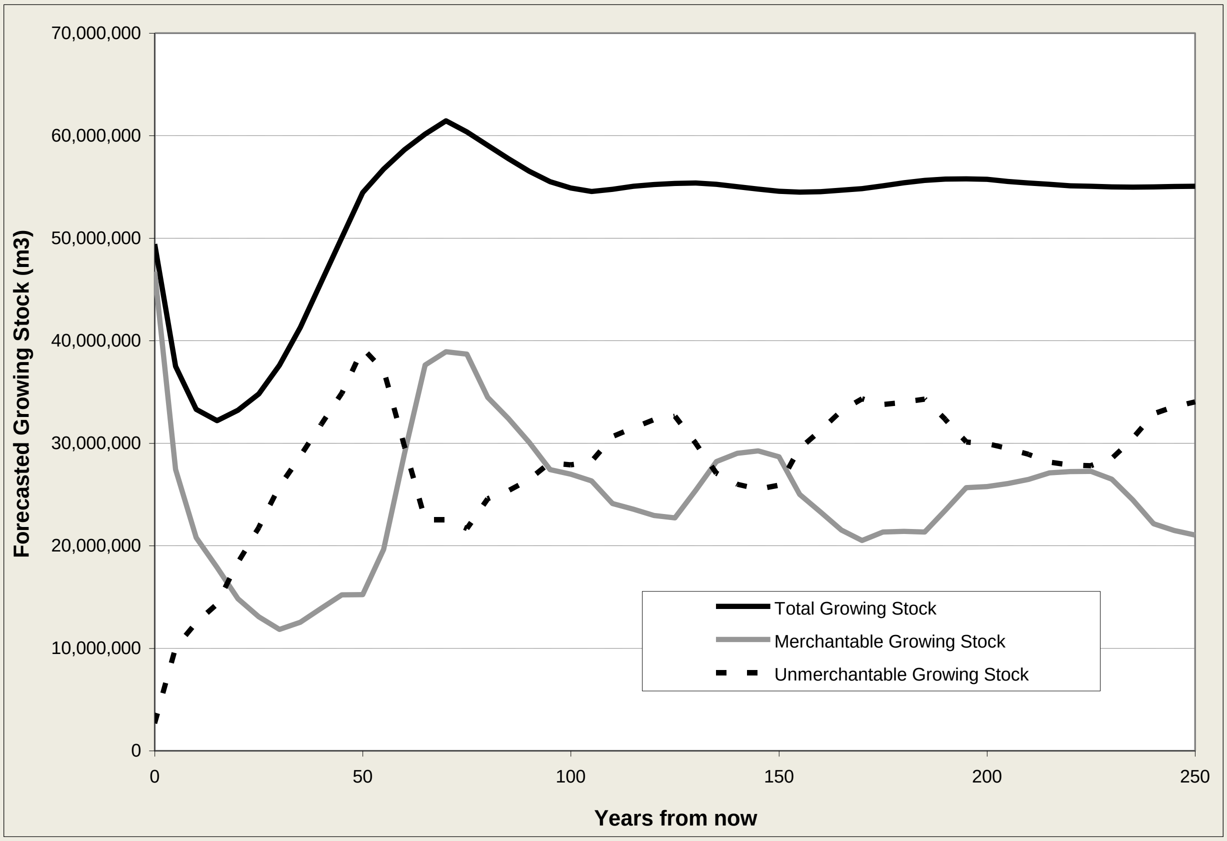


Figure 3: Predicted growing stock development: base case

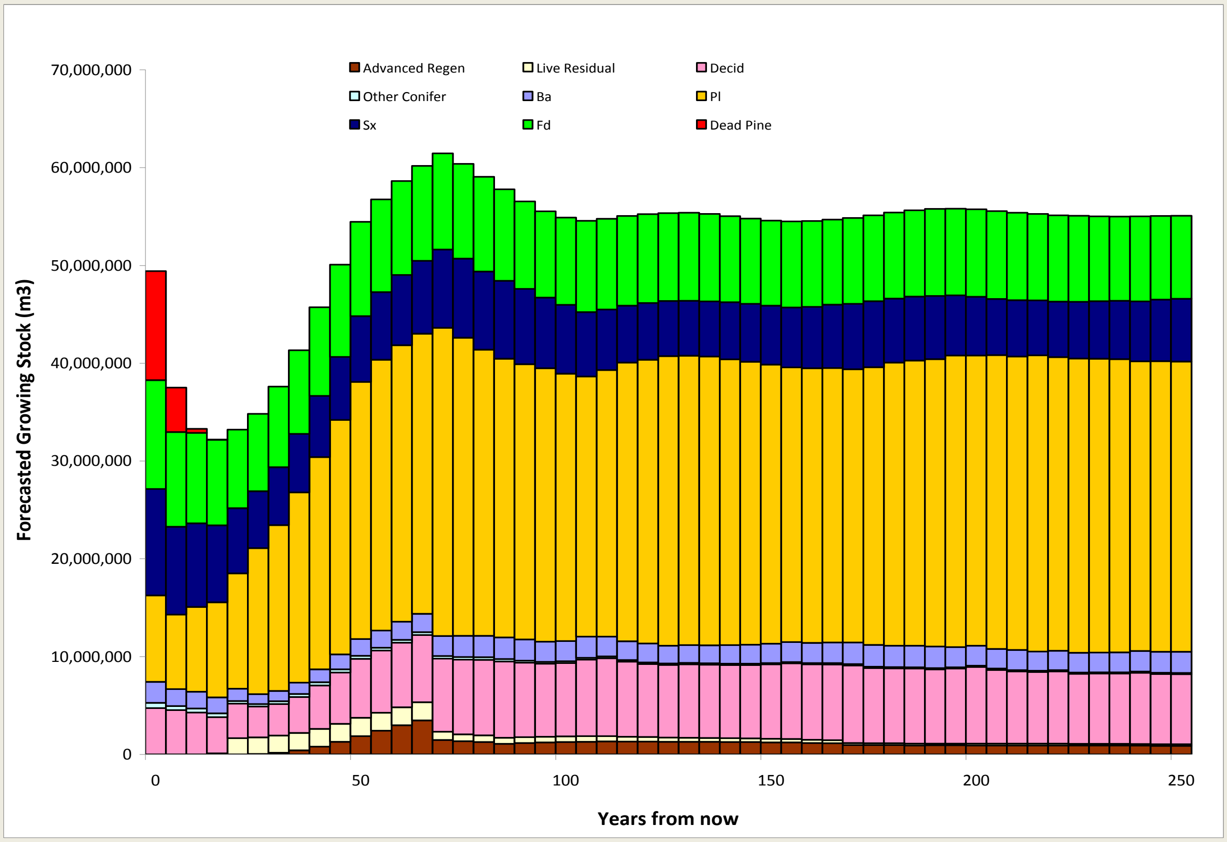


Figure 4: Predicted growing stock development by species: base case

2.1.4 Harvest by Species and Forest Unit

Figure 5 shows the base case harvest forecast by species. Almost all the merchantable dead pine is harvested in the first five years in the model. Only 21% of the harvest in the first 5 years is dead pine; however, 70% of the harvest comes from MPB attacked stands. Approximately 25 % of the harvest in the first five years is spruce, mostly from spruce-leading stands susceptible to spruce bark beetle. Douglas-fir, balsam, and deciduous species are mixed with the dead pine and spruce, and are harvested as the secondary species in the first five years. In the long term, over 60% of the harvest is predicted to consist of pine.

Figure 6 illustrates the harvest forecast by forest unit. The model output was divided into 5 classes: more than 50% killed (severe), 50% or less killed (mild), no MPB attack (natural), managed stands, and residual/advanced regeneration. Note that while all dead pine is gone after the first 5 years, harvesting of stands that were 50% or more killed (red) still occurs between years 6 and 15; they still contain enough volume – even after the pine is lost – to meet the minimum merchantability criteria to be harvested. If these stands are not harvested within 20 years of death, they become residual/advanced regeneration stands. Their ages are reset to that of advanced regeneration.

Managed stands consist of all stands that are currently younger than 50 years of age and future managed stands. The harvest of these stands starts between years 26 and 30 and by year 35 makes up about 60% of the total harvest (Figure 6). During the rest of the mid-term, managed stands make up more than 90% of the harvest with the exception of years 65 to 70 where the harvest of a substantial amount of residual/advanced regeneration stands is forecast to occur. The health, quality and performance of the managed stands are crucial to the mid-term timber supply. Treatments which increase growth and yield of these stands have the potential to improve the mid term harvest.

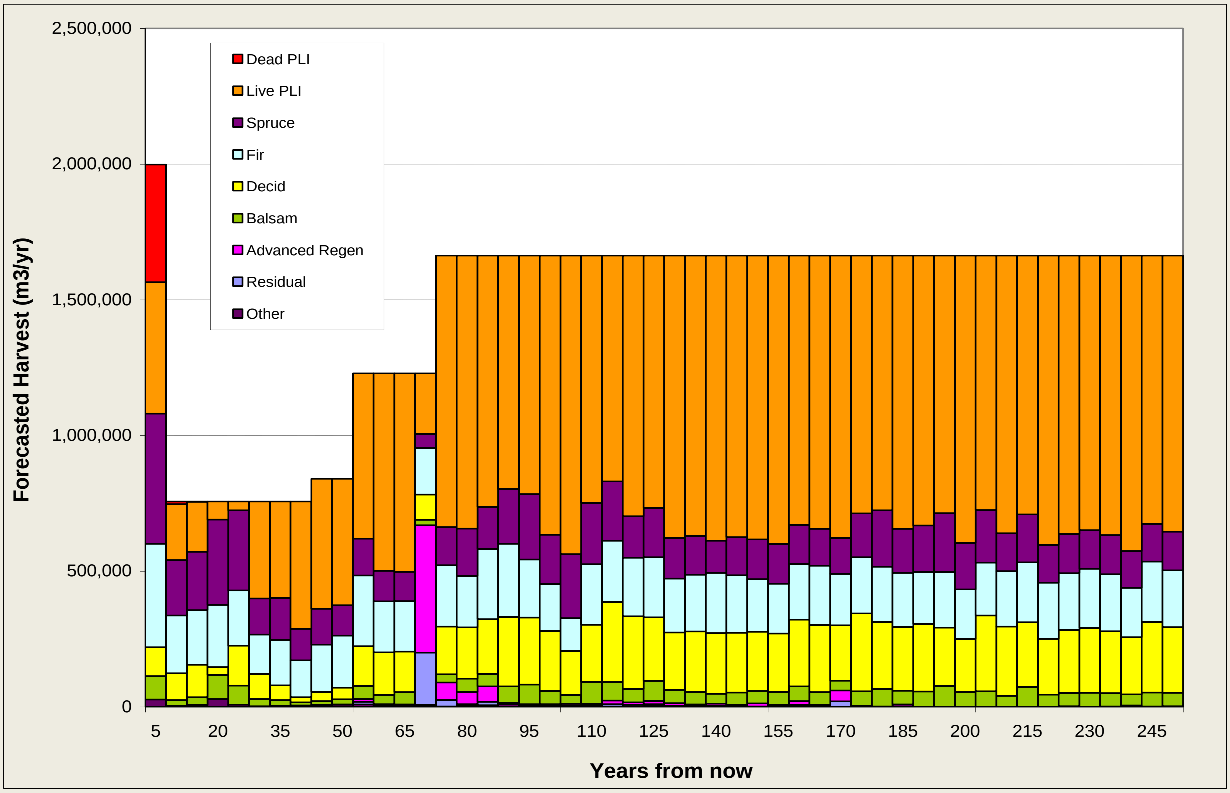


Figure 5: Harvest forecast by species; base case

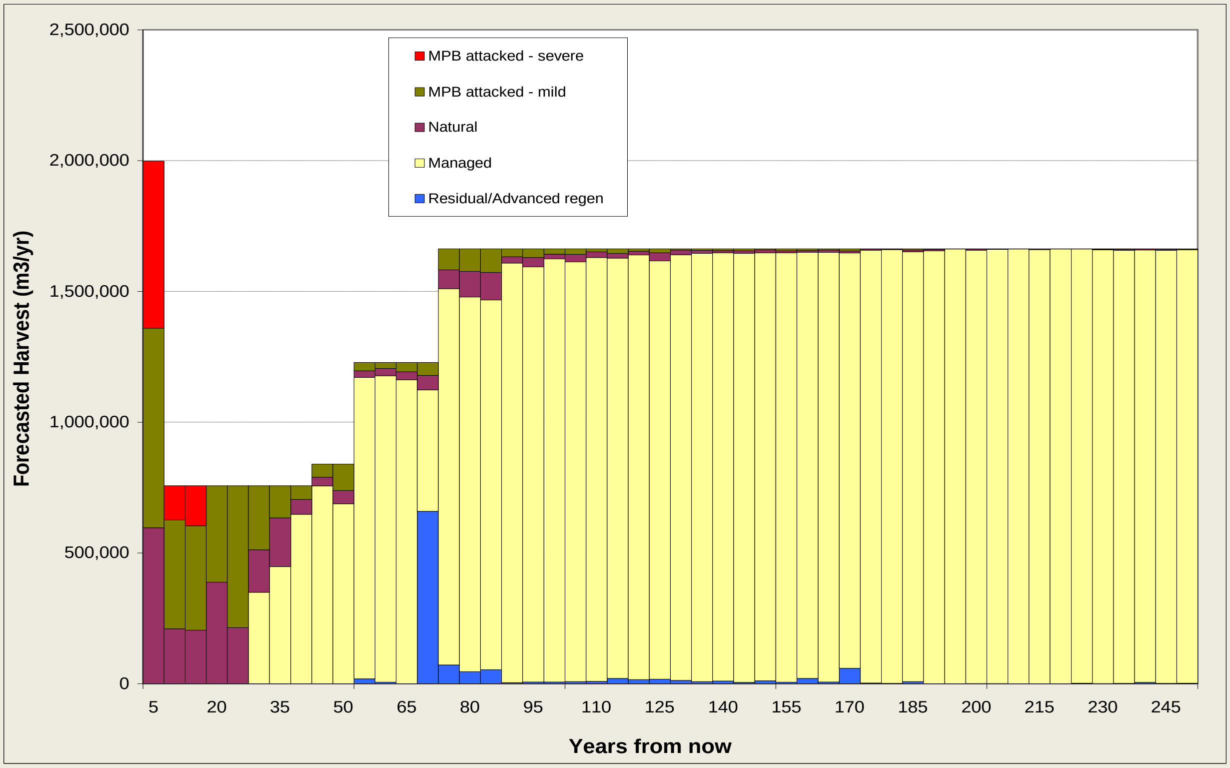


Figure 6: Harvest forecast by forest unit; base case

2.1.5 Harvest by Age, Volume and Area

Figure 7 shows the forecasted harvest volume broken down by age class. Initially most harvested stands are older (>100 years old). At year 26, managed stands which are harvested between ages 61 and 80 start contributing significantly to the timber supply. In the long term over 60% of the harvest volume comes from pine leading managed stands harvested at ages between 61 and 80 years old, with the majority of the remaining volume coming from managed stands harvested at ages 81 to 100. This is also depicted in Figure 8 showing the predicted average harvest age over time. In the long term the average harvest age settles at around 75 years.

Figure 9 illustrates the harvest forecast by volume class. In the first five years, which represents the end of the heavy salvage period, a significant proportion of the harvest is predicted to come from stands with volumes of 100 to 200 m^3 per hectare. The managed stand harvest volumes are also relatively small at first; between years 26 to 30 40% of the harvest that occurs in managed stands is predicted to come from stands with volumes of 100 to 200 m^3 per hectare. Between years 35 and 40 this proportion is 69%.

Some low volume stands (<100 m^3) are harvested later on in the planning horizon; many of these stands are residual stands or advanced regeneration stands. Over the long-term, most of the harvest is predicted to come from stands with volumes between 200 and 300 m^3 per hectare.

The same trends can be seen in Figure 10 depicting the predicted average harvest volume per ha. In the short and mid term the average harvest volume fluctuates but settles at around 275 m^3 per ha towards the end of the planning horizon.

Figure 11 illustrates the predicted annual harvest area. As with the volume per ha, the fluctuations are large in the short and mid term with the long term average settling at around 6,500 ha per year.

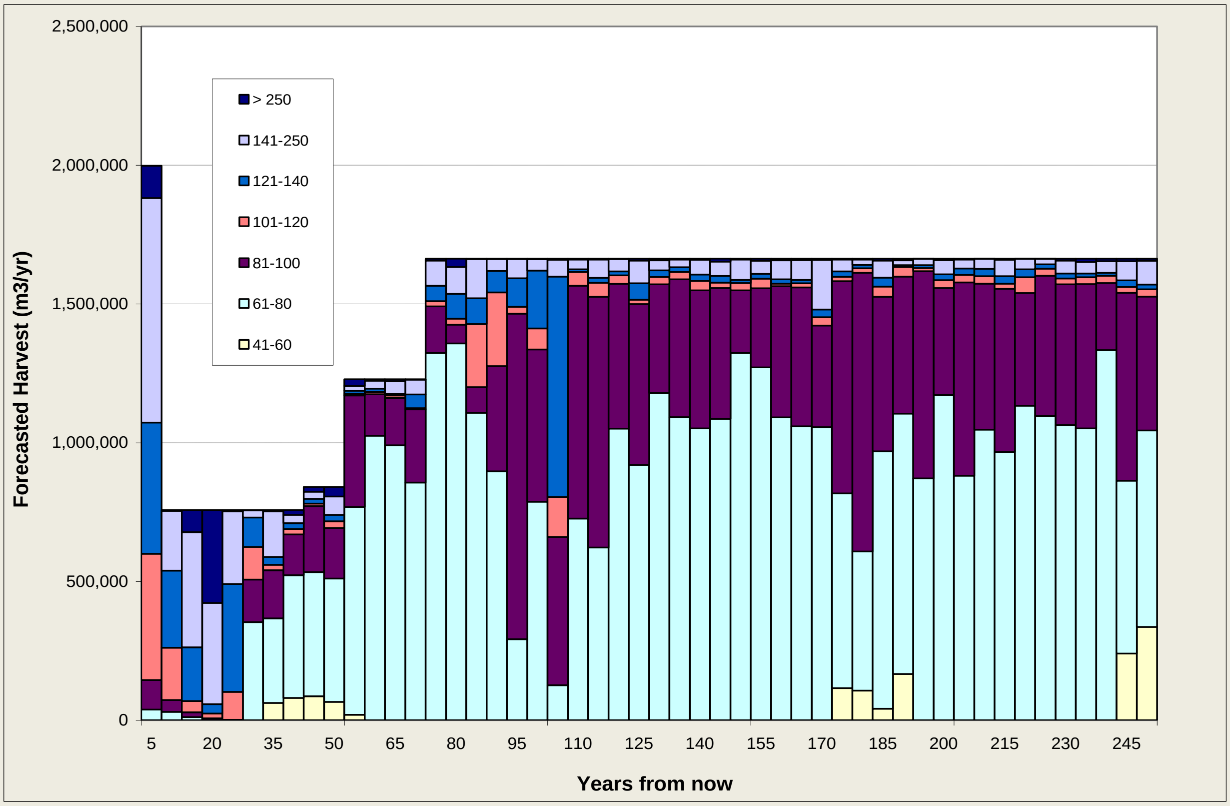


Figure 7: Base case harvest by age class

Figure 8: Average harvest age; base case

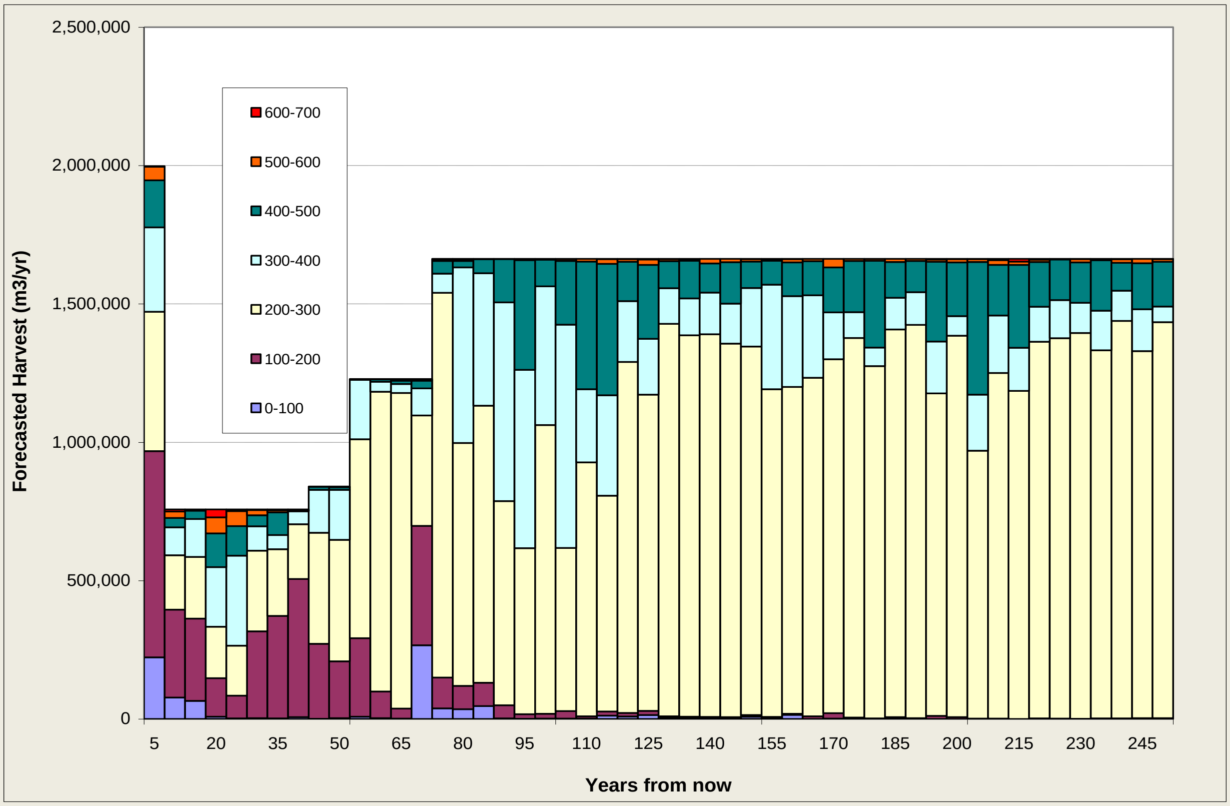


Figure 9: Base case harvest by volume per ha class

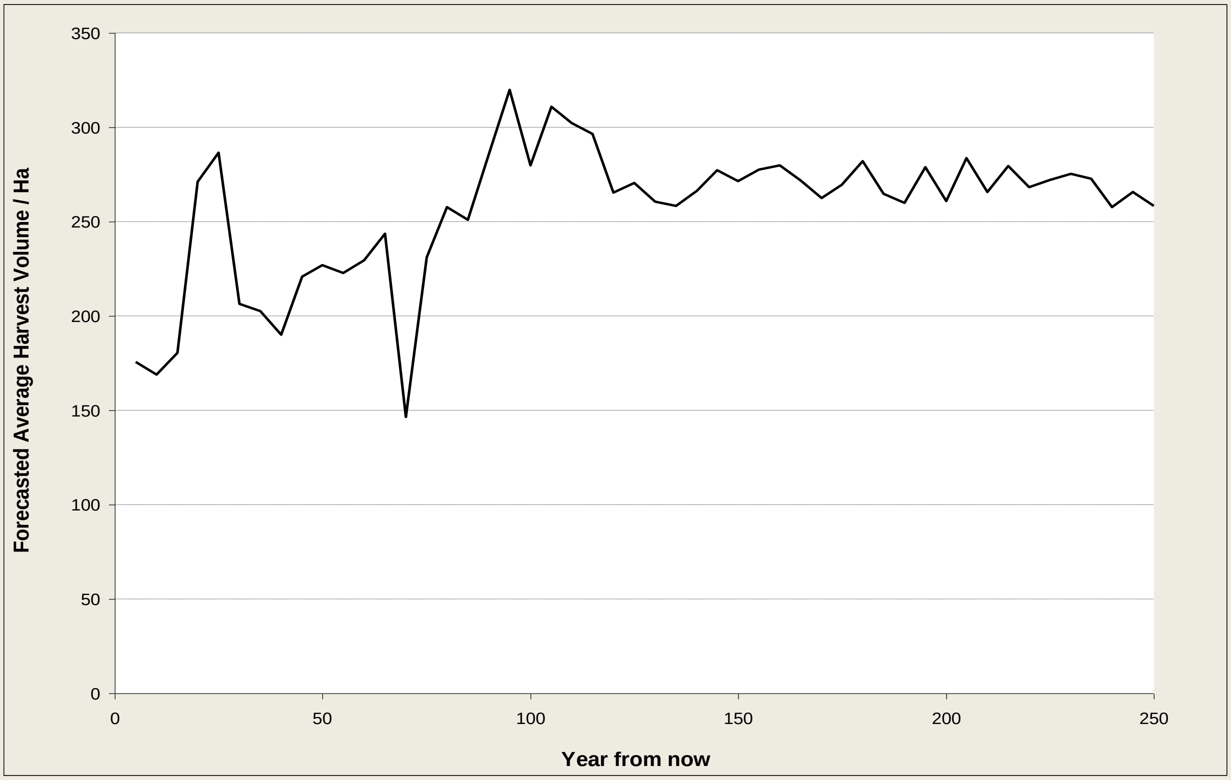


Figure 10: Average harvest volume per ha; base case

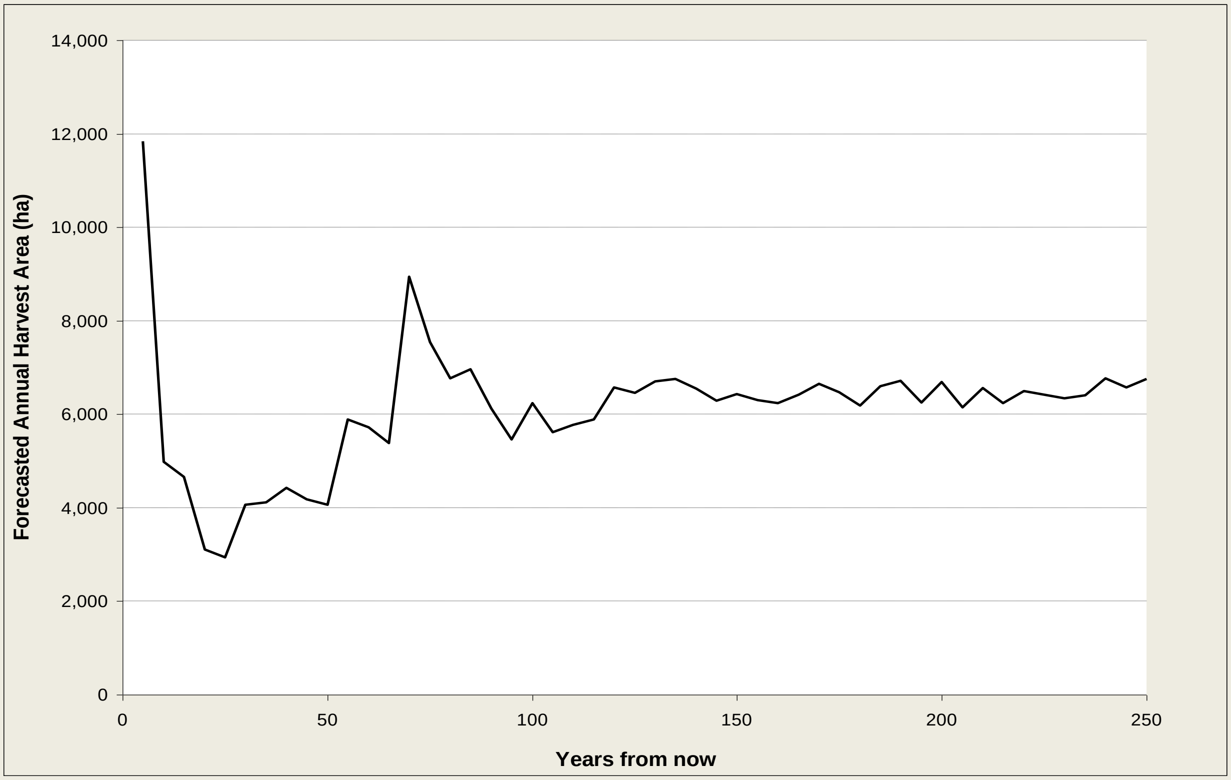
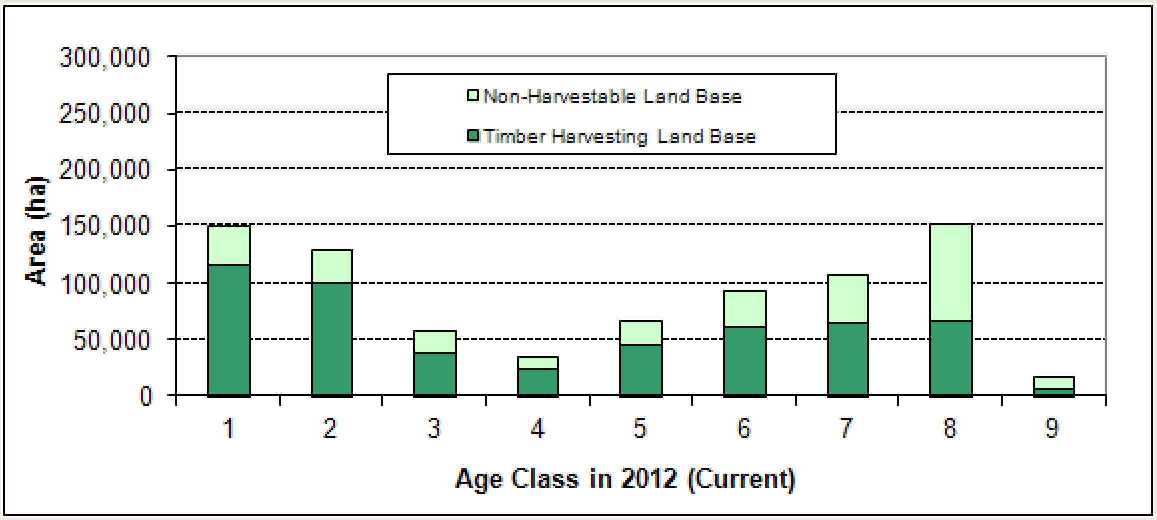


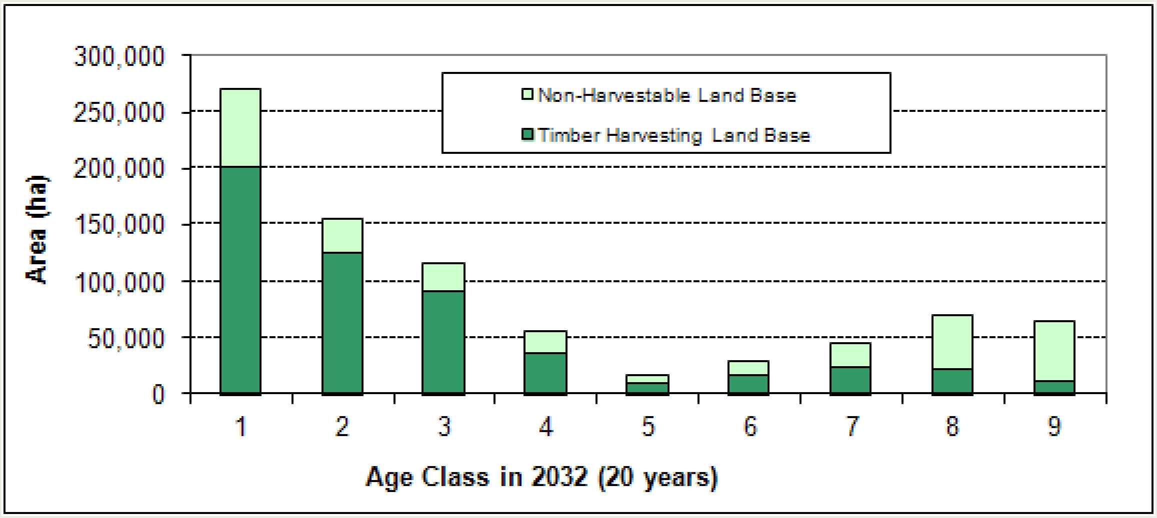
Figure 11: Average annual harvest area; base case

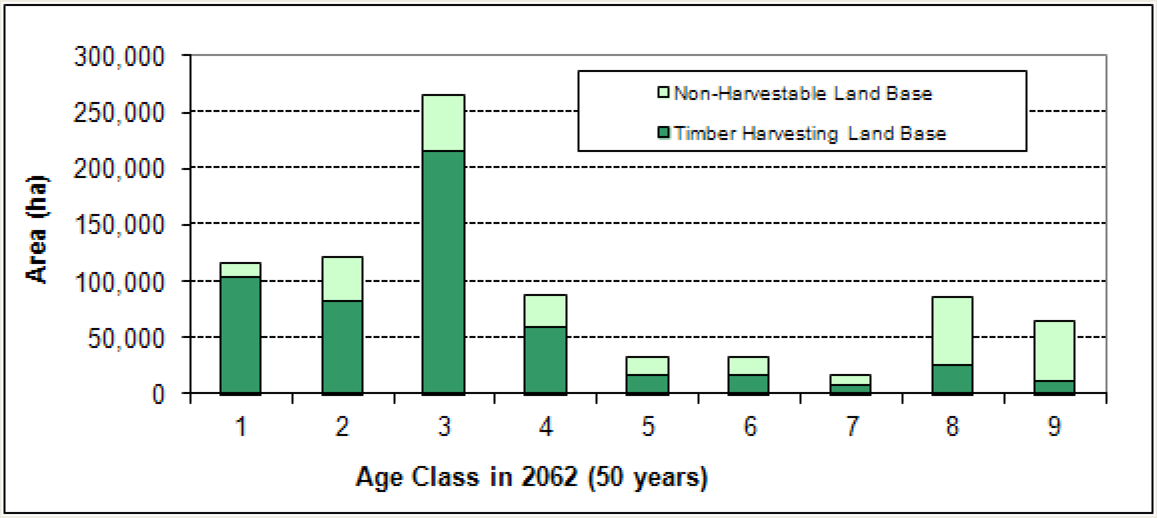
2.1.6 Age Class Distribution

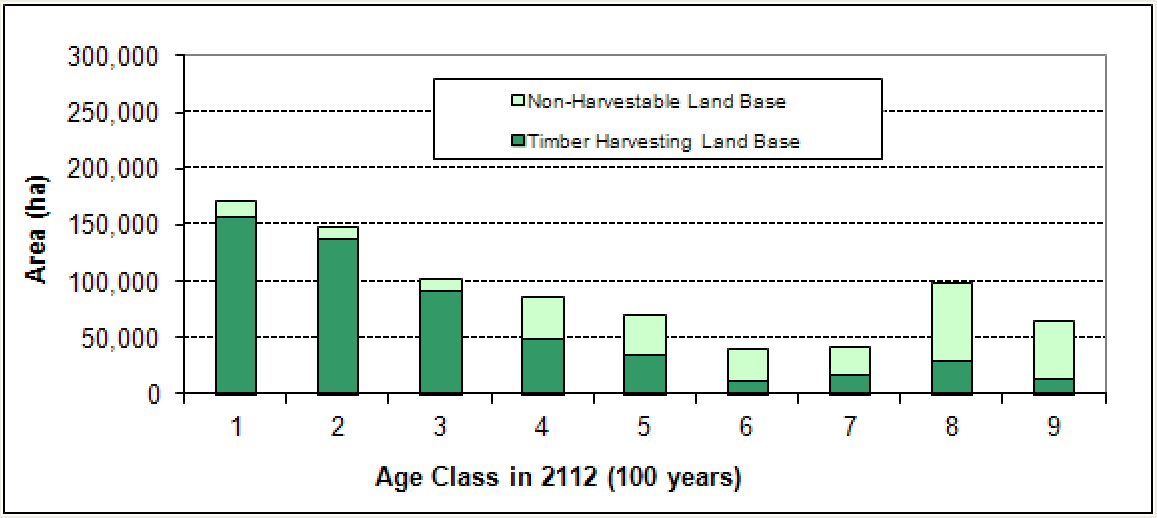
Figure 12 consists of several graphs that illustrate the predicted development of age classes in the 100 Mile House TSA over a period of 250 years. The high harvest level and the mortality of MPB attacked pine stands draw down the older age classes in the short term (first 20 years). The area of age class 1 increases correspondingly. At times Figure 12 shows small reductions in the area of older age classes (8 and 9) within the NHLB; this is caused by modeled succession.

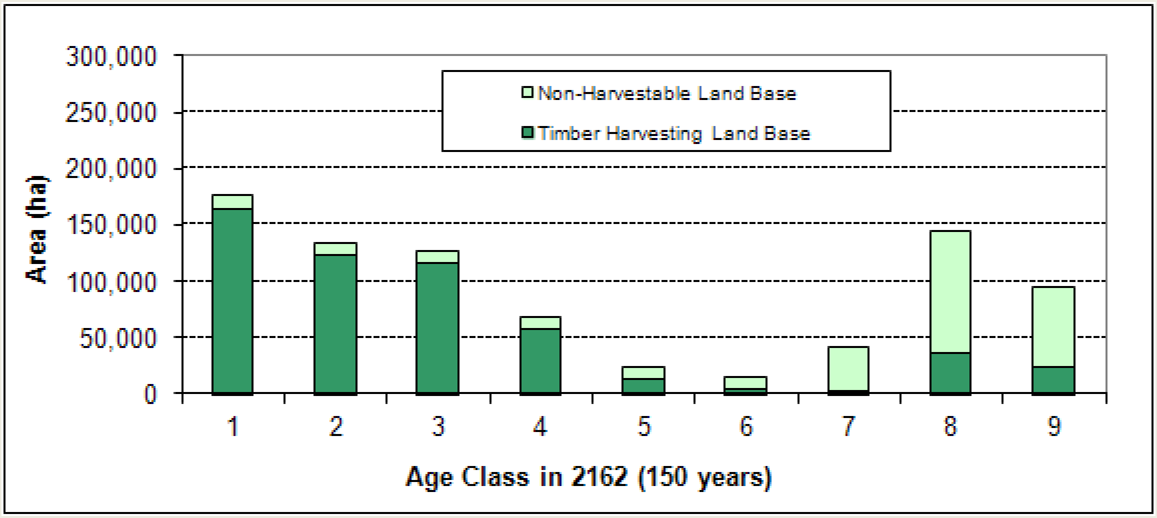
In the course of time the age class distribution remains unbalanced; age class 1 area decreases after the first 50 years and remains relatively constant after that. Age classes 5, 6 and 7 (mature forest) decrease and almost cease to exist, while age classes 1, 2, and 3 (young forest) and 8 and 9 (old forest) become dominant. This development is caused by the retention of old forest; the harvest becomes focused in age class 4 and 5 stands. Aside from the retained old forest, the majority of the stands in the THLB rarely age beyond 80 years. This is a potential risk factor as no reserves or recruitment opportunities exist in case of large-scale fires or other natural disasters that may occur in mature and old or old forest in the future.






300,000
250,000
200,000
150,000
100,000
50,000
0
Area (ha)
Non-Harvestable Land Base
Timber Harvesting Land Base
1
2
3
4
5
6
7
8
9
Age Class in 2062 (50 years)


300,000
250,000
200,000
150,000
100,000
50,000
0
Area (ha)
Non-Harvestable Land Base
Timber Harvesting Land Base
1
2
3
4
5
6
7
8
9
Age Class in 2112 (100 years)


300,000
250,000
200,000
150,000
100,000
50,000
0
Area (ha)
Non-Harvestable Land Base
Timber Harvesting Land Base
1
2
3
4
5
6
7
8
9
Age Class in 2162 (150 years)

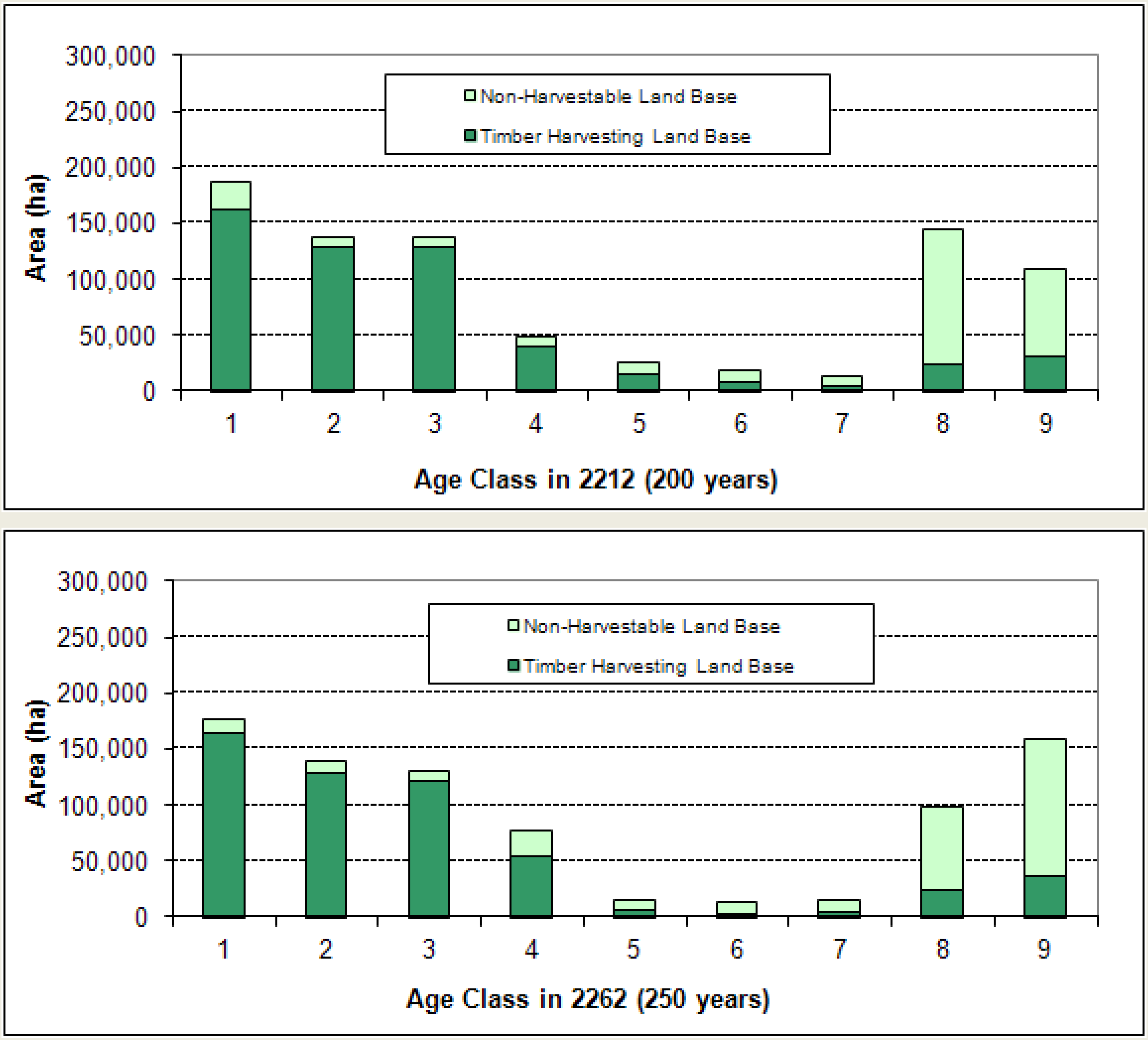


Figure 12: Forecasted age class distribution in the THLB and NHLB over the next 250 years

2.1.7 Biodiversity and Non-Timber Values

This section describes the environmental and non-timber values incorporated in the model.

2.1.7.1 Landscape level Biodiversity

In the 100 Mile House TSA landscape level biodiversity targets exist for mature and old seral stages. These targets are part of the Cariboo-Chilcotin Land Use Plan (CCLUP) and are based on landscape unit, natural disturbance type, biodiversity emphasis option, and BEC zone. For the IDF zone, species composition is also a factor. These targets are defined in more detail in the data package.

Figure 13 shows an example of a landscape unit where a biodiversity target constrains the harvest significantly. The example illustrates the impact of the MPB infestation in the Big Bar landscape unit; the target cannot be met during the mid term. This IDF, non-Douglas-fir leading unit is natural disturbance type 4, with a high biodiversity emphasis option. The Crown Forested Land Base (CFLB) area is 10,933 ha, with a minimum of 34% of the forest expected to be older than 100 years. The sharp drop in mature and old forest at year 20 is due to the break-up of the MPB attacked stands; the unharvested dead stands are not assumed to remain old in the analysis. This landscape unit continues in violation of the target until year 80, when the target is met. However, in the long term (after 75 years) available timber supply in this landscape unit continues to be constrained by the limited area of mature and old forest in the THLB.

In contrast, Figure 14 shows an example of a moderately large landscape unit where the biodiversity target does not constrain available timber supply. This example of the Bonaparte Lake landscape unit illustrates the predicted mature and old seral outcome of the base case harvest in this SBS zone, natural disturbance type 3 unit with a low biodiversity emphasis option. Throughout the planning horizon the relatively low target of 11% is met in the NHLB portion of the unit. The total CFLB area of the unit is 7,917 ha.

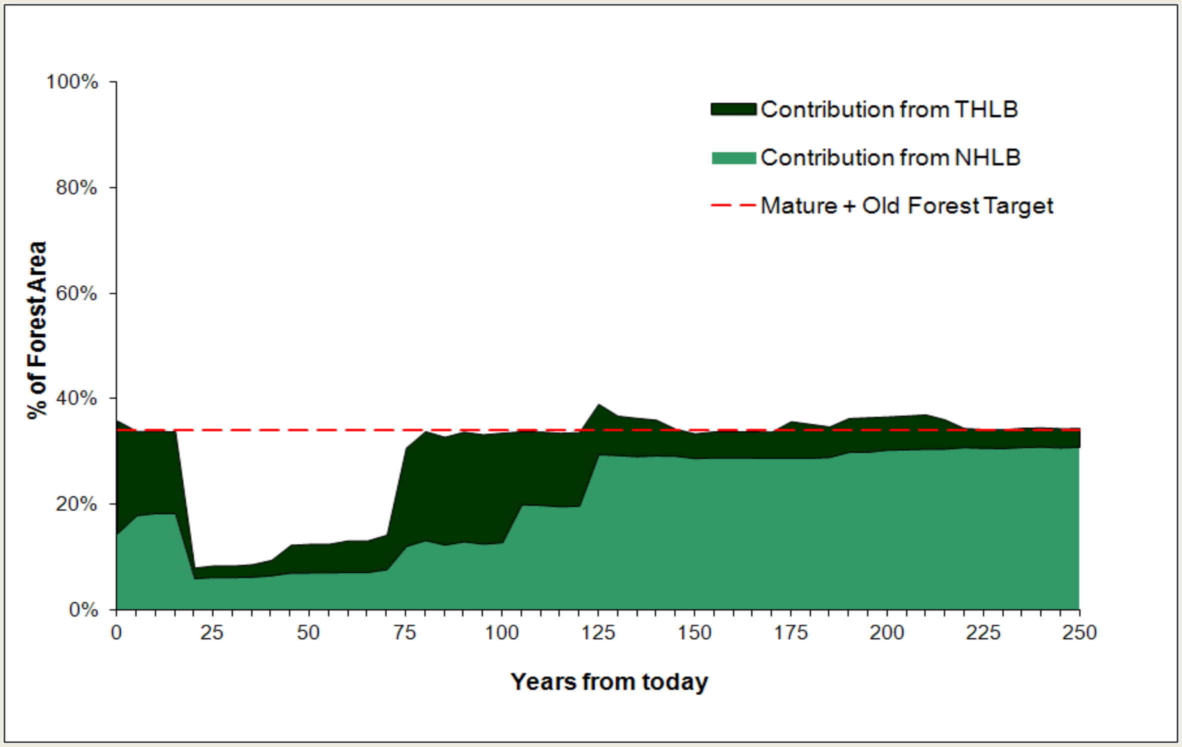


Figure 13: Example of a constraining LU/BEC unit; Big Bar, IDF, non-fir, NDT4, high BEO, Area 10,933 ha

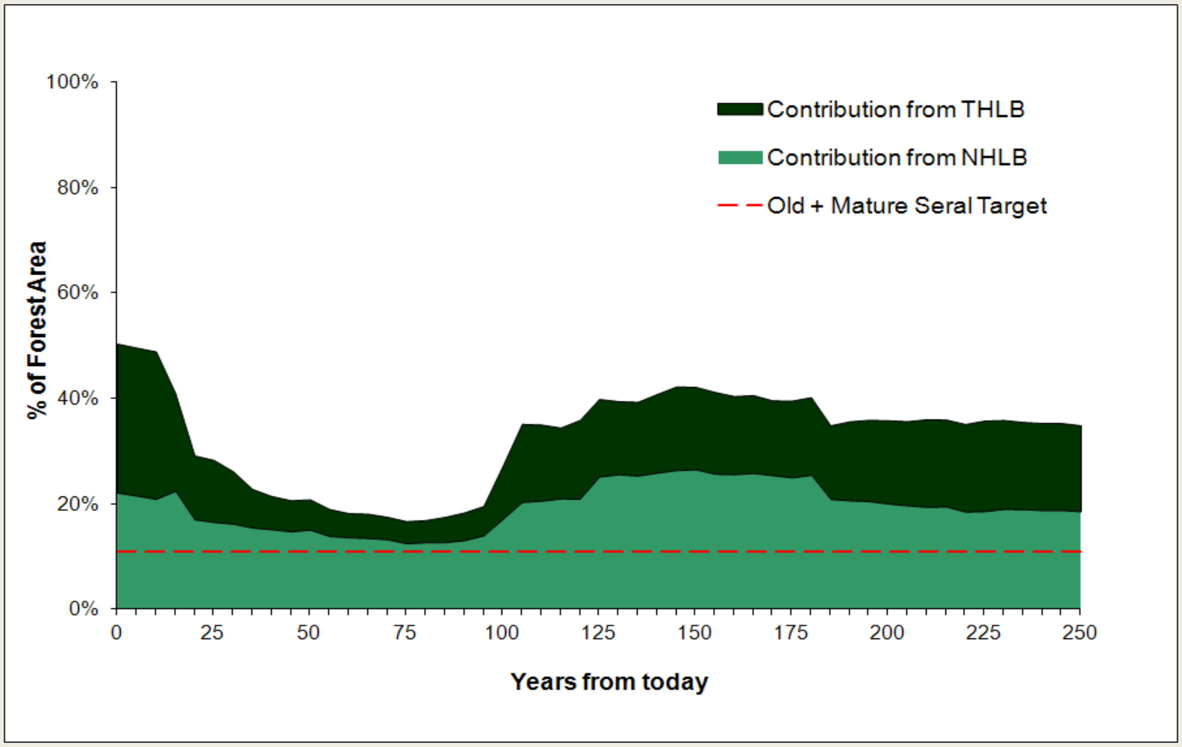


Figure 14: Example of a non-constraining LU/BEC unit; Bonaparte Lake, SBS, NDT3, low BEO, Area 7,917 ha

2.1.7.2 Ungulate Winter Range

There are approximately 57,000 ha of CFLB in the 100 Mile TSA that are within ungulate winter range (UWR) areas. These areas have specific harvesting rules based on the depth of the snow pack, the amount of Douglas-fir in the stand and the habitat structure. The targets for each category are described in the data package.

Figure 15 and Figure 16 show the targets and the achievement of these targets for two UWR units. Figure 15 represents a unit with a transitional to deep snow pack and less than 40% Douglas-fir in the stand. The total area of THLB in this unit is 2,800 ha with the expectation that a maximum of 40% of the THLB can be less than 80 years old at any time. The unit is in violation for the first 35 years due to the MPB infestation.

Figure 16 shows a unit of shallow to moderate snow pack, with high structure habitat. It has 1,457 ha of THLB with a target of a maximum of 15% under 30 years old. This unit is never in violation, but is consistently right at the target from year 45 on to the end of the modelling period.

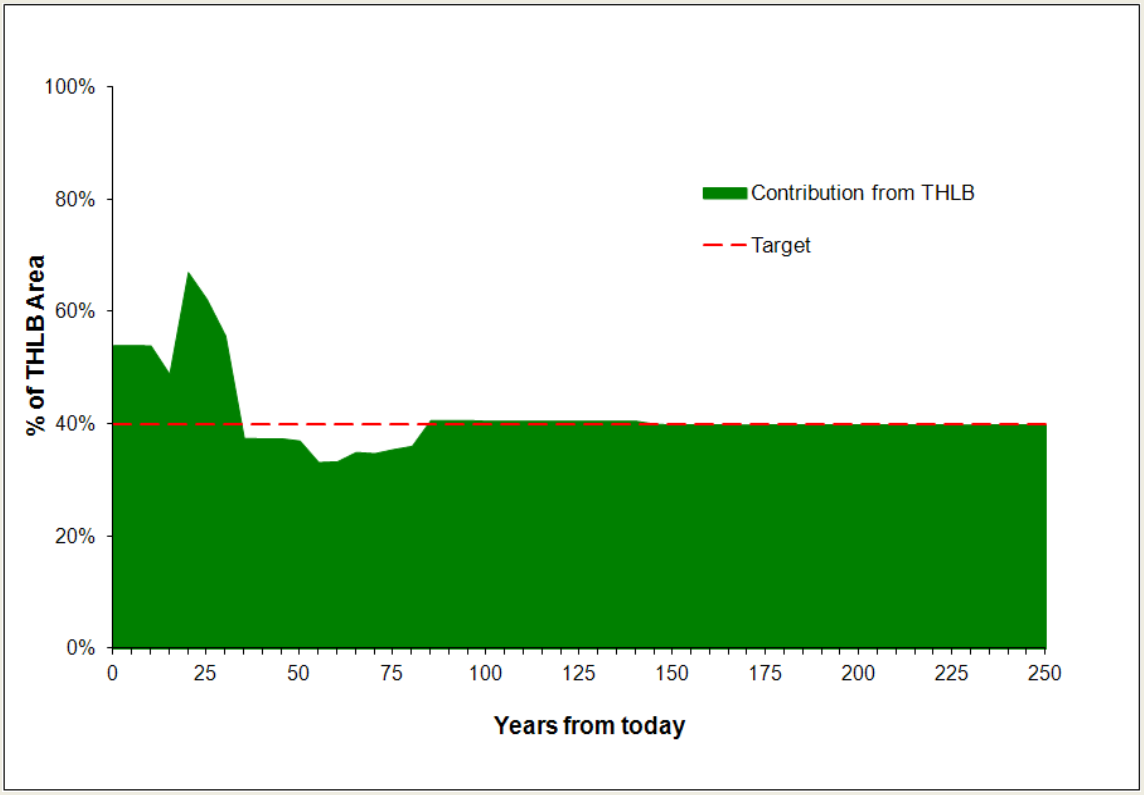


Figure 15: Example of UWR unit in violation for the first 35 years of the model; max target

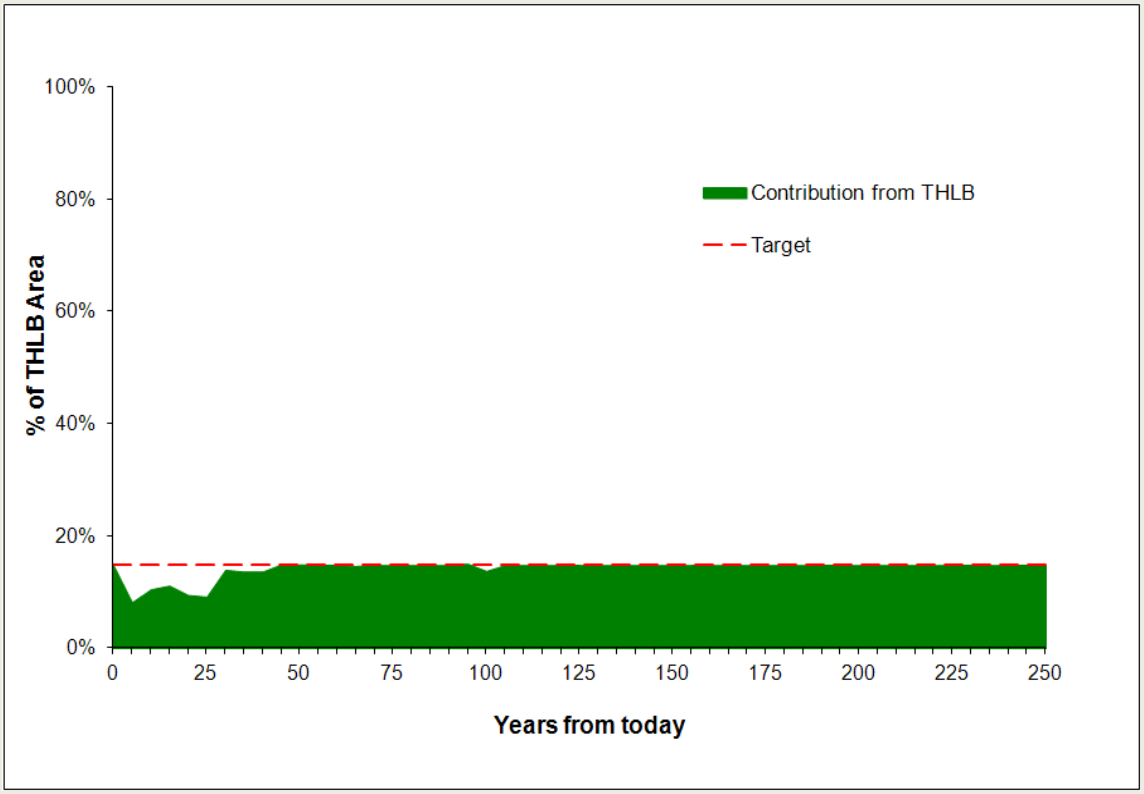


Figure 16: Example of a UWR unit with no violation, max target

2.1.7.3 Green-Up

As a surrogate for cutblock adjacency, a green-up target was applied to the THLB. A maximum of 33% of the THLB was allowed to be less than 3 m in height throughout the planning horizon. This limit was applied by landscape unit in all areas that are not within visual polygons. As an example, Figure 17 illustrates the achievement of the green-up target in the Murphy Lake landscape unit where the area of THLB outside of visual polygons is 27,650 ha. For the first 10 years of the model, more than 33% of the THLB in this landscape unit does not meet the green-up height due to the dying pine stands and salvage harvesting.

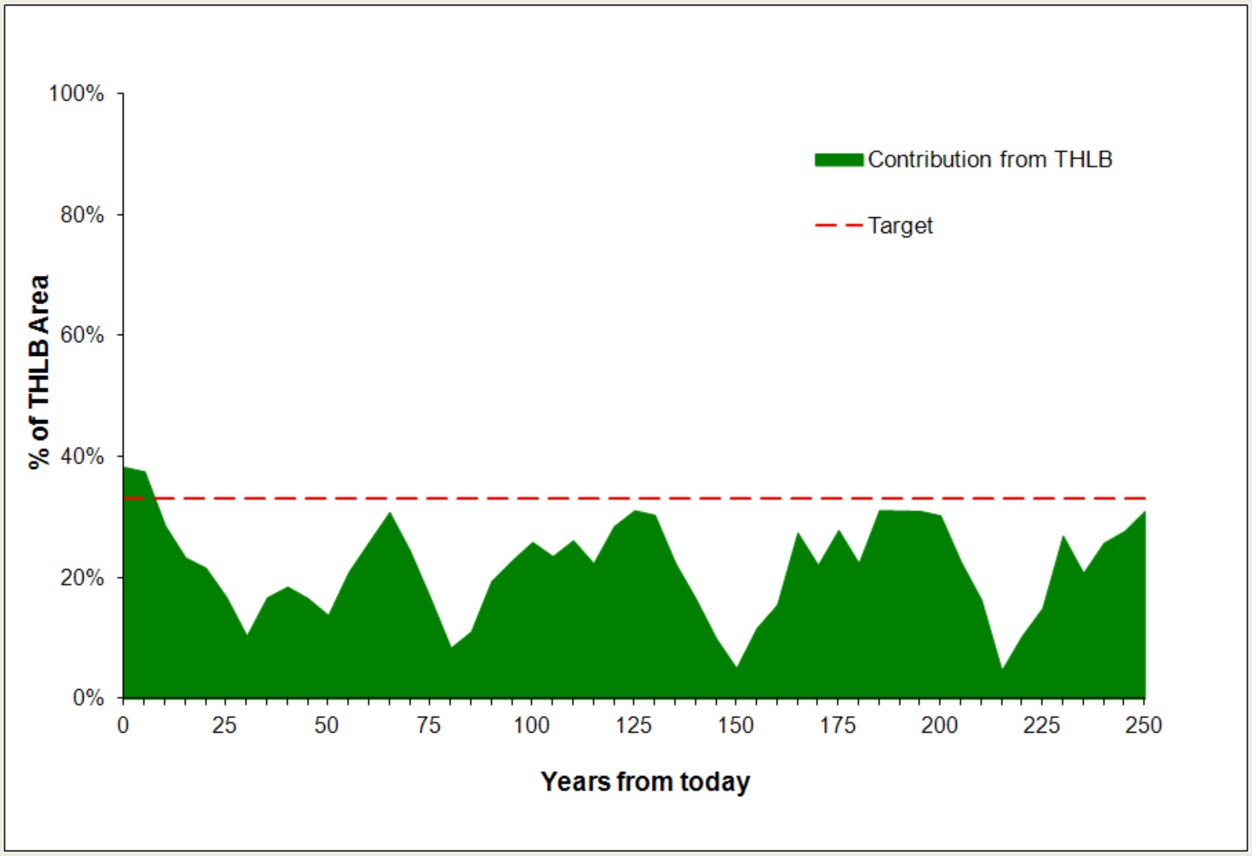


Figure 17: Example of an IRM target, achievement of the green-up target in the Murphy Lake landscape unit

2.1.7.4 Visual Quality Objectives

Visually effective green-up (VEG) heights were used model the protection of visual values. Visual quality objectives were found to be somewhat constraining on the timber supply at the beginning of the planning horizon due to combination of harvest and stand break-up.

2.2 Comparison of Base Case to Latest TSR

2.2.1 Shelf Life

Most analysis assumptions used in this analysis were the same as those used in the most recent TSR, however differences exist. A significant difference is the way shelf life of the dead pine was modeled. In this analysis shelf life is defined as the time a stand remains economically viable for sawlog harvesting. The shelf life starts at the year of death; defined as when cumulative kill reaches 50%. The merchantability is assumed to be 100% at the year of death and for the next 2 years and then declines to 0 at year 16 as shown in Figure 18. This general approach is consistent with other on-going type 4 silviculture strategies with differences in the length of shelf life and slope of the volume reduction. The shelf life for other product types could be longer; however, it is not modeled in this analysis.

The latest TSR assumed 100% retention of merchantability for 15 years, after which the volume is no longer usable (Figure 18). These different approaches to modeling shelf life have a significant impact on the modeled availability of dead pine.

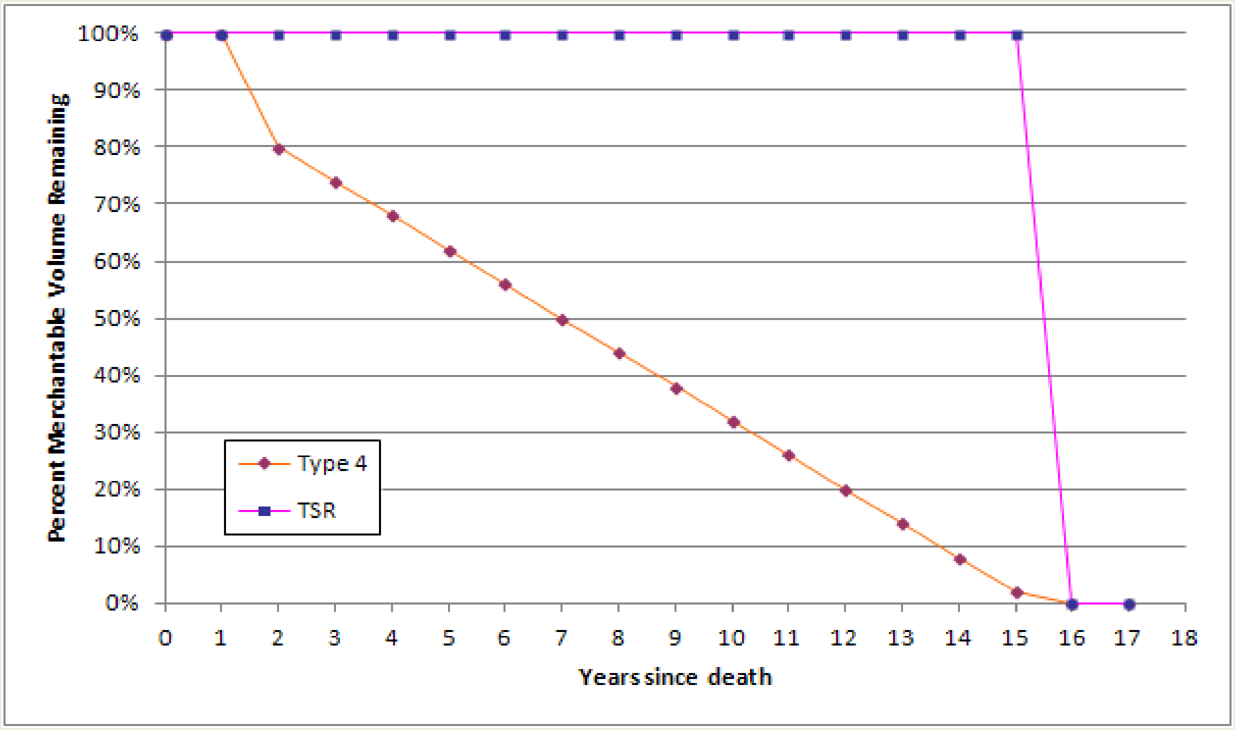


Figure 18: Type 4 and TSR shelf life curves

2.2.2 Advanced Regeneration

All Type 4 scenarios assumed that advanced regeneration exists in all stand types. In the latest TSR no advanced regeneration was assumed and the killed, unharvested stands were assumed to remain in the landscape and age over time. Many of the killed stands never recover adequately to be harvested again; this may have a negative impact on the long-term harvest level. Advanced regeneration adds volume over time and the stands may eventually become harvestable. After harvest these stands regenerate to more productive future managed stands.

2.2.3 Seral Stage of Unharvested Dead Pine Stands

The latest TSR assumed that unharvested dead pine stands maintained their ages and continued to age and grow over time, providing that live trees remained in the stand. The Type 4 analysis used a different approach: all unharvested stands with more than 50% mortality were assumed to breakup and continued growing using the age of advanced regeneration as a new start age. The Type 4 method of modelling constrains the timber supply in those areas where green-up requirements or seral stage requirements are limiting factors on timber supply.

2.2.4 Site Index for Managed Stands

The Type 4 analysis used the provincial site index coverage for future managed stands while the TSR used BEC based averages where available. The area-weighted average site indices for the Type 4 analysis compared to TSR site indices are shown in Table 2. The site indices used for the Type 4 analysis are higher than those used for TSR which results in higher future stand yields.

Table 2: Area weighted average site indices for future stands; Type 4 analysis compared to TSR

Analysis Unit	Leading species	Average TSR SI	Average Type 4 SI	THLB Area (ha)
Decid poor	Aspen, Birch	n/a	n/a	0
Decid medium	Aspen, Birch	12.1	19.1	1,093
Decid good	Aspen, Birch	17.3	19.9	34,871
Decid very good	Aspen, Birch	20.1	22.0	4,310
Douglas-fir poor	Douglas-fir (pine in FM)	8.0	9.4	251
Douglas-fir medium	Douglas-fir (pine in FM)	11.4	12.6	1,203
Douglas-fir good	Douglas-fir (pine in FM)	17.0	19.1	130,532
Douglas-fir very good	Douglas-fir (pine in FM)	21.3	21.7	27,355
Balsam poor	Balsam	n/a	n/a	0
Balsam medium	Balsam	11.9	14.7	1,844
Balsam good	Balsam	16.7	17.8	8,136
Balsam very good	Balsam	21.0	22.2	3,725
Pine poor	Pine	6.3	7.1	29
Pine medium	Pine	11.7	13.3	385
Pine good	Pine	18.4	18.9	292,896
Pine very good	Pine	21.0	21.1	98,424
Spruce poor	Spruce	7.4	9.8	1
Spruce medium	Spruce	12.2	13.5	105
Spruce good	Spruce	17.1	18.6	34,661
Spruce very good	Spruce	21.4	21.9	22,280

2.2.5 Harvest Forecast Comparison

Figure 19 and Figure 20 illustrate the difference in harvest forecast between the Type 4 base case and the TSR base case, using two different shelf life assumptions. In Figure 19 the Type 4 shelf life base case is shown while Figure 20 illustrates a harvest forecast for the Type 4 base case with shelf life assumptions similar to those in the latest TSR that assumed 100% retention of merchantability for 15 years, after which the volume is no longer usable. Other differences in assumptions as discussed above in sections 2.2.2, 2.2.3 and 2.2.4 were not changed.

The mid-term harvest level in the most current version of the TSR is 890,000 m^3 per year. This is 133,000 m^3 per year more than the mid-term harvest level of the Type 4 Base Case of 757,000 m^3 per year. When using TSR shelf life assumptions a mid-term harvest level of 919,000 m^3 – 29,000 m^3 higher than that of the TSR – was reached.

The long term harvest level (LTHL) in the TSR base case is 1.51 million m^3 per year. Both Type 4 scenarios produced a LTHL of over 1.6 million m^3 per year. The site index differences and the way unharvested dead pine stands were modeled is the likely reason for the differences in the LTHL. In the TSR these stands were left in the landscape and many were never harvested. In this analysis, unharvested stands broke up (age was changed) and continued growing on yield curves that were made up from residual trees and advanced regeneration. Most of these stands were eventually harvested and converted to productive managed stands in the model.

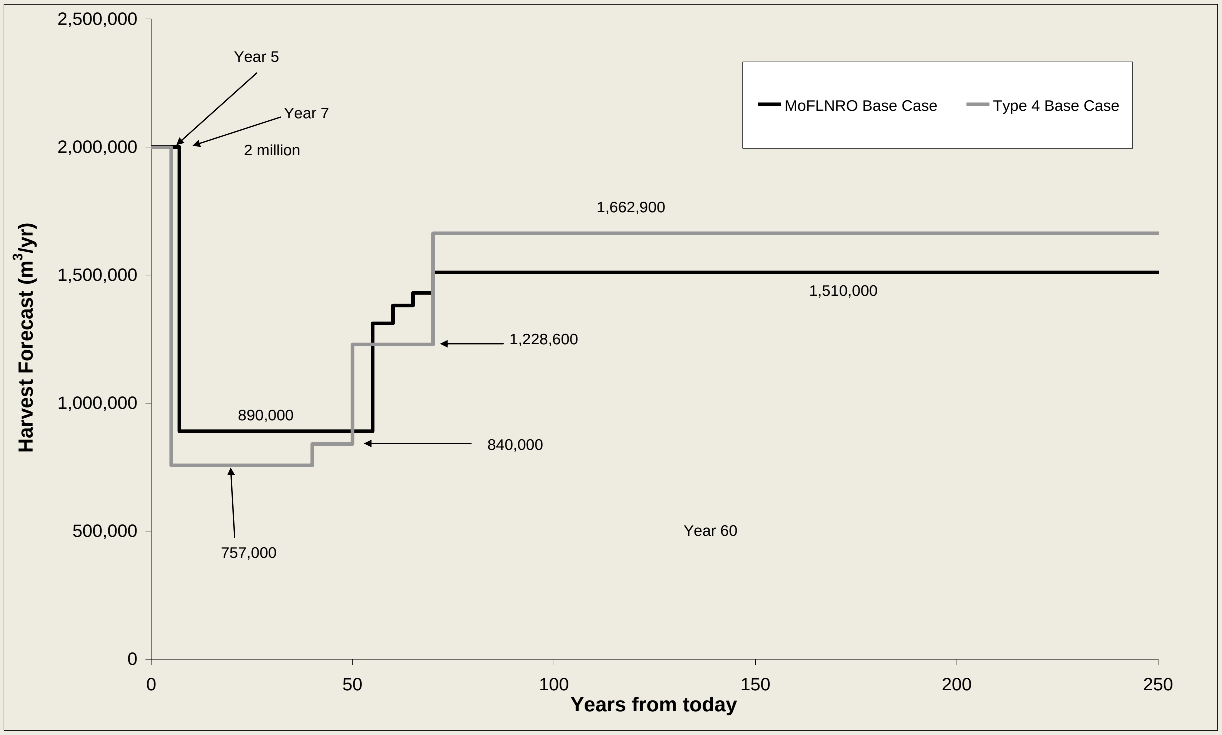


Figure 19: Comparison of harvest forecast between Type 4 and TSR base case

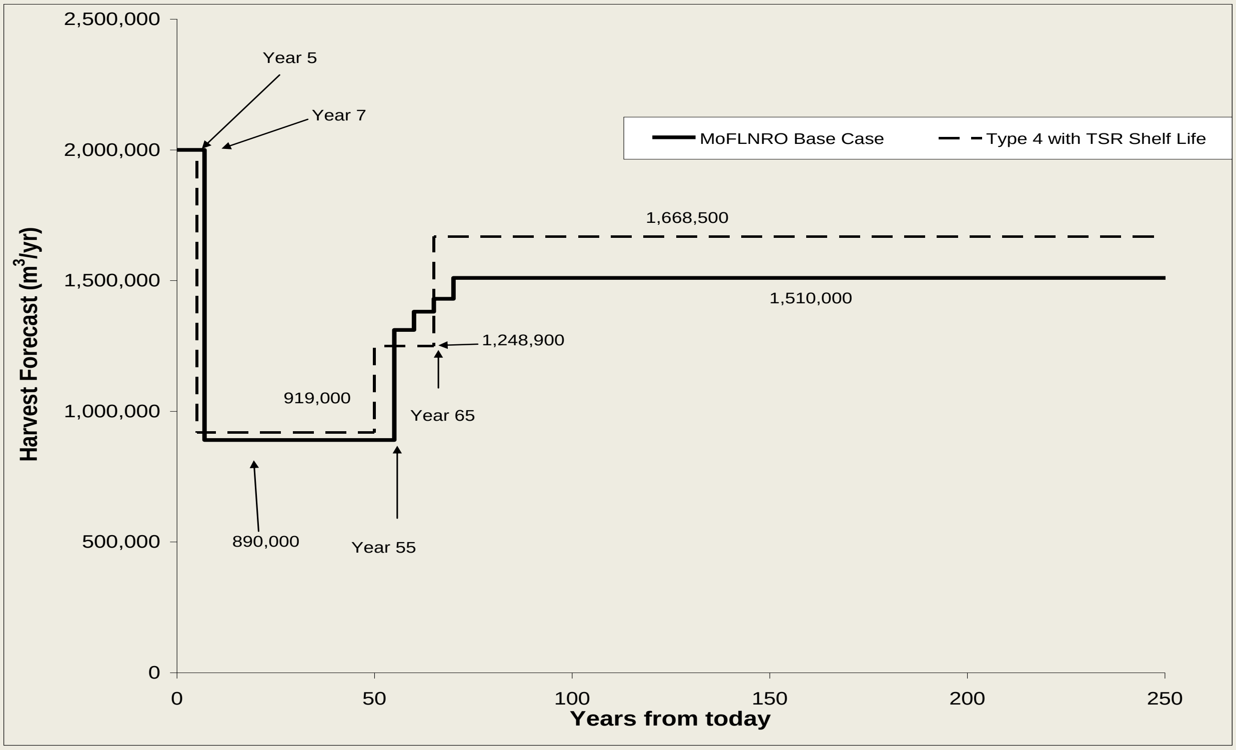


Figure 20: Comparison of harvest forecast between TSR base case and Type 4 with TSR shelf life assumptions

3 Strategies and Scenarios

The strategies that could be employed to improve the timber supply in the 100 Mile House TSA were discussed at the second workshop with the district licensees and staff. The discussed strategies are presented below and will be explored in this analysis. Some of them were investigated through scenario analysis while others were examined through stand level analysis and operational experience.

1. Assessment of quality and health of managed stands which will be relied on to support the mid term

   This strategy does not provide immediate help in dealing with the mid-term timber supply, however it is imperative for understanding the condition and the growth and yield potential of the existing managed stands that are predicted to form the majority of the mid-term timber supply from year 30 on. This strategy was not modeled using scenario analysis.

2. Fertilization, single and multiple treatments

   This strategy, while often used throughout the province, received limited support at the 100 Mile House TSA stakeholder group meetings. The impact of fertilization treatments were investigated through scenario analysis.

3. Strategies to manage dry belt Douglas-fir stands

   The Interior Douglas-fir (IDF) biogeoclimatic subzone covers approximately 47% of the THLB in the 100 Mile House TSA. The IDF is a critical component of the timber supply in the TSA. A large portion of the post salvage harvest is assumed to come from dry belt Douglas-fir stands.

   Many of these stands are uneven-aged Douglas-fir forests. Large areas have been harvested by diameter-limit cutting in the past; merchantable Douglas-fir were removed and the stands were left stocked or often over-stocked with advanced regeneration. The current condition of these stands varies with many of them overstocked and stagnated.

   Growth and yield data to predict the growth of these stands in their current state is lacking as is the data to predict any treatment responses. While this analysis proposes strategies and treatments in the dry belt Douglas-fir stands, no forest level scenarios were constructed due to lack of appropriate modeling data. The following management strategies will be considered in this silviculture strategy:

   - Spacing of over-dense understories in partially harvested dry belt Douglas-fir Stands (results of stand-level analysis is included in this report);
   - Overstory removal and spacing of partially harvested dry belt Douglas-fir Stands;
   - Spacing low density, diseased and damaged pine stands in the IDF to favour existing layer 3 and 4 Douglas-fir.

4. Rehabilitating MPB-Attacked Stands

   Many MPB attacked stands have lost a sufficiently large amount of their merchantable volume such that they are not economical to harvest and will remain in the landscape. These stands are a potential fire hazard and drag to the timber supply. Rehabilitating these stands will have a positive impact on the timber supply. The positive impacts will extend to fire hazard abatement and watershed recovery as well. The impact of rehabilitating MPB-attacked stands was investigated through scenario analysis.

5. Rehabilitation of Dead and Damaged Managed Pine-leading Stands

   Due to the MPB and other forest health impacts, there is a concern regarding the health and quality of managed pine-leading stands which are being relied upon to support the mid-term timber supply.

Assessment of these stands is a priority. Some stands may not have sufficient stocking and value to support a merchantable harvest in the mid-term; however, the understory in these stands may be adequate for them to be considered harvestable in the long term at lower yields and values than fully stocked stands. Some of these MPB attacked young stands may be NSR.

Whether to retain under-performing stands as candidates for mid-term harvest, or rehabilitate them to produce fully stocked, productive stands is a significant decision with mid and long term timber supply and value implications in the TSA. While it is not possible to provide definitive answers to this question in this project, stand-level analysis was used to examine this situation. This strategy was not modeled using scenario analysis.

6. Repression spacing of over-dense pine

   According to the district staff, small areas of repressed over-dense pine stands exist in the TSA. Spacing these stands may be beneficial. This treatment was not modeled in the analysis due to the small area involved; however, spacing repressed over-dense pine stands will remain as one of the candidate treatments for the 100 Mile House TSA silviculture strategy.

7. Enhanced basic reforestation

   Some 100 Mile TSA stakeholders were concerned that the assumed future stand establishment densities used for the base case were lower than the current practice. A strategy employing more planting and higher establishment densities was supported. This strategy is expected to impact mostly the long term timber supply producing more resilient stands with higher yields. This strategy also presents the complementary benefit of producing more high quality logs and improving the economic returns from harvesting. The volume responses and financial returns from potential fertilization treatments are also increased. Furthermore, stands with higher initial densities tend to be better candidates for incremental silviculture.

   This analysis tested the potential impacts of enhanced basic reforestation.

8. Spacing/cleaning of diseased, damaged poor quality pine leading stands in the SBS and ICH to favor existing Fd and Sx stocking.

   According to the 100 Mile Forest District staff there are low productivity pine leading stands with significant Douglas-fir component in the district where the stands may benefit from spacing to favor Douglas-fir and possibly spruce if present. As with the spacing of over-dense pine stands, the inventory file does not provide adequate detail for these stands to facilitate modeling. However, this treatment will remain as an option for the silviculture strategy.

9. Under planting of low density, poor quality young pine stands in the IDF

   There is evidence that some existing managed pine leading stands in the IDF are of such poor quality that they may benefit from rehabilitation and/or under planting Douglas-fir. The area of these stands is not known, nor is there inventory and growth and yield data that would support forest estate modeling of these stands. As such they were not included in the scenario analysis, but will form a part of the overall silviculture strategy for the 100 Mile House TSA.

10. Converting non-forested area into THLB

    Converting non-productive areas is always a viable option to increase timber production. Generally the timber supply impact occurs in the long term. The district does not have readily available candidate areas for this conversion; however, this treatment remains as an option in the silviculture strategy.

11. Harvest scheduling

While not fitting with the traditional view of a silviculture strategy, harvest scheduling has the potential to impact the mid-term timber supply significantly and reveal previously unexplored management issues. The impact of harvest scheduling was investigated in this analysis.

3.1 Harvest Scheduling

3.1.1 Lower Initial Harvest

This scenario tested the impact of lowering the initial harvest level to 1,334 million m^3 per year. This was the pre-MPB AAC prior to 2006 before it was increased to 2.0 million m^3 per year to facilitate accelerated harvesting and salvaging of attacked and dead pine stands.

Harvesting less in the first five years, increased the mid-term harvest level between years 6 and 40 by 11.2% - from 757,000 m^3 per year to 842,400 m^3 per year (Figure 21). As in the base case, most dead pine is harvested during the first 5 years (Figure 22). The mid-term increase comes at a small cost: this scenario results in a reduced total harvest over the first 40 years of about 330,600 m^3 or 1 %.

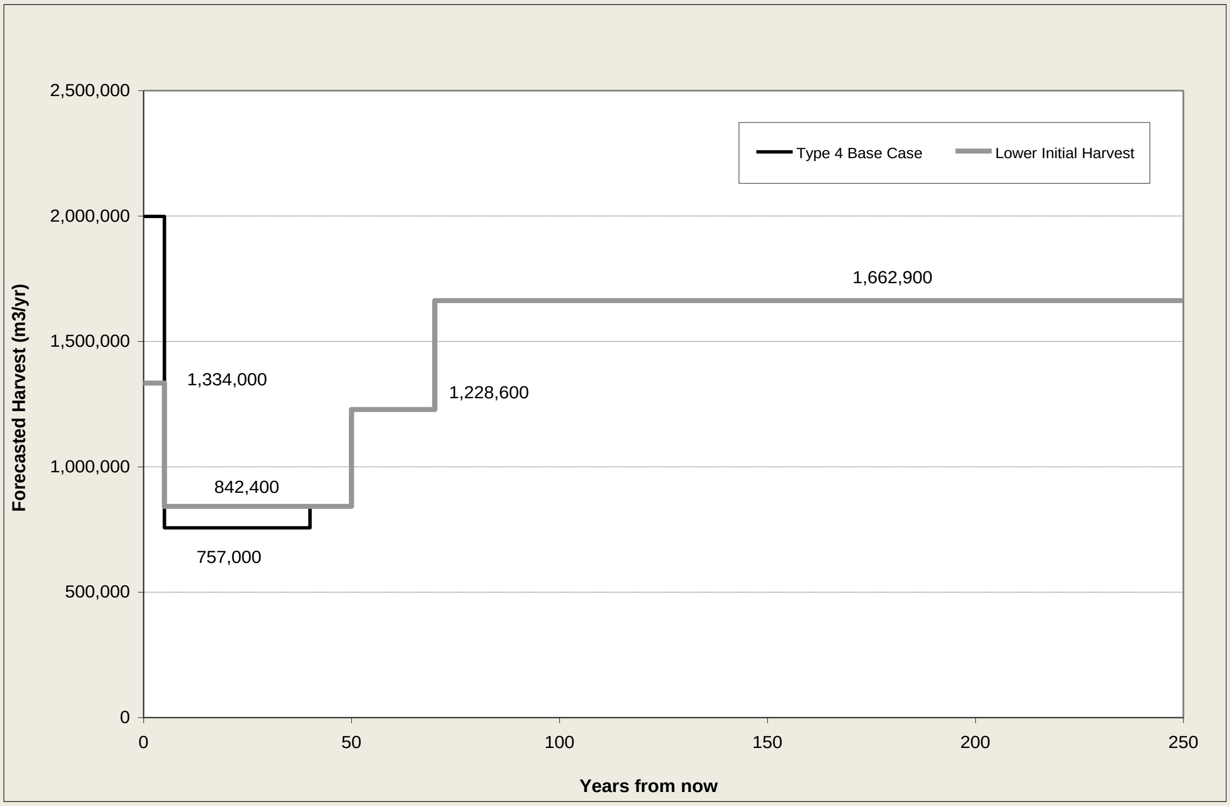


Figure 21: Lower initial harvest scenario

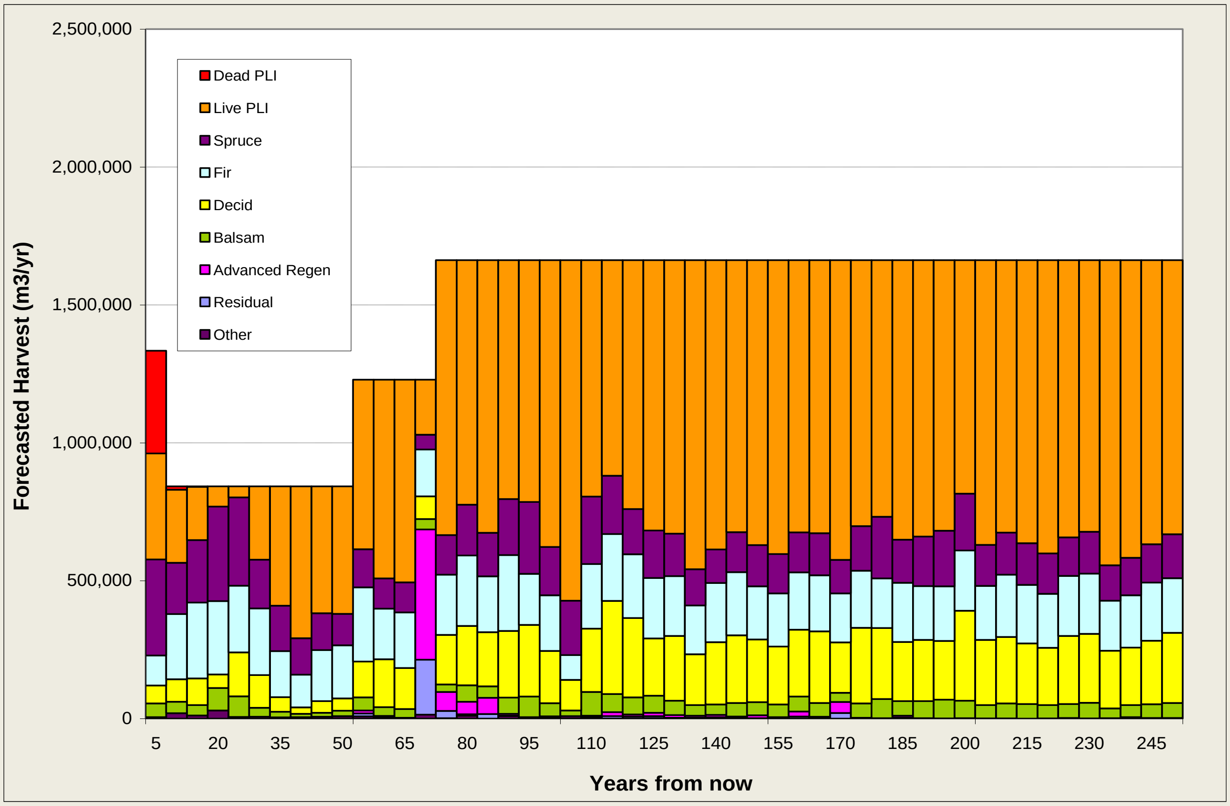


Figure 22: Harvest by species; base case

3.2 Silviculture Scenarios

3.2.1 Opportunities

The base case provides a starting point for assessing potential silviculture strategies that may improve the mid-term timber supply in the 100 Mile House TSA (Figure 23). In the base case approximately 65,000 ha of dead pine stands were not harvested; these stands remain in the landscape as a potential fire hazard. They will also stay as a drag on the timber supply for years to come. The rehabilitation of these stands or a portion of them will reduce the fire hazard and increase the timber supply in the late mid term and the early long term.

There are limited opportunities to increase the growth and yield of natural stands in the 100 Mile House TSA. The harvest in the near mid term comes from age class 6, 7 and 8 stands, which are too old for incremental silviculture treatments (fertilization). Some opportunities exist in stands that are currently between 50 and 80 years old.

The harvest of existing managed stands starts in the base case 26 to 30 years from the present. Increasing the growth and yield of existing managed stands that are currently between 11 and 50 years old may allow for a higher mid-term harvest level or an earlier shift to higher level of harvest. There are uncertainties associated with the health and quality of these stands. Therefore, the assumptions used in the base case to model these stands are also subject to uncertainty and risk. One of the priorities for the 100 Mile TSA stakeholders is an assessment of the managed stands that will dominate the harvest starting around year 30.

Improving basic reforestation in the TSA was rated high as an action item with the TSA stakeholder group. This strategy is expected to impact mostly the long term timber supply.

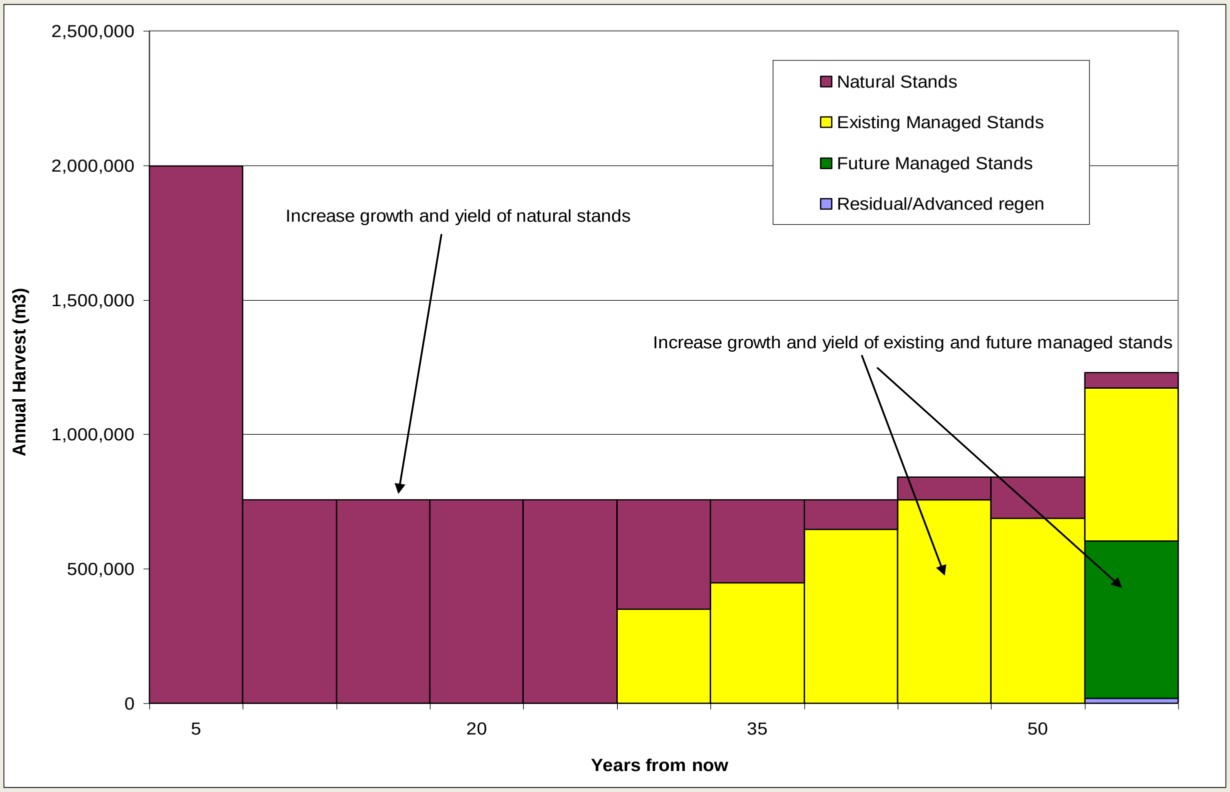


Figure 23: Base case; mid term silviculture opportunities

Improving the management of dry belt Douglas-fir is another silviculture opportunity in the 100 Mile TSA. Due to difficulty in representing these stands and their treatment in the timber supply model adequately, this opportunity was not modeled; however it will form part of the silviculture strategy for the TSA.

3.2.2 Scenario Approach

In many of the following scenarios the bookend approach was adopted. Initially, the timber supply impacts were tested by treating all the theoretically available areas in the model regardless of access, financial feasibility or actual condition of the treated stands. This was expected to generate the maximum theoretical treatment impacts. Subsequently, the intent is then to use stand-level analysis to identify the preferred stand types for treatment and net down the treatment populations based on the stakeholders estimates of the extent of the opportunity areas in the TSA. Next the desired treatments are combined into one scenario, the preferred scenario. This scenario will then form the basis for the silviculture strategy in the 100 Mile House TSA. All the silviculture scenarios were run for the period of 150 years.

The minimum harvest criteria were adjusted for all silviculture scenarios. In the base case the minimum harvest criteria consisted of a combination of minimum harvest volume and minimum harvest age. In the silviculture scenarios only minimum harvest volume was used; it was set to the harvest volume that was achieved at the minimum harvest age of the corresponding base case managed stand yield curve. This ensured that the treated stands were not harvested at lower volumes than in the base case; however, the exclusion of the age criterion allowed some of the stands to be harvested earlier than in the base case.

3.2.3 Rehabilitation of Dead Pine Stands

In the base case approximately 65,000 ha of MPB attacked stands were not harvested within the first 20 years; these stands had lost most of their merchantable sawlog volume due to decay and were assumed to break up in the timber supply model. This population was the basis for the rehabilitation scenario. The area was reduced by excluding all stands within the UWR and those stands that in the timber supply model were assumed to have high densities of advanced regeneration. The remaining area of 23,000 ha was considered to be the maximum treatable area. The theoretical spatial locations of the treated stands are shown in Figure 24. This area was assumed to be treated during the first 5 years at the total cost of $46 million ($2,000 per ha); $9.2 million annually over the next 5 years. The assumed rehabilitation treatment consisted of overstory removal, with no recovery of merchantable volume, followed by planting as per the enhanced reforestation scenario described below in section 3.2.6.

Figure 25 shows the forecasted harvest for the rehabilitation scenario. Rehabilitating the 23,000 ha of beetle killed areas increased the timber supply by 8.8% between years 41 and 50 from 840,000 m^3 per year to 918,000 m^3 per year. Note that approximately 13% of the total volume in this period of 10 years (years 41 to 50) is predicted to come from natural stands with no MPB attack, or stands with only mild attack. Holding on to these stands while harvesting severely attacked dead stands at the beginning of the planning horizon can have a positive impact on the mid-term timber supply.

Rehabilitation also allowed for an earlier transition to the long-term harvest level compared to the base case; at year 51 compared to 71 in the base case.

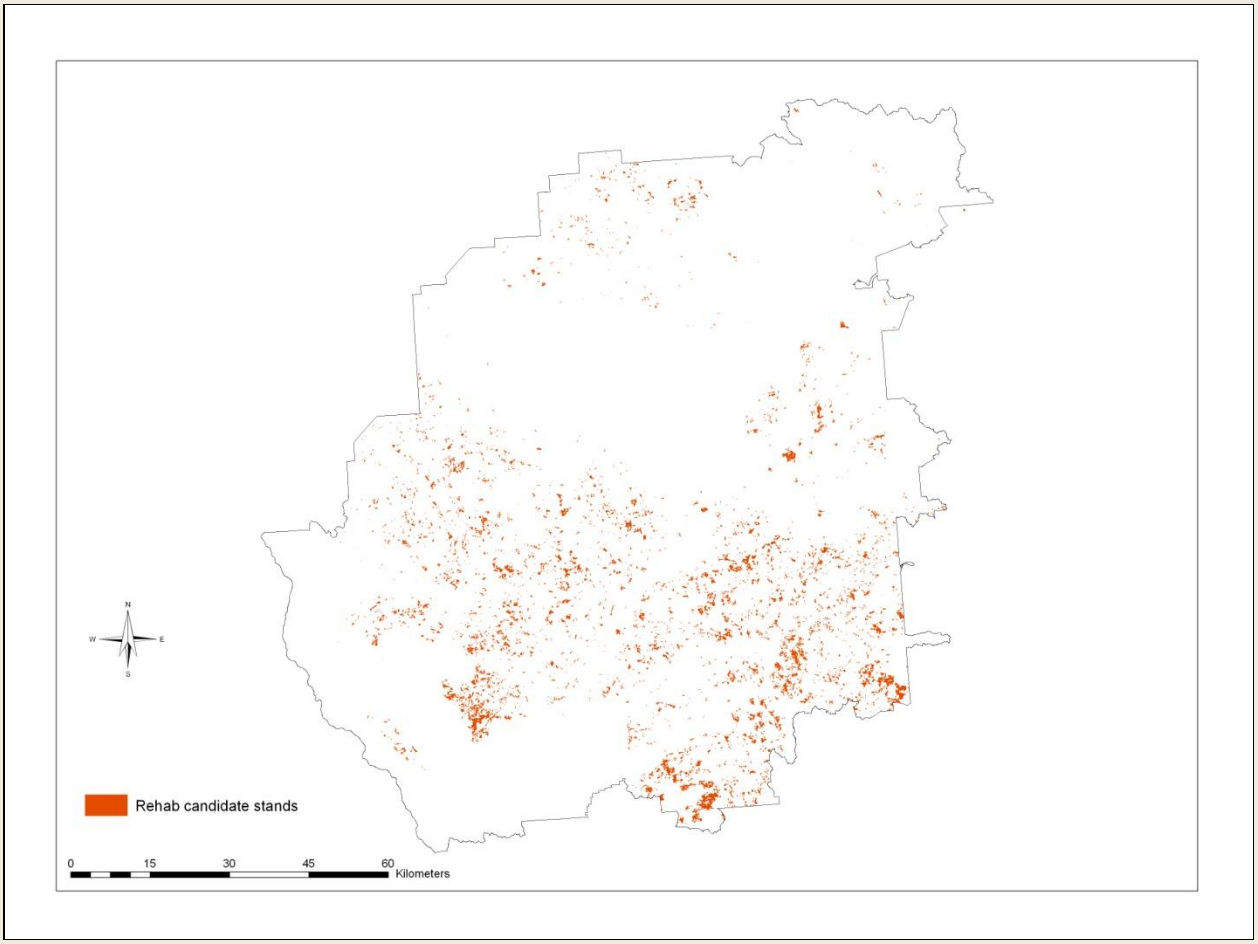


Figure 24: Stands rehabilitated in the model

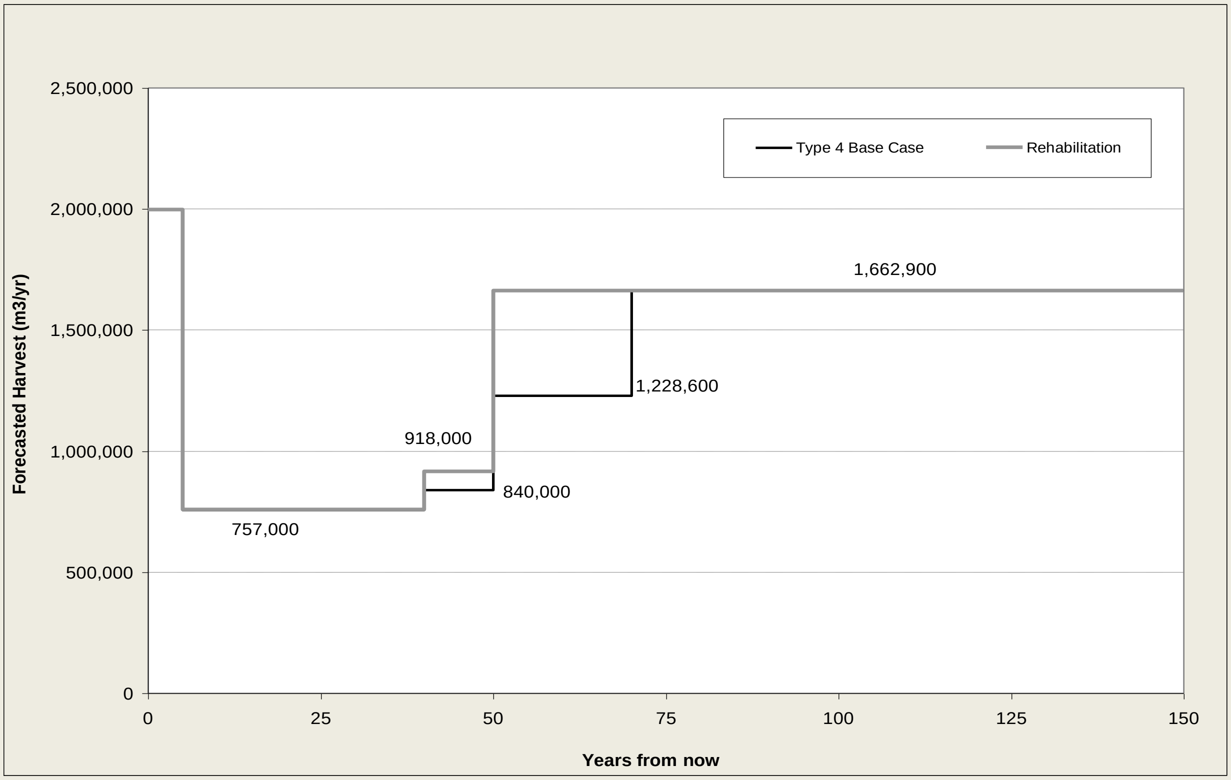


Figure 25: Rehabilitation scenario

3.2.4 Rehabilitation and Fertilization

This scenario added fertilization to rehabilitation. Rehabilitated areas, excluding those candidates in the IDF zone, were fertilized at ages 25, 35, 45 and 55. The fertilization costs are additional to the rehabilitation costs; the predicted annual fertilization costs are shown in Table 3. The fertilized area is reduced slightly in years 46-50 and considerably in years 56-60 because harvesting of the rehabilitated stands has already begun.

Table 3: Fertilization areas and costs

Years	Annual Fertilization Area (ha)	Annual Fertilization Cost ($)
1 to 5		
6 to 10		
11 to 15		
16 to 20		
21 to 25		
26 to 30	4,603	$2,761,811
31 to 35		
36 to 40	4,603	$2,761,811

Years	Annual Fertilization Area (ha)	Annual Fertilization Cost ($)
41 to 45		
46 to 50	4,140	$2,484,052
51 to 55		
56 to 60	965	$578,975

Rehabilitating the 23,000 ha of beetle killed areas and fertilization increased the timber supply by 19% between years 41 and 50 from 840,000 m^3 per year to 997,000 m^3 per year (Figure 26) (an incremental response of about 11% by fertilizing the rehabilitated stands). Fertilization of rehabilitated stands did not increase the harvest beyond 50 years.

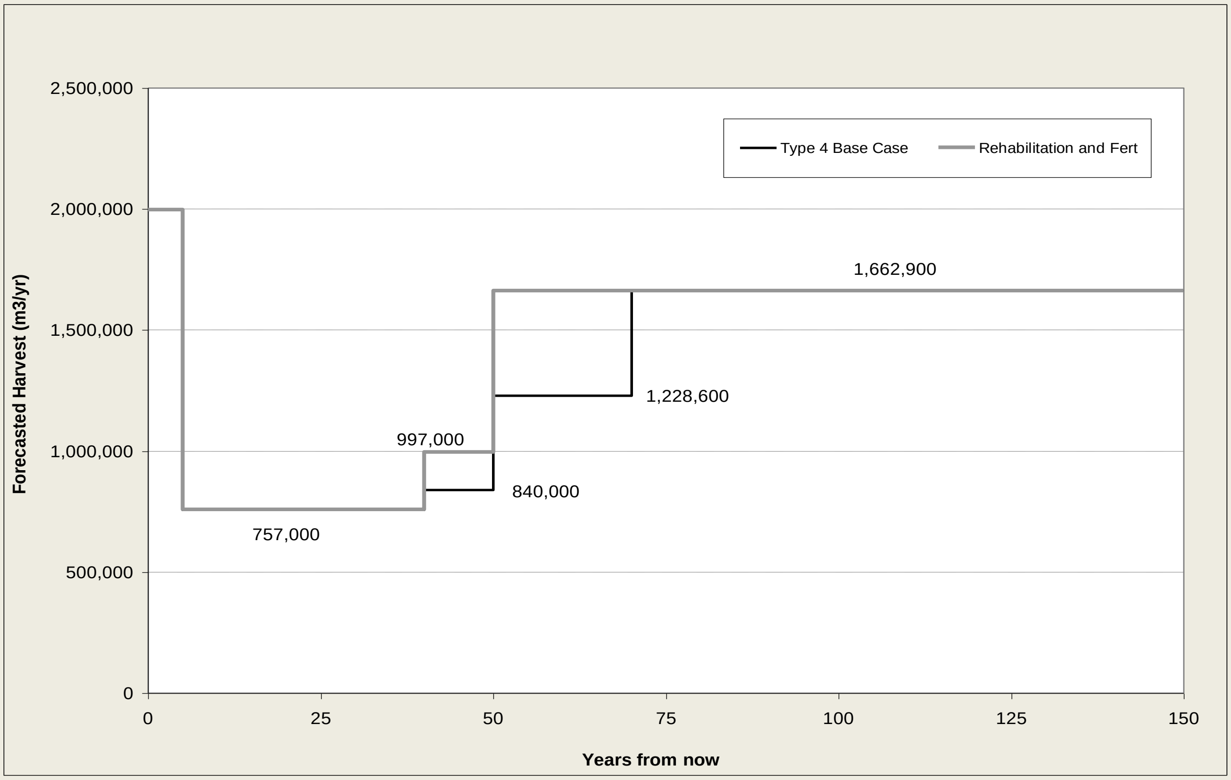


Figure 26: Rehabilitation plus fertilization scenario

3.2.5 Fertilization

Three fertilization scenarios were explored, increasing the fertilization population each time. No treatments were planned for the IDF zone. The first scenario included only the population that was fertilized between 2006 and 2012 (this was assumed to be the maximum available area of existing Douglas fir or spruce-leading stands suitable for treatment). These stands were set to be fertilized again either once more at age 55 or twice more at ages 40 and 50.

The second scenario added 2,000 ha of young, pine-leading managed stands that are currently included in fertilization plans for 2014 to the first scenario. These stands are to be treated at ages 25 (2014), 35, 45 and 55.

Scenario three added 25,000 ha to the first two fertilization populations; the target stands were existing pine, Douglas-fir and spruce-leading managed stands between 1 and 30 years of age. The stands were fertilized up to 4 times in the model at ages 25, 35, 45 and 55. Fertilization costs are assumed to be $600/ha. Table 4 summarizes the target populations for each of the scenarios. Figure 27 shows the spatial locations of those candidate stands between 11 and 50 years old. Stands that are currently between 1 and 10 years old are not shown in Figure 27, because their fertilization would not take place until 15 years from today.

Table 4: 100 Mile House Fertilization Scenarios Summary

Fertilization Scenario	Current age	Fertilize age	Total area (ha)	Cumulative Area (ha)
Fertilization 1	40-50	55	1,584	3,340
	30-40	40,50	1,756	
Fertilization 2	20-30	25,35,45,55	2,000	5,340
Fertilization 3	1-30	25,35,45,55	24,955	30,295

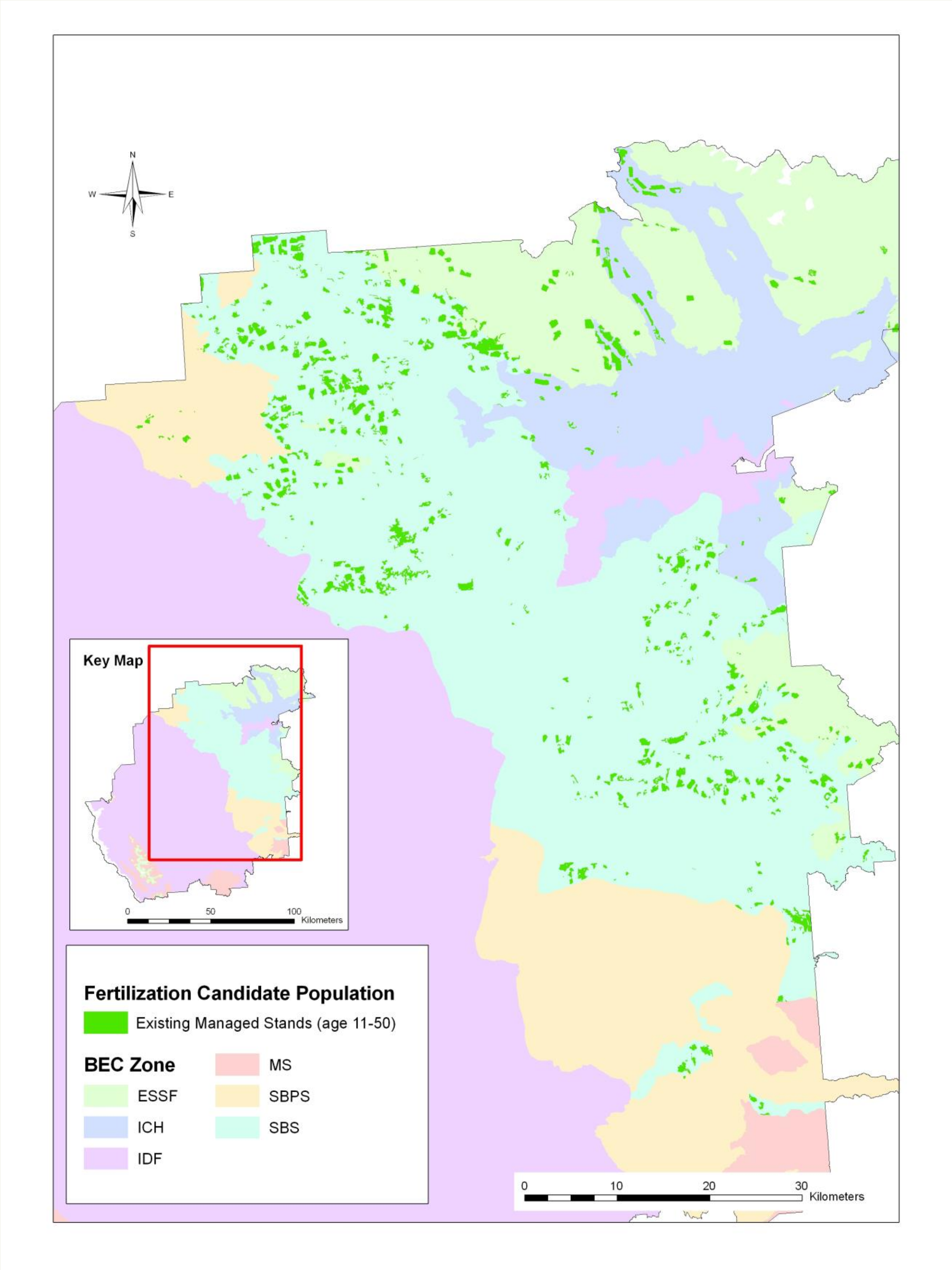


Figure 27: Candidate stands for fertilization; scenario 3 (includes scenario 1 and 2)

3.2.5.1 Fertilization 1

A total of 3,340 ha of existing managed stands between age 30 and 50 that were already fertilized in either 2006 or 2012, were fertilized once or twice in this scenario. Table 5 shows the annual cost associated with this scenario.

Table 5: Fertilization areas and costs for scenario 1

Years	Annual fertilization area (ha)	Annual fertilization cost ($)
1-5	131	$78,396
6-10	389	$233,464
11-15	207	$124,269
16-20	224	$134,683
21-25	68	$40,706

The impact is modest with approximately 40,000 m^3 annual increase over the base case in projected harvest from year 21 to 40 accompanied with a small reduction in harvest between years 41 and 50, as shown in Figure 28.

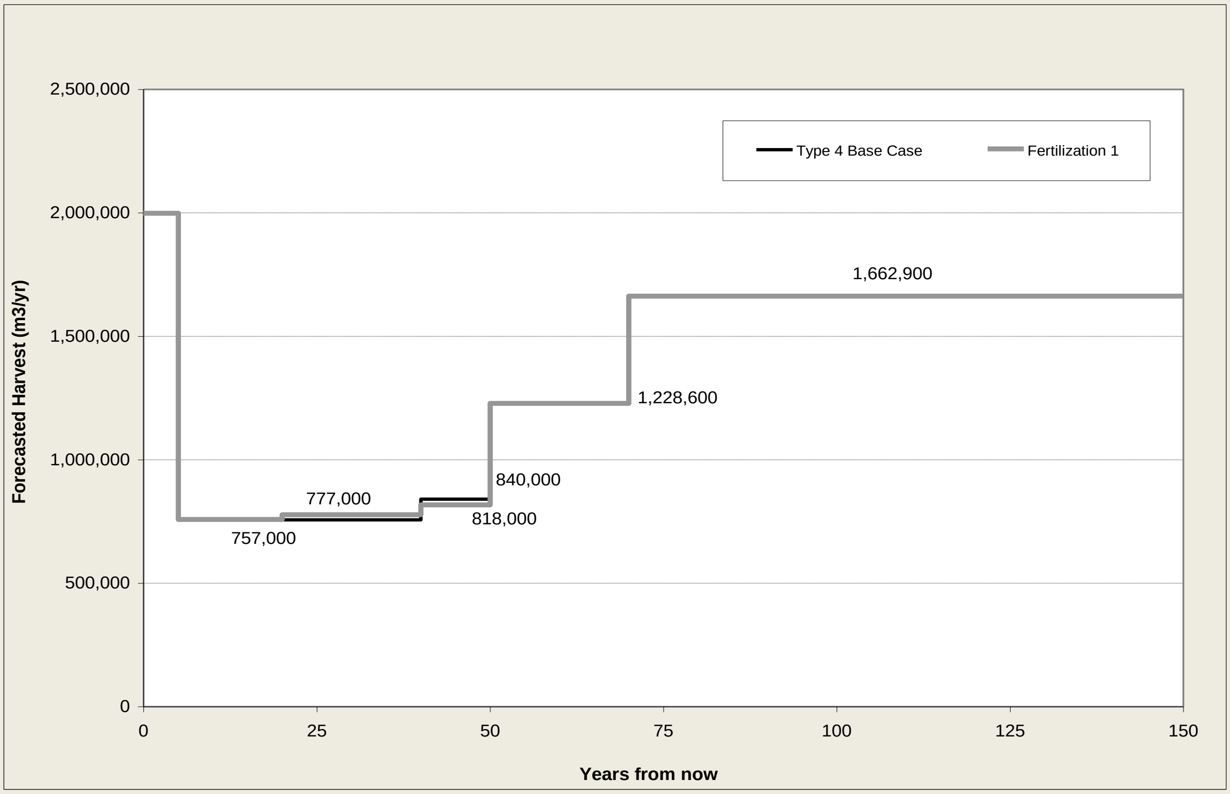


Figure 28: Forecasted harvest for fertilization scenario 1

3.2.5.2 Fertilization 2

In addition to the areas fertilized in scenario 1, 2,000 ha of pine-leading stands age 20-30 that are planned for fertilization in 2014 were added to the target population. These stands were fertilized in the model at ages 25 (2014), 35, 45, and 55. While this scenario increased the fertilization costs (Table 6), there was no impact on the forecasted harvest (Figure 29) over scenario 1.

Table 6: Fertilization areas and costs for scenario 2

Years	Annual fertilization area (ha)	Annual fertilization cost ($)
1-5	557	$334,045
6-10	575	$345,018
11-15	421	$252,713
16-20	410	$246,236
21-25	282	$169,149
26-30	25	$15,178
31-35	21	$12,571

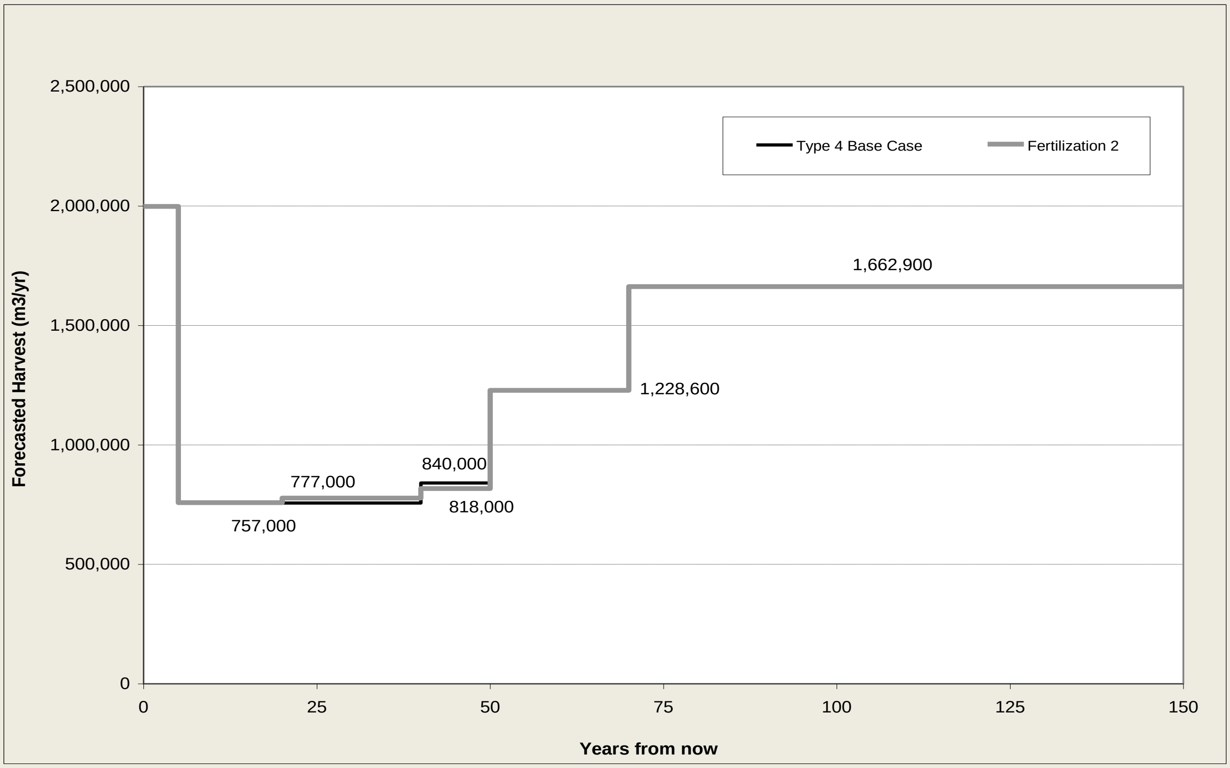


Figure 29: Forecasted harvest for fertilization scenario 2

3.2.5.3 Fertilization 3

In addition to the areas fertilized in scenarios 1 and 2, approximately 25,000 ha of young existing managed stands were added to the fertilization population. The treated areas and costs for this scenario are shown in Table 7.

Table 8 presents the same by leading species for the first 10 years. Figure 30 illustrates the fertilization schedule for the first 10 years spatially.

Table 7: Fertilization costs for scenario 3

Years	Annual fertilization area (ha)	Annual cost ($)
1-5	1,338	$802,774
6-10	1,443	$865,999
11-15	1,446	$867,604
16-20	3,398	$2,038,617
21-25	2,283	$1,370,065
26-30	2,769	$1,661,129
31-35	1,656	$993,409
36-40	2,220	$1,331,769
41-45	1,136	$681,835
46-50	384	$230,202
51-55	182	$109,070

Table 8: Fertilization; scenario 3; years 1 to 10, annual areas and costs by leading species

Years	Pine	Spruce	Douglas-fir	Total Area (ha)	Annual Cost ($)
1 to 5	1,207	9	121	1,338	$802,774
6 to 10	1,054	190	172	1,416	$865,999

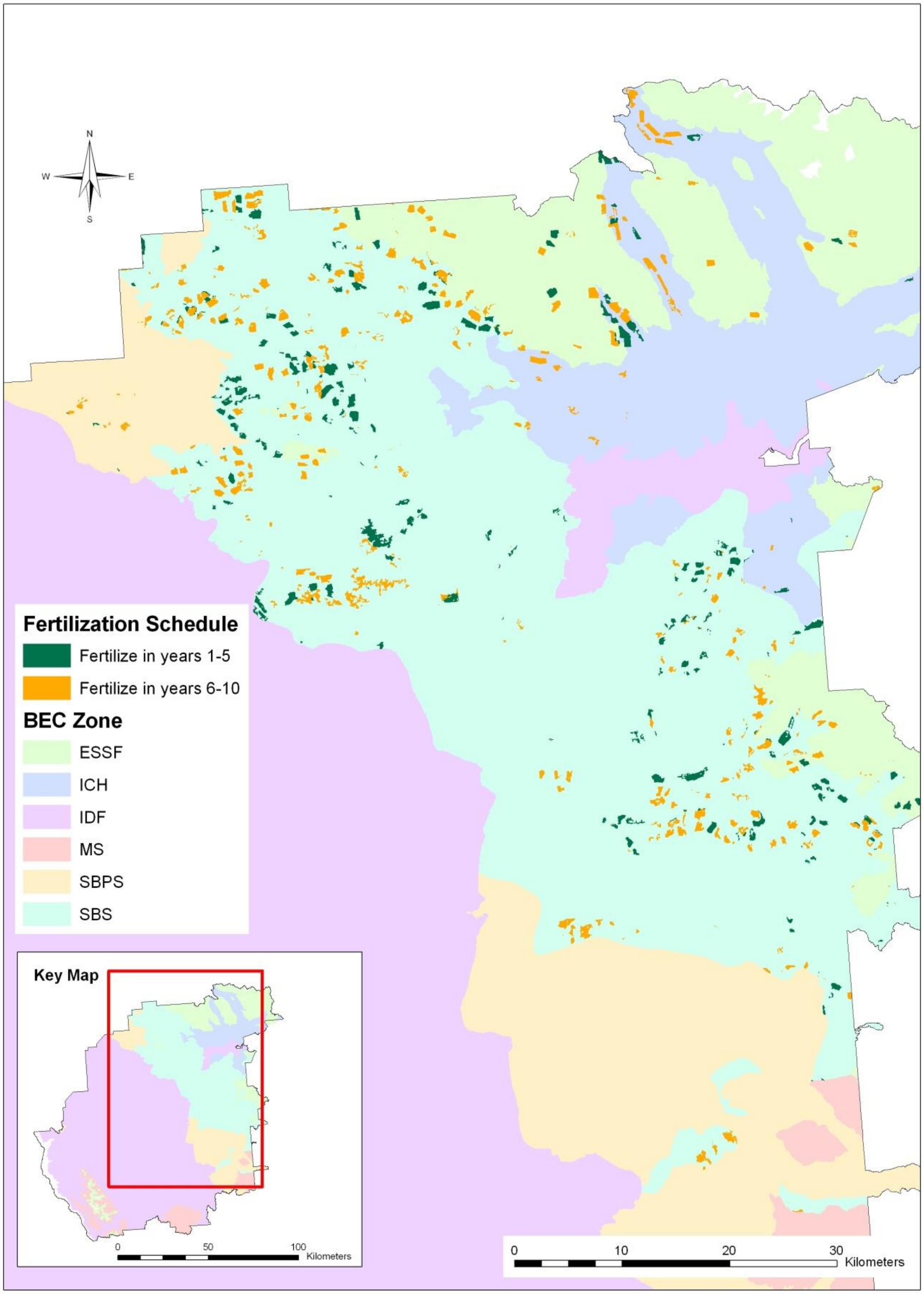


Figure 30: Stands fertilized in the model years 1 to 10

The impact of scenario 3 was an increase in the predicted harvest level by 12% between years 21 and 40. The increase was more modest at 3.9% between years 41 and 50, as shown in Figure 31.

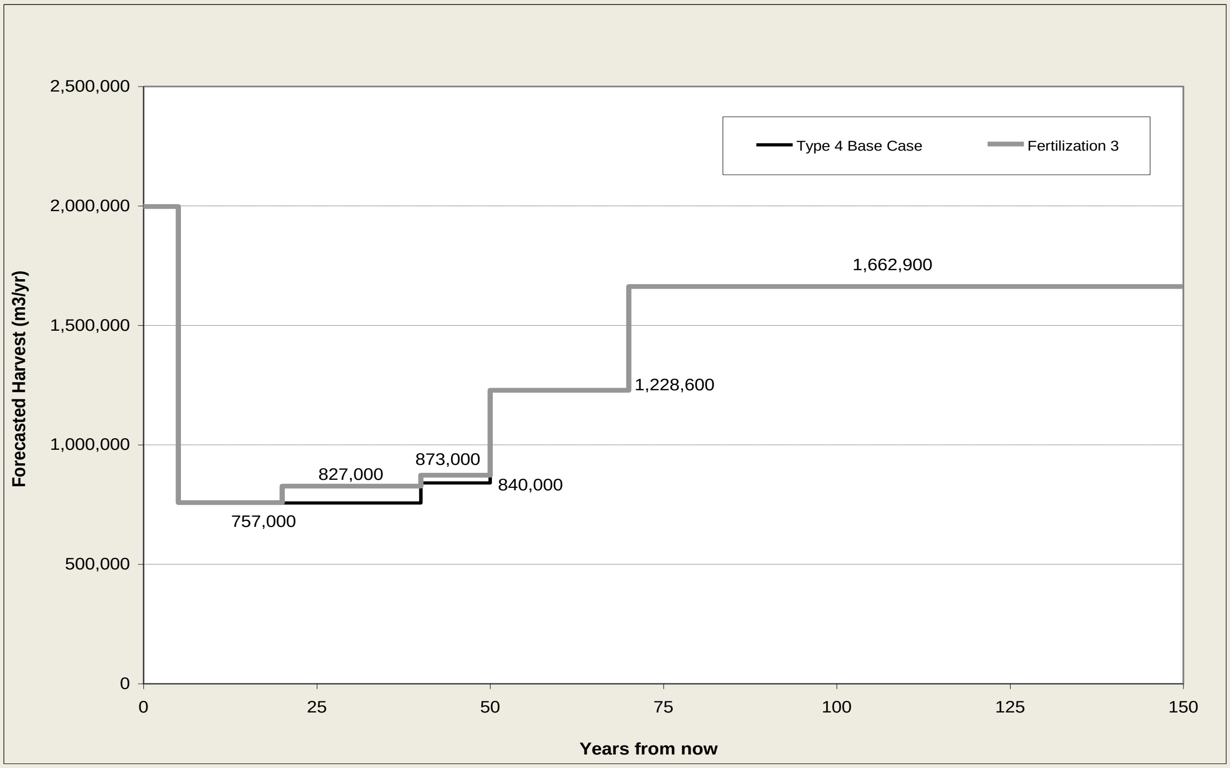


Figure 31: Forecasted harvest for fertilization scenario 3

3.2.6 Enhanced Reforestation

This scenario investigated the impact of an enhanced basic reforestation strategy (e.g.; improved site preparation, reforestation and brushing). Enhanced basic reforestation was simulated by planting more area as opposed to relying on natural regeneration, and increasing the planting densities of future managed stands. The candidate stands were conifer-leading stands on good and very good sites, outside of UWR areas. The seedlings were planted at a density of 1600 stems per hectare (approximately 50% more stems per ha than in the base case) and they were assumed to be from class A seed where this seed is currently available. The THLB area that was considered suitable for this treatment at some point in the future was 445,354 ha.

The incremental regeneration cost was assumed to be about $300 per hectare ($0.57/tree for an additional 526 stems/ha). Table 9 shows the annual costs and treated areas for the first 50 years of the model.

Table 9: Enhanced reforestation; annual areas and costs over next 50 years

Years	Annual Treatment Area (ha)	Incremental treatment cost ($)
1-5	12,515	$3,773,089
6-10	4,834	$1,459,857
11-15	4,618	$1,402,796
16-20	2,961	$912,376
21-25	2,001	$621,963
26-30	3,236	$990,463
31-35	3,479	$1,067,514
36-40	3,976	$1,204,627
41-45	3,656	$1,111,834
46-50	3,507	$1,064,820

This scenario had no impact on the harvest level in the mid-term; however the predicted harvest increases significantly after year 50 and into the long term. As illustrated in Figure 32, the increase over the base case between years 51 and 75 is 40%. During years 76 to 100 the increase is only 3%, while at year 101 the long term harvest increases to 1,826,700 m^3/year; a 10% increase over the base case.

In addition to producing more resilient stands with higher yields, this strategy offers the supplementary benefit of producing more high quality logs and improving the economic returns from harvesting. It also increases the volume responses and financial returns from subsequent fertilization treatments. Stands with higher initial densities are also candidates for future commercial and/or pre-commercial density management treatments.

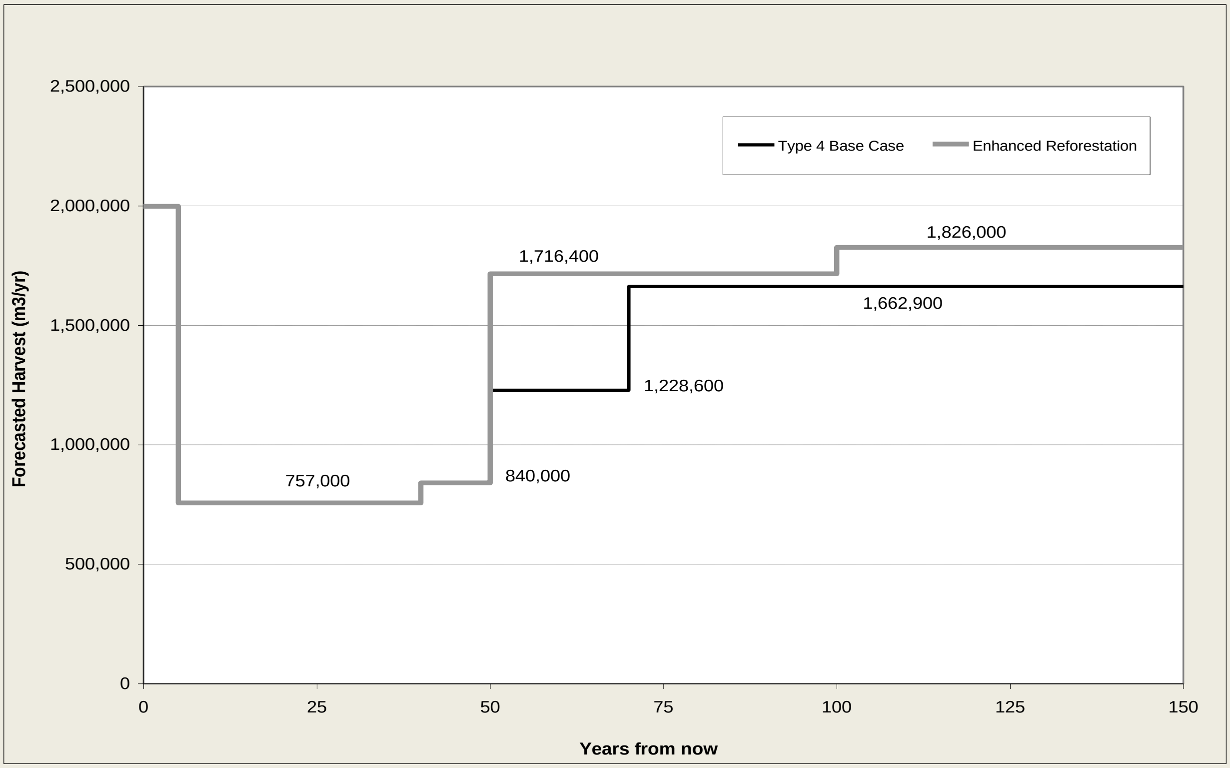


Figure 32: Forecasted harvest for the enhanced reforestation scenario

3.2.7 Enhanced Reforestation and Fertilization

This scenario added fertilization to some of the enhanced reforestation areas. The candidate areas for fertilization were outside the IDF zone, and non-balsam leading stands. These areas were fertilized at age 30, 40, and 50. The area of fertilization was 227,455 ha, 51% of the enhanced reforestation area. The fertilization costs were assumed to be $600/ha, as in the other fertilization scenarios. The costs for this scenario for the first 50 years of the model are shown in Table 10.

Table 10: Annual areas and costs for enhanced reforestation and fertilization scenario

Years	Annual planted area (ha)	Incremental planting cost ($)	Annual fertilization area (ha)	Annual fertilization cost ($)
1-5	12,515	$3,773,089		$0
6-10	4,834	$1,459,857		$0
11-15	4,618	$1,402,796		$0
16-20	2,961	$912,376		$0
21-25	2,001	$621,963		$0
26-30	3,236	$990,463		$0
31-35	3,479	$1,067,514	6,325	$3,794,906
36-40	3,976	$1,204,627	2,342	$1,404,961
41-45	3,656	$1,111,834	9,865	$5,919,249
46-50	3,507	$1,064,820	4,522	$2,713,338

As in the enhanced reforestation scenario above, this scenario had no impact in the mid-term; however a significant increase in annual harvest occurs after year 50. The increase in years 51 to 75 is 48% over the base case harvest level, followed by a 9% increase between years 76 and 100, as shown in Figure 33. At year 101, the long-term harvest level increases to 1,916,000 m^3/year; a 15% raise over that of the base case.

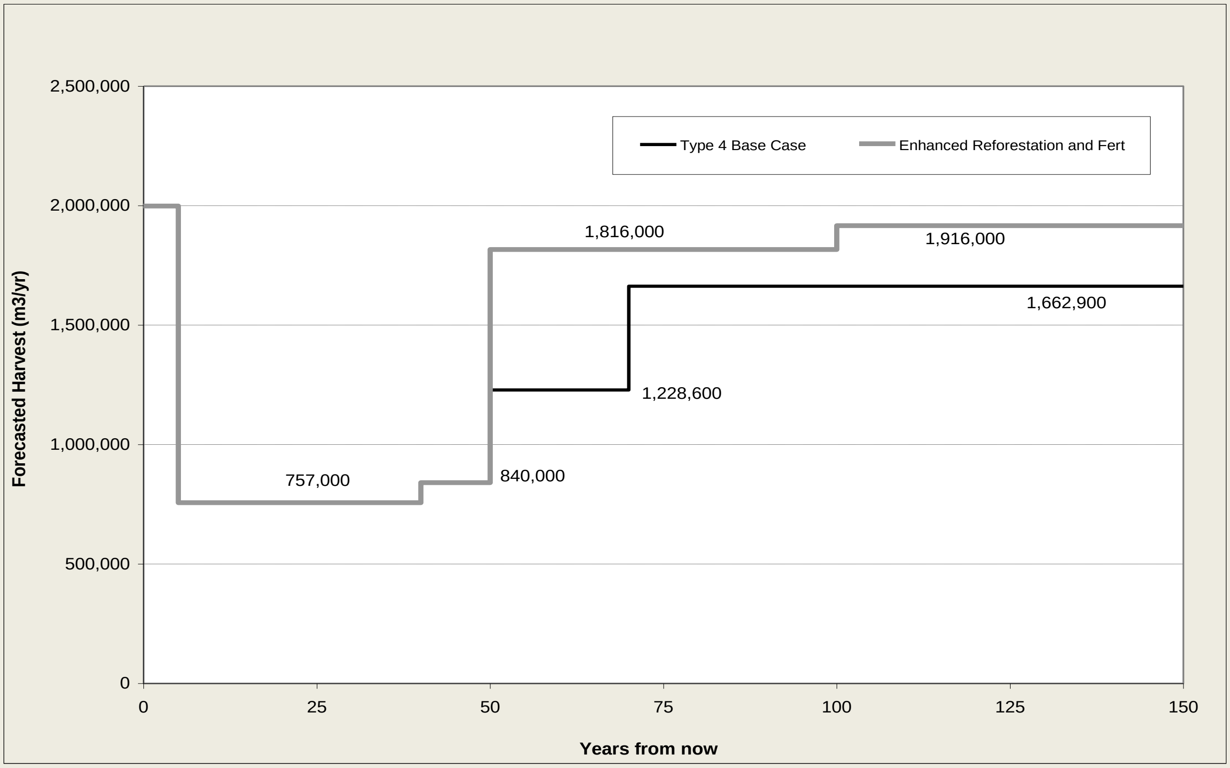


Figure 33: Forecasted harvest for enhanced reforestation plus fertilization scenario

3.2.8 Scenario Summary

Table 11 and Table 12 provide a summary of treatment impacts compared to the base case

Table 11: Scenario summary; harvest forecast (m^3/year)

Years from Now	Base Case Harvest Level	Scenario							
		Low Initial Harvest	Rehab Dead Pine	Rehab Dead Pine & Fertilize	Fertilize 1	Fertilize 2	Fertilize 3	Increase Planting Densities	Increase Planting Densities and Fertilize
1 to 5	2,000,000	1,334,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000
6 to 10	757,000	842,400	757,000	757,000	757,000	757,000	757,000	757,000	757,000
11 to 15	757,000	842,400	757,000	757,000	757,000	757,000	757,000	757,000	757,000
16 to 20	757,000	842,400	757,000	757,000	757,000	757,000	757,000	757,000	757,000
21 to 26	757,000	842,400	757,000	757,000	777,000	777,000	827,000	757,000	757,000
26 to 30	757,000	842,400	757,000	757,000	777,000	777,000	827,000	757,000	757,000
31 to 35	757,000	842,400	757,000	757,000	777,000	777,000	827,000	757,000	757,000
36 to 40	757,000	842,400	757,000	757,000	777,000	777,000	827,000	757,000	757,000
41 to45	840,000	842,400	918,000	997,000	818,000	818,000	873,000	840,000	840,000
46 to 50	840,000	842,400	918,000	997,000	818,000	818,000	873,000	840,000	840,000
51 to 55	1,228,600	1,228,600	1,662,900	1,662,900	1,228,600	1,228,600	1,228,600	1,716,400	1,816,000
56 to 60	1,228,600	1,228,600	1,662,900	1,662,900	1,228,600	1,228,600	1,228,600	1,716,400	1,816,000
61 to 65	1,228,600	1,228,600	1,662,900	1,662,900	1,228,600	1,228,600	1,228,600	1,716,400	1,816,000
66 to 70	1,228,600	1,228,600	1,662,900	1,662,900	1,228,600	1,228,600	1,228,600	1,716,400	1,816,000
71 to 75	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900	1,826,000	1,616,000
76 to 80	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900	1,826,000	1,616,000
81 to 85	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900	1,826,000	1,616,000
86 to 90	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900	1,826,000	1,616,000
91 to 95	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900	1,826,000	1,616,000
96 to 100	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900	1,826,000	1,616,000
101 to 105	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900
106 to 110	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900
111 to 115	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900
116 to 120	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900
121 to 125	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900
126 to 130	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900
131 to 135	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900
136 to 140	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900
141 to 145	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900
146 to 150	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900	1,662,900

Table 12: Scenario summary; treatment impact; harvest level compared to the base case

Years from Now	Base Case Harvest Level	Scenario							
		Low Initial Harvest	Rehab Dead Pine	Rehab Dead Pine & Fertilize	Fertilize 1	Fertilize 2	Fertilize 3	Increase Planting Densities	Increase Planting Densities and Fertilize
1 to 5	2,000,000	**-33.3%**	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
6 to 10	757,000	**11.3%**	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
11 to 15	757,000	**11.3%**	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
16 to 20	757,000	**11.3%**	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
21 to 26	757,000	**11.3%**	0.0%	0.0%	**2.6%**	**2.6%**	**9.2%**	0.0%	0.0%
26 to 30	757,000	**11.3%**	0.0%	0.0%	**2.6%**	**2.6%**	**9.2%**	0.0%	0.0%
31 to 35	757,000	**11.3%**	0.0%	0.0%	**2.6%**	**2.6%**	**9.2%**	0.0%	0.0%
36 to 40	757,000	**11.3%**	0.0%	0.0%	**2.6%**	**2.6%**	**9.2%**	0.0%	0.0%
41 to45	840,000	**0.3%**	**9.3%**	**18.7%**	**-2.6%**	**-2.6%**	**3.9%**	0.0%	0.0%
46 to 50	840,000	**0.3%**	**9.3%**	**18.7%**	**-2.6%**	**-2.6%**	**3.9%**	0.0%	0.0%
51 to 55	1,228,600	0.0%	**35.3%**	**35.3%**	0.0%	0.0%	0.0%	**39.7%**	**47.8%**
56 to 60	1,228,600	0.0%	**35.3%**	**35.3%**	0.0%	0.0%	0.0%	**39.7%**	**47.8%**
61 to 65	1,228,600	0.0%	**35.3%**	**35.3%**	0.0%	0.0%	0.0%	**39.7%**	**47.8%**
66 to 70	1,228,600	0.0%	**35.3%**	**35.3%**	0.0%	0.0%	0.0%	**39.7%**	**47.8%**
71 to 75	1,662,900	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	**9.8%**	**-2.8%**
76 to 80	1,662,900	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	**9.8%**	**-2.8%**
81 to 85	1,662,900	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	**9.8%**	**-2.8%**
86 to 90	1,662,900	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	**9.8%**	**-2.8%**
91 to 95	1,662,900	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	**9.8%**	**-2.8%**
96 to 100	1,662,900	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	**9.8%**	**-2.8%**
101 to 105	1,662,900	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
106 to 110	1,662,900	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
111 to 115	1,662,900	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
116 to 120	1,662,900	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
121 to 125	1,662,900	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
126 to 130	1,662,900	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
131 to 135	1,662,900	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
136 to 140	1,662,900	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
141 to 145	1,662,900	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
146 to 150	1,662,900	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

3.2.9 Strategies Examined with Stand-level Analysis

3.2.9.1 Dry Belt Douglas fir

Analysis of RESULTS data reveals that, outside of MDWRs and OGMA's, there are about 30,000 to 35,000 hectares of uneven aged Douglas fir-leading stands in the IDFdk3 and dk4 in the 100 Mile House TSA, which were partially harvested between about 1960 and 1995. This equates to about 27 to 32% of the managed stand subpopulation in the IDF. According to Day and McWilliams (2013) many of these stands in the southern portion of the Cariboo are stocked or overstocked with Douglas fir advanced regeneration and various levels of moderate to poor-quality residual Douglas fir. Many of these stands have also experienced some impacts from spruce budworm infestations. RESULTS data and feedback from local foresters indicate that some of these stands have undergone spacing treatments. According to the base case, a significant portion of the mid-term timber supply is expected to come from these stands. However; uncertainties associated with inventory data and growth and yield data make analysis of treatment strategies challenging.

According to previous strategies and analysis (Day and McWilliams 2013, Blackwell et al., 2009 and DWB et al., 2009) there are several key strategies to consider for uneven aged Douglas fir-leading stands in the IDFdk3 and dk4 in the 100 Mile House TSA. The most beneficial treatment for the mid-term timber supply might be the spacing of over-dense understories. Figure 34 illustrates in a general way which types of stands are suitable for this treatment.

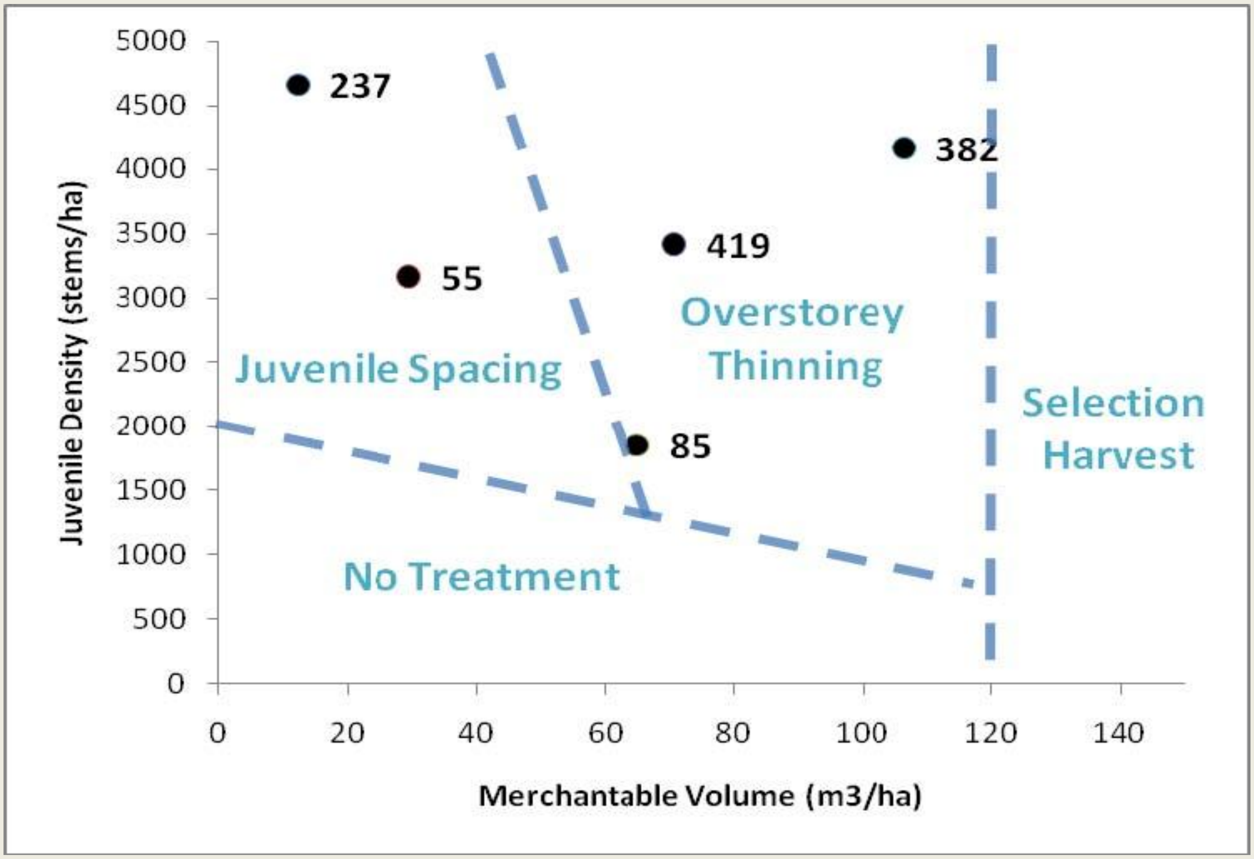


Figure 34: Simplified Decision Matrix for Density Management in dry belt Douglas fir (Blackwell, 2009)

A stand-level growth and yield analysis (PROGNOSIS$_{BC}$ Version 3.3) and financial analysis on relatively common, partially harvested dry belt stand types in the southern portion of the Williams Lake TSA predicted understory thinning to have a positive impact on the mid-term harvest levels and be financially viable on specified stand types (DWB Consulting Services Ltd., Tesera Systems Inc. and B.A. Blackwell and Associates Ltd., 2010).

The following are the key characteristics of the stands suitable for understory thinning;

- IDFdk3 (dk4, SBSdw2);
- Site index >15m;
- Harvested in the 1960's (and 1970's) and no previous pre-commercial thinning has occurred;
- No current commercial harvest opportunity, <100m^3/ha (>27.5cm dbh limit);
- L2 and L3 total densities of >2500sph;
- Layer 1 overstory basal area of <10m^2/ha;
- Outside of MDWR areas;
- No additional significant constraints to future harvest;
- Forest Health (areas with low to moderate incidence of spruce budworm or that have been previously treated with Btk).

These stand types can be most efficiently managed with a shelterwood system. The regime consists of juvenile spacing of the stagnated understory, preparation cut and final cut. Juvenile spacing can generate incremental intermediate harvest volumes of 15 to 80m^3/ha 30 to 40 years after treatment (preparation cut) and a final harvest of 58 to 138m^3/ha 70 years after juvenile spacing. The efficiency of the treatment depends on the specific stand type. On one stand type the spacing and the intermediate harvest caused a reduction of about 14m^3/ha in the final harvest while in another stand type the treatment regime allowed the final harvest volume to increase by about 64m^3/ha. Financial analysis shows that this treatment regime can be viable using a 2% interest rate (see Section 4.3.1 for more details on the financial analysis).

3.2.9.2 Rehabilitation of Dead and Damaged Managed Pine-leading Stands

The base case assumptions for MPB impacts in managed pine leading stands (65,000 ha) reduced the yield of these stands by 20%. Most of these stands are expected to be harvested or at least harvestable in the mid term given the minimum harvest criteria (>60 years old and >60m^3/ha). However, this assumption may be incorrect.

The MPB impacts on these stands are averaged over the entire population in the analysis. While the assumed average impact may be reasonable, the actual impact varies depending on population, its location and management condition. As an example, the MPB impacts have been shown to be more severe on juvenile spaced stands. As many of the accessible managed pine leading stands have been spaced in the 100 Mile House TSA, it is not unreasonable to suspect that at least some of these treated stands may have been more significantly impacted by the MPB than has generally been assumed.

The base case assumes that – aside from the MPB impacts – the pine leading managed stands are relatively healthy. Some recent studies have discovered various other forest health problems in these stands. The cumulative impact of the MPB and other forest health agents may reduce the growth and yield of these stands so much that they fail to become merchantable during the mid term.

The assumed minimum harvest criteria may not be appropriate for damaged managed stands. This is due to lower expected wood quality from damaged stands and higher harvest costs which are necessary to protect the non-merchantable stocking, which is expected to be common in these stands.

Rehabilitation of those stands that may not be harvested in the mid term may be beneficial for the long term timber supply. Assessing damaged managed stands to determine whether they will develop into future harvesting opportunities is complex. While it is not possible to provide a definitive solution to this issue in this project, following is an attempt to provide a framework for discussion using stand level analysis.

The pine leading managed stands can be variable and complex in terms of species, density, forest health and stocking by layer. In general, the opportunity for mid term harvest will be based on the stocking, health and quality of layers 1 and 2 (overstory) versus layers 3 and 4 (understory) which at best may provide late mid-term to long term harvest opportunities. Several key assumptions are required to assess the prospects of these variable stands:

- Risk of loss of the stand due to fire related to the elevated fuel loadings from dead and down trees within the stand and in adjacent stands;
- Damage to overstory and understory trees due to the breakup of the standing dead component of the overstory;
- Growth rates for healthy overstory and understory trees (impacts of shading);
- Impacts on survival and growth from the main forest health agents present in the stand now, and agents which could impact the stand in the future;
- Quality of wood expected from the overstory;
- Minimum merchantability (volume x value) required to harvest the overstory with or without the protection of the understory.

Blackwell (2009) developed a customized spreadsheet approach for the Forests for Tomorrow (FFT) program using TIPSYv4.2 to facilitate the analysis of these stands; the approach incorporated financial analysis. For this stand level analysis, two scenarios were developed and analyzed using recent survey results from 30 to 40 year old managed pine leading stands in the 100 Mile House TSA.

Scenario 1

For the first scenario, the stand ecological classification is IDFdk3 site series 01. The stand was planted with pine about 30 years ago and was juvenile spaced. The SIBEC site index (SI BH age 50 years) for pine is 19m. The stand is currently NSR. Table 13 summarizes the recent silviculture survey results by overstory and understory.

Table 13: Stand Description for Scenario 1

	Age	Species Mix	Total SPH	WS SPH	Disease (severity)
Overstory (Layers 1-2)	30	Pli80At20	560	92	DFE (M-H)
Understory (Advanced Regen) (Layers 3-4)	12	At70Pli30	4700	350	DFE (M)

Figure 35 summarizes selected growth and yield modeling results for Scenario 1 by layer (with all layers representing the total of the overstory and understory layers). The scenario compared a no treatment option to rehabilitation. Rehabilitation treatment consists of overstory and understory removal followed byplanting of pine at1,600sph, with a genetic worth of 2%. Time zero is the present which represents an overstory stand age of about 30 with the MPB impacts resulting in the steep drop in the overstory stocking about 5 years ago.

Key assumptions for the no treatment regime are a reduction in overstory SI of 1m to reflect the actual growth intercept estimate for the stand and a 10% reduction in growth of the understory due to estimated impacts of shading and disease severity.

The merchantable volume results from this scenario indicate that the base case minimum harvest criteria of 65 m^3/ha will be achieved in about 25 and 29 years from now (red arrows on the merchantable volume graphs) at overstory stand ages of 55 and 59 years for the no treatment and rehabilitation options respectively.

If both regimes are harvested 60 years from now, the merchantable volume estimates are about 200 and 284m^3/ha respectively. Based on these results there are volume and timing tradeoffs to consider when deciding about whether to wait and harvest in the mid-term or to rehabilitate now (see Section 4.3.1 for the financial results for this analysis).

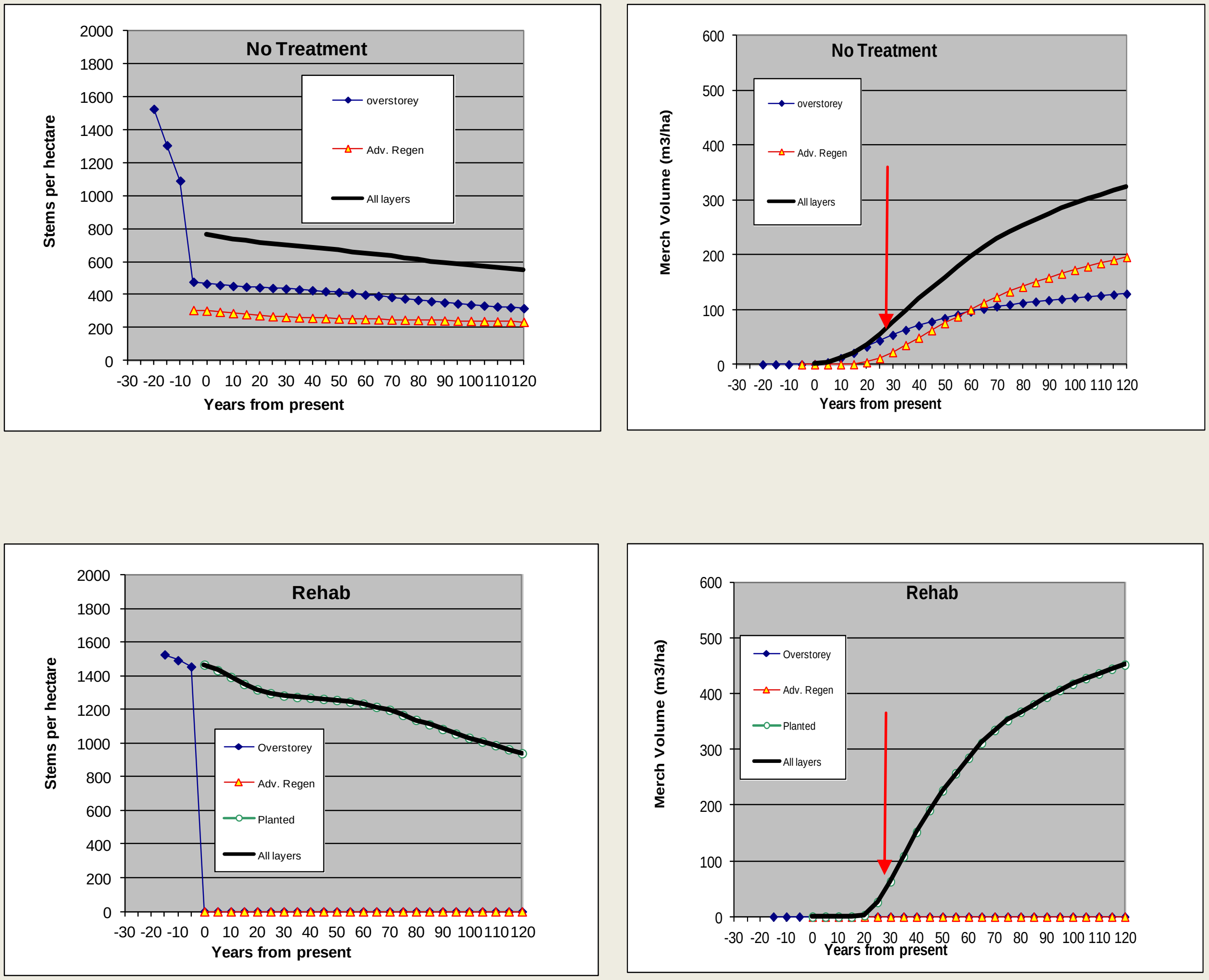


Figure 35: Modeling results for Scenario 1 comparing no treatment (top graphs) and rehabilitation (bottom graphs) by sph (left graphs) and merchantable volume by layer (right graphs)

Scenario 2

This stand is very similar to that of Scenario 1 with the exception that it is sufficiently restocked (SR) with most of the additional well spaced stocking in the understory. The near-term harvesting opportunities (close to the minimum harvest volume criteria) are expected to be similar to those is Scenario 1. The concern is that if the economic minimum harvest age is actually significantly higher, and disease severity causes the live pine overstory and understory to continue to under-perform expectations, then the existing stand could stagnate. If so, rehabilitation could provide a better outcome. Table 14 summarizes the recent silviculture survey results by overstory and understory.

Table 14: Stand Description for Scenario 2

	Age	Species Mix	Total SPH	WS SPH	Disease (severity)
Overstory (Layers 1-2)	30	Pli80At20	700	110	DFE (M-H)
Understory (Advanced Regen) (Layers 3-4)	12	At60Pli40	5500	600	DFE (M)

Figure 36 summarizes selected growth and yield modeling results by layer for Scenario 2. The scenario compared a no treatment option to rehabilitation. As in scenario 1, rehabilitation treatment consists of overstory and understory removal, followed by planting of pine at 1,600sph with a genetic worth of 2%. Assumptions for the base version of the no treatment option are the same as for Scenario 1.

A variation of the no treatment option (V2) is presented. This simulates a worse case situation for the continued impacts of forest health, where the overstory pine SI is reduced to 15m and the understory growth is reduced by an additional 20%.

The merchantable volume results from this scenario indicate that if harvesting is delayed until 60 years from now, the harvestable volumes will be about 295, 200 and 295m^3/ha respectively for the base version of the no treatment option, the V2 no treatment option and the rehabilitation option (red arrows on graphs). These results illustrate that if the future impacts of forest health on stand development are expected to be small, there is little reason to consider rehabilitation. However, if the forest health impacts are expected to be significant and the earliest harvest entry cannot be made until later, then rehabilitation may become a viable option (see Section 4.3.1 for the financial results for this analysis).

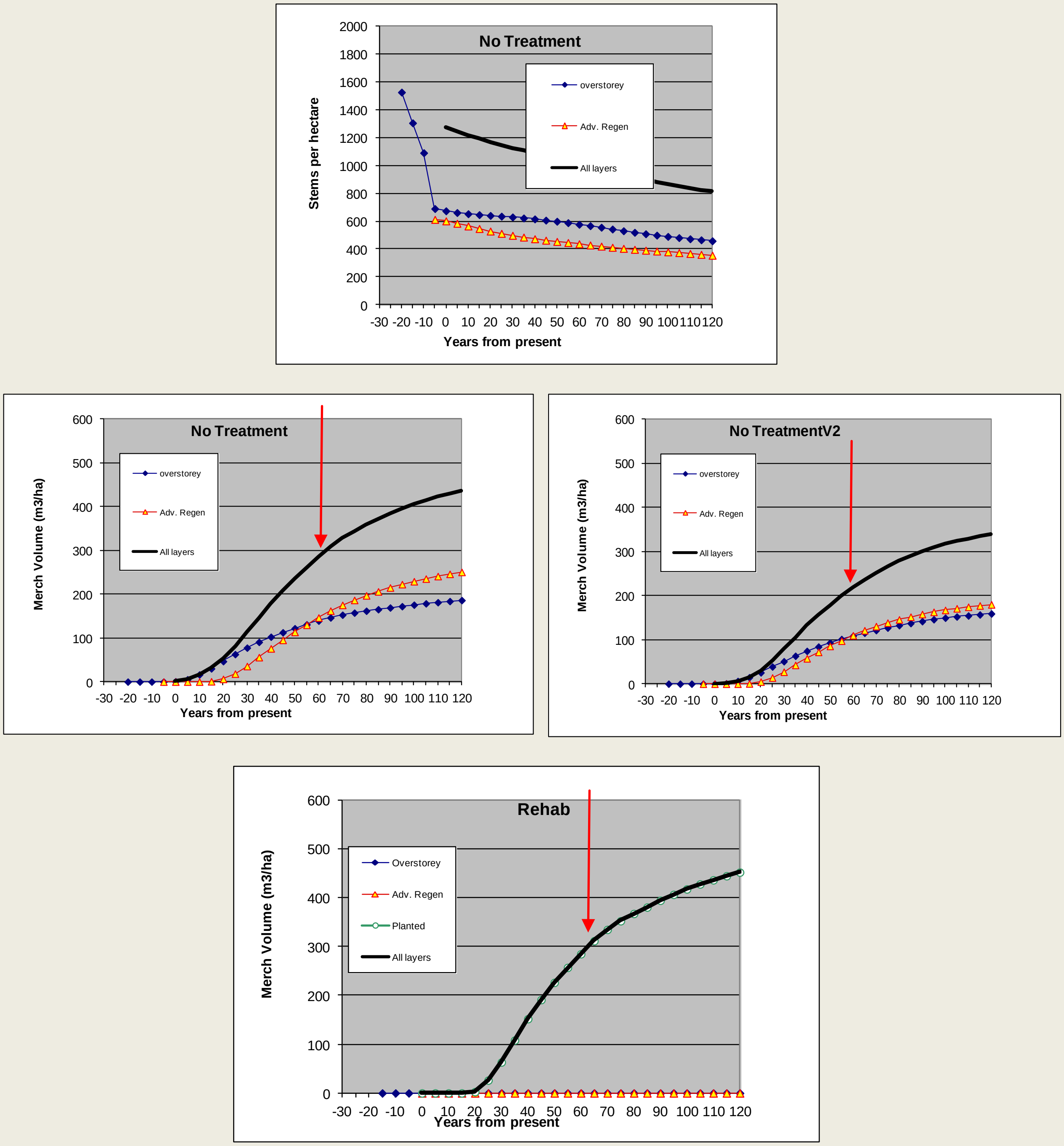


Figure 36: Modeling results for Scenario 2 by layer; the top graph shows the development of total stand density for the base, No Treatment option; the middle two graphs compare merchantable volume development for the base and a variation (V2) of the No Treatment option; the lower graph shows merchantable volume development for the rehabilitation option

4 Composite Scenarios

Two composite scenarios were constructed. For both scenarios the fertilization costs were adjusted to $500.00 per ha from the $600.00 used in the initial scenarios. The costs of rehabilitating dead pine stands were assumed to be $2,000 per ha as before. The costs for increased planting densities were unchanged from the earlier scenarios, approximately $300 per ha.

The first scenario was designed by the 100 Mile House TSA stakeholder group. It set a modest incremental silviculture target of 600 ha of fertilization per year for the next 5 years at the cost $300,000 per year. The annual fertilization program is set to increase to 1,000 ha per year in the post salvage period starting 6 years from today. The rehabilitation of dead pine stands will start at year 6 as well and by this time, enhanced basic silviculture will be considered for the silviculture program. The annual budget for the first 5-year period was set at $300,000 (fertilization) and at $2.3 million for years 6 to 10 ($500,000 fertilization, $1.5 million rehabilitation and $300,000 for enhanced reforestation). An addition $50,000 was allocated to Dry belt fir management; this was not modeled in the analysis but will be considered in the final silviculture strategy.

The second scenario increased the annual funding for the first 5-year period to $2.3 million and maintained this budget through years 6 to 10. The funding increase for the first 5 years consisted of rehabilitation of dead pine stands and enhanced reforestation; fertilization treatment areas and costs remained identical to those in the first scenario.

Both scenarios were modeled using a combination of heuristics and time-step simulation techniques. Heuristics were used to help determine the stands for treatments, while time step simulation techniques were employed to determine the harvest forecast for the composite scenarios.

4.1 Composite Scenario 1

This scenario represents a recommended incremental silviculture funding level for the 100 Mile TSA. Using a $300,000 annual budget for the first 5 years and $2.3 million for consecutive 5 year periods resulted in a 4.5% increase in harvest between years 21 and 45 (Figure 37). The increase was more pronounced between years 41 and 50 at approximately 5.7%. A 15.2% higher harvest level was achieved between years 51 and 70. No increases in the LTHL were observed.

It was assumed that the silviculture funding would not be limited to the short term; rather the funding in the model continued into the future. The treatment areas (ha) as modeled are shown in Table 15.

Table 16 shows the budget split by treatment. Note that fertilization was assumed only on existing stands (managed, currently 1 to 50 years old). Rehabilitation of MPB attacked pine stands was assumed to continue only for 20 years. Enhanced reforestation was assumed to continue for 50 years.

In the first 5-year period fertilization was funded approximately at $386,500 per annum (773 ha annually). This is higher than the target budget. The budget was exceeded because fertilization treatments are modeled in the forest estate model as regimes; stands are fertilized several times and somewhat higher level of fertilization was required in the first 5 years to meet the fertilization requirement for years 11 to 15. Between years 6 and 10, fertilization expenditures were approximately $473,000 per annum (946 ha). In this time period, the rehabilitation dead pine stands commenced at the annual expenditure of $1.35 million (675 ha/year). The annual budget allocation for enhanced reforestation was approximately $308,000 (1,021 ha/year).

As only existing stands were fertilized, the fertilized area and expenditures decline over time and eventually go to 0 (not shown).

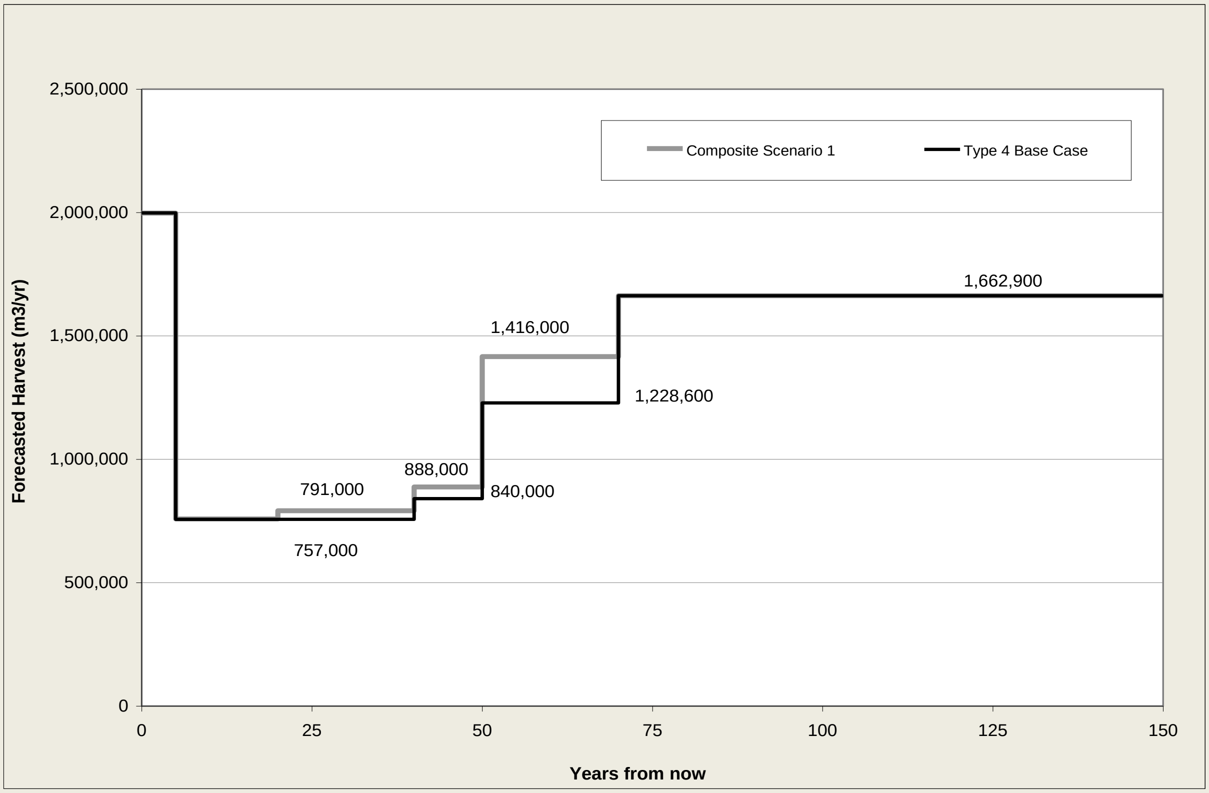


Figure 37: Composite Scenario 1 compared to the base case

Table 15: Annual treatment areas (ha); Composite Scenario 1

Year	Enhanced Reforestation	Fertilize	Rehab	Total
1 to 5		773		773
6 to 10	1,021	946	675	2,643
11 to 15	1,014	960	820	2,794
16 to 20	1,002	981	681	2,664
21 to 25	664	1,107		1,771
26 to 30	894	689		1,583
31 to 35	827	531		1,358
36 to 40	772	378		1,151
41 to 45	439	284		723
46 to 50	324	40		364

Table 16: Annual budget split by treatment; Composite Scenario 1

Year	Enhanced Reforestation	Fertilize	Rehab	Total
1 to 5		$386,489		$386,489
6 to 10	$307,992	$472,998	$1,350,680	$2,131,671
11 to 15	$307,951	$480,185	$1,639,852	$2,427,989
16 to 20	$307,682	$490,632	$1,361,383	$2,159,697
21 to 25	$206,292	$553,588		$759,880
26 to 30	$272,729	$344,475		$617,204
31 to 35	$254,450	$265,299		$519,750
36 to 40	$234,138	$189,185		$423,323
41 to 45	$133,481	$141,957		$275,437
46 to 50	$98,346	$19,915		$118,261

Figure 38 illustrates the harvest forecast by forest unit for the Composite Scenario 1. The harvest of fertilized stands starts in year 26 and contributes to the increased harvest. The harvest of rehabilitated dead pine stands and higher density future managed stands starts at year 61.

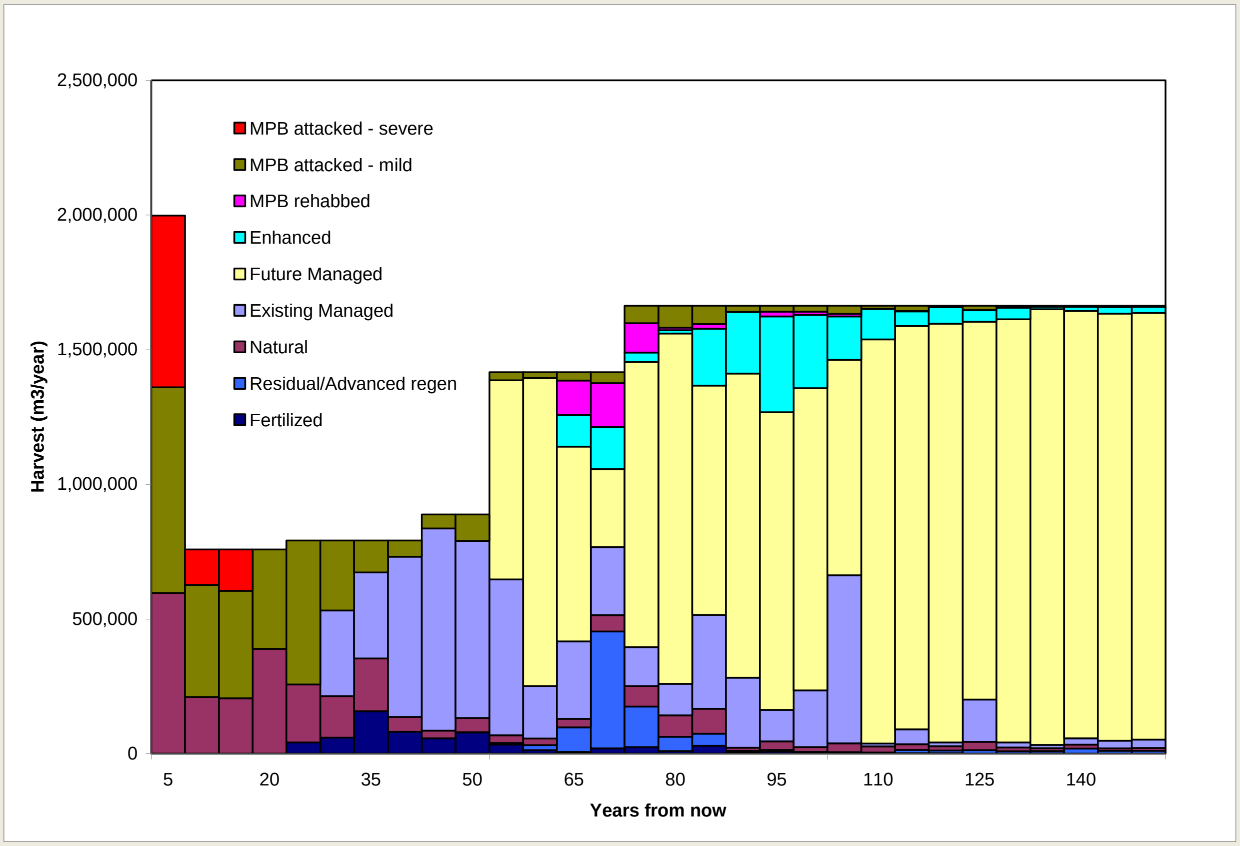


Figure 38: Harvest forecast by forest unit; Composite Scenario 1

Figure 39 compares the predicted quadratic mean diameter of managed stands between the base case and Composite Scenario 1. In the base case graph, existing managed stands and future managed stands are combined. For Composite Scenario 1, 3 categories are identified: untreated managed stands, fertilized stands, and enhanced reforestation stands. Existing and future managed stands with no silviculture treatments are combined and called untreated managed stands. Fertilized managed stands are illustrated as a separate category, while enhanced reforestation stands include MPB impacted stands that were rehabilitated and future stands that were reforested with higher densities in the model.

The fertilized stands are predicted to have highest mean diameter at harvest, while the higher planting densities result in smaller diameters in enhanced reforestation stands. The same results are also presented in Table 17.

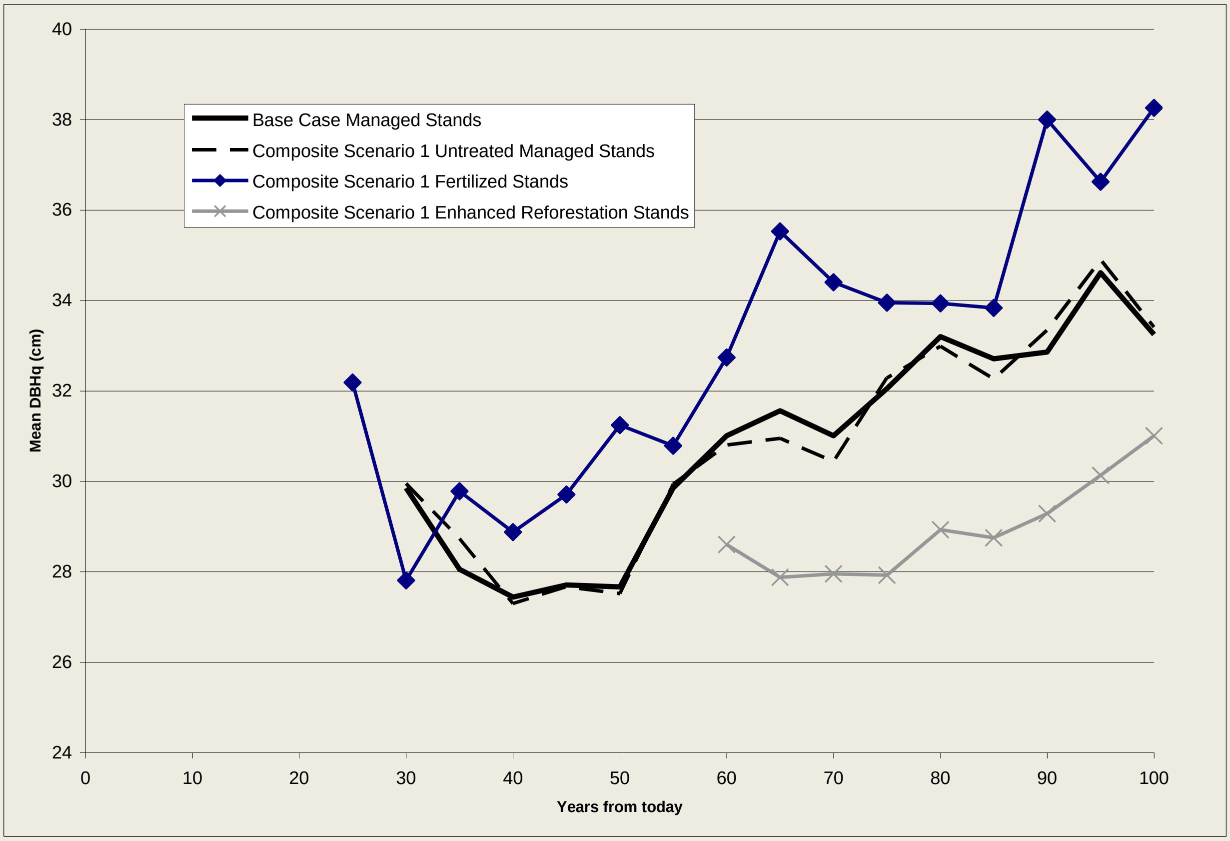


Figure 39: Predicted quadratic mean dbh, managed stand harvest; Composite Scenario 1

Table 17: Predicted quadratic mean dbh, managed stand harvest; Composite Scenario 1

Year	Base Case		Composite Scenario 1					
	Managed Stands		Managed Stands		Fertilized Stands		Enhanced Reforestation Stands	
	Harvest/yr	Mean DBHq	Harvest/yr	Mean DBHq	Harvest/yr	Mean DBHq	Harvest/yr	Mean DBHq
1-5	0		0		0		0	
6-10	0		0		0		0	
11-15	0		0		0		0	
16-20	0		0		0		0	
21-25	0		0		41,035	32.2	0	
26-30	350,127	29.9	317,370	29.9	59,021	27.8	0	
31-35	447,926	28.1	319,671	28.7	157,351	29.8	0	
36-40	647,807	27.4	594,912	27.3	81,422	28.9	0	
41-45	756,351	27.7	751,097	27.7	56,509	29.7	0	
46-50	688,044	27.7	657,049	27.5	79,200	31.2	0	
51-55	1,152,025	29.9	1,317,249	29.9	33,592	30.8	0	
56-60	1,171,757	31.0	1,337,276	30.8	12,964	32.7	1,588	28.6
61-65	1,161,865	31.6	1,011,236	31.0	6,865	35.5	245,366	27.9
66-70	464,530	31.0	542,424	30.4	19,507	34.4	319,112	28.0
71-75	1,438,159	32.1	1,202,988	32.3	24,745	33.9	143,449	27.9
76-80	1,432,678	33.2	1,417,941	33.0	10,076	33.9	22,079	28.9
81-85	1,413,742	32.7	1,199,820	32.3	28,942	33.8	228,477	28.8
86-90	1,604,135	32.9	1,389,952	33.3	5,308	38.0	229,046	29.3
91-95	1,586,979	34.6	1,221,621	34.9	8,121	36.6	374,112	30.1
96-100	1,617,920	33.2	1,331,941	33.4	890	38.3	284,768	31.0

Table 18 shows the treatment areas by BEC zone for increased planting densities for the first 10 years.

Table 18: Enhanced reforestation; annual areas and costs by BEC zone; Composite Scenario 1

Years	BG (ha)	ESSF (ha)	ICH (ha)	IDF (ha)	MS (ha)	SBPS (ha)	SBS (ha)	Total Area (ha)	Annual Cost ($)
1 - 5									
6 - 10	1	51	82	441	151	100	196	1,021	$307,992

Table 19 presents the fertilized stands by leading species for the first 10 years. Figure 40 illustrates the fertilization schedule for the first 10 years spatially.

Table 19: Fertilization; annual areas and costs by leading species; Composite Scenario 1

Years	Pine	Spruce	Douglas-fir	Total Area (ha)	Annual Cost ($)
1 to 5	642	9	121	773	$386,489
6 to 10	409	314	224	946	$472,998

Table 20 shows the rehabilitated areas by BEC zone for the first 10 years; these are presented spatially in Figure 41.

Table 20: Rehabilitation of dead pine stands; annual areas and costs by BEC zone; Composite Scenario 1

Years	ESSF (ha)	ICH (ha)	IDF (ha)	MS (ha)	SBPS (ha)	SBS (ha)	Total Area (ha)ha	Annual Cost ($)
1 - 5								
6 - 10	9	0	498	134	24	9	675	$1,350,680

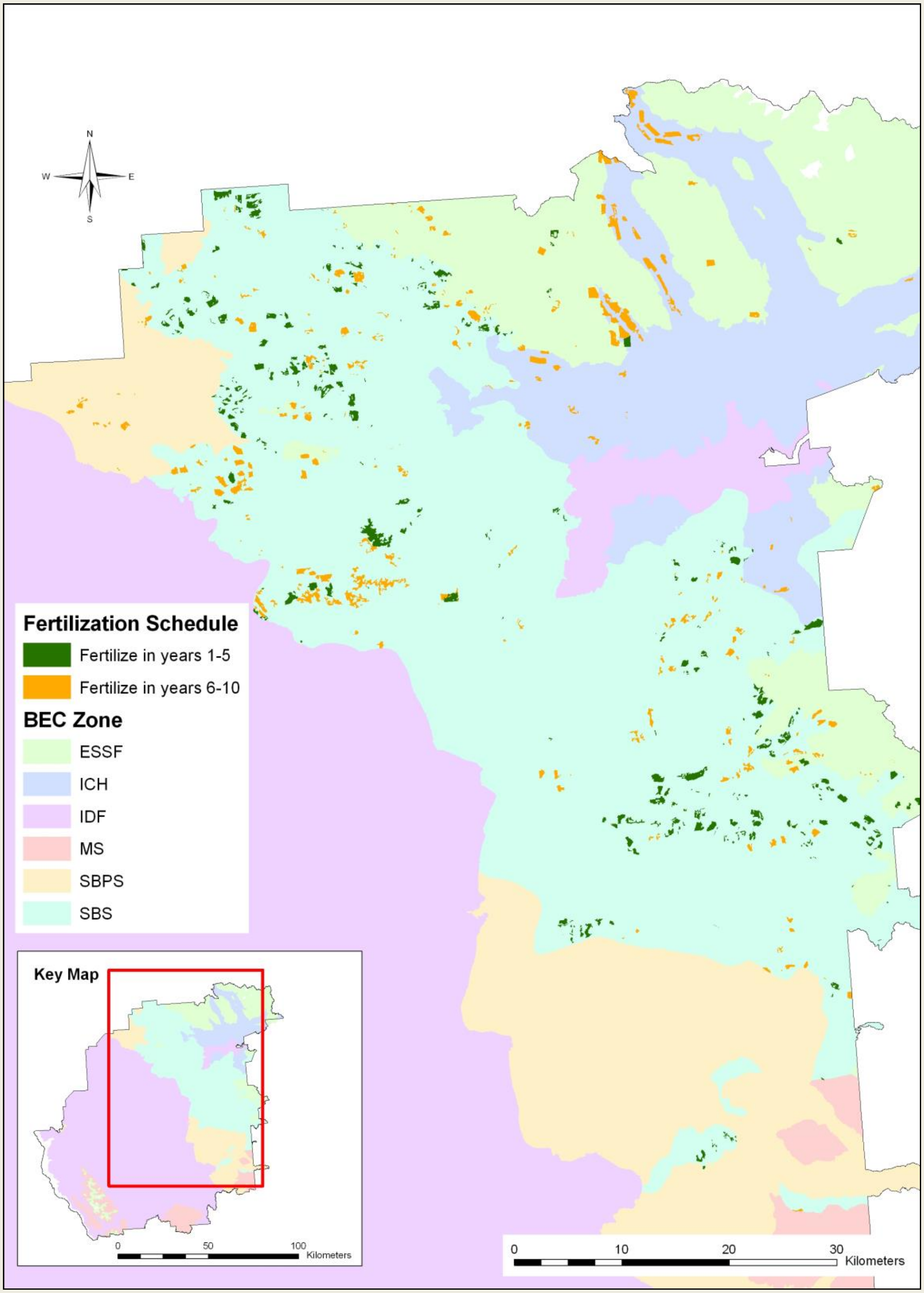


Figure 40: Stands fertilized in the model years 1 to 10; Composite scenarios 1 and 2

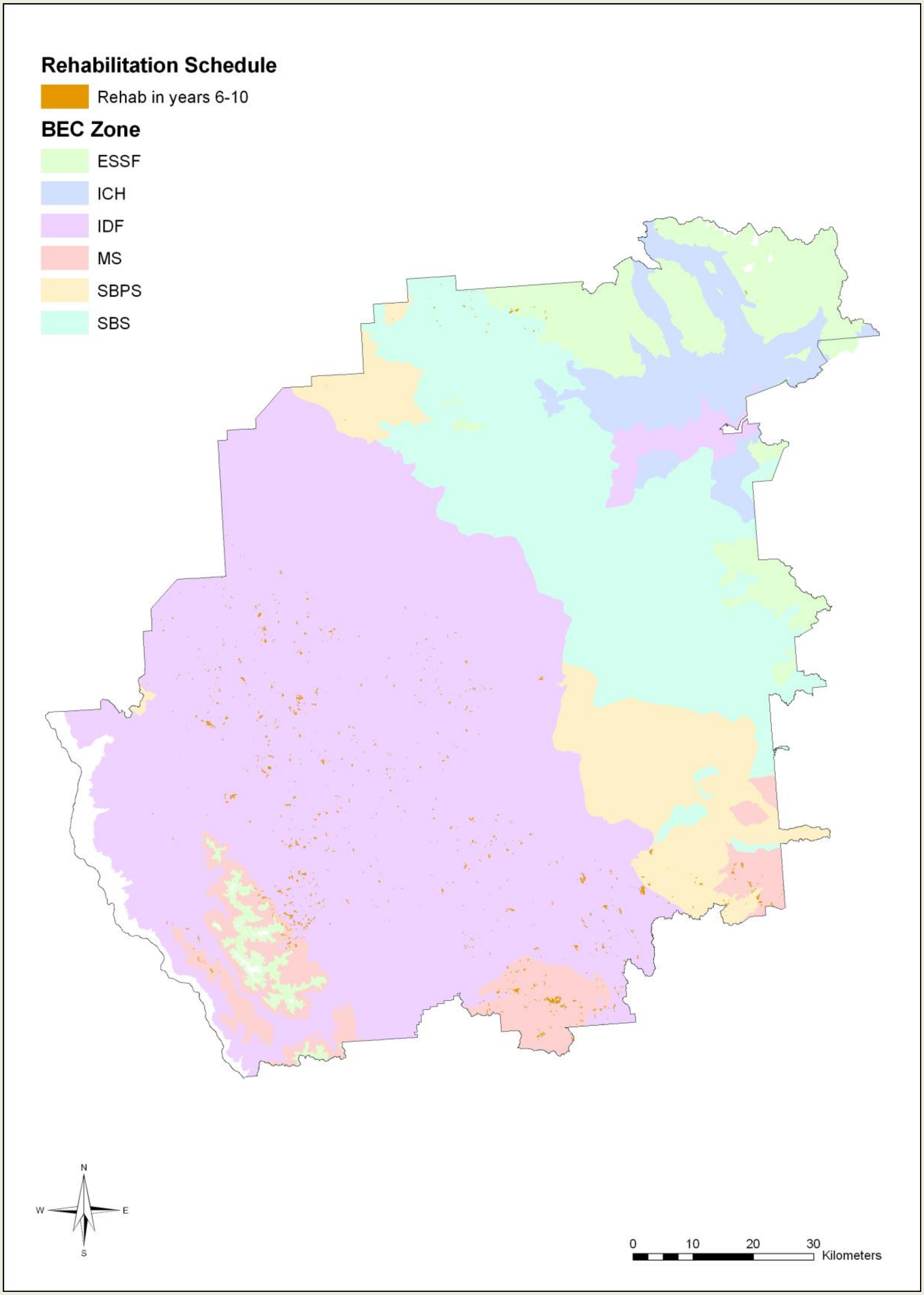


Figure 41: Stands rehabilitated in the model years 6 to 10, Composite Scenario 1

4.2 Composite Scenario 2

This scenario increased the incremental silviculture budget to $2.3 million annually for the first 5 year period. This budget level resulted in a 4.5% increase in harvest between years 21 and 45 (Figure 42) as in the previous scenario. The increase was more pronounced between years 41 and 50 at approximately 8.9%. A 26.8% higher harvest level was achieved between years 51 and 70. No increases in the LTHL were observed.

The treatment areas (ha) as modeled are shown in Table 21. Table 22 shows the budget split by treatment.

Fertilization areas and budget in this scenario are identical to those in Composite Scenario 1. In the first 5-year period fertilization was funded at $386,500 (773 ha annually). Between years 6 and 10, fertilization expenditures were approximately $473,000 per annum (946 ha).

In this scenario rehabilitation of dead pine stands and enhanced reforestation started at the beginning of the planning horizon. The annual expenditures for rehabilitation were approximately $1.35 million (675 ha) between years 1 and 10. The expenditures for enhanced reforestation for the next 10 years were approximately $300,000 per annum.

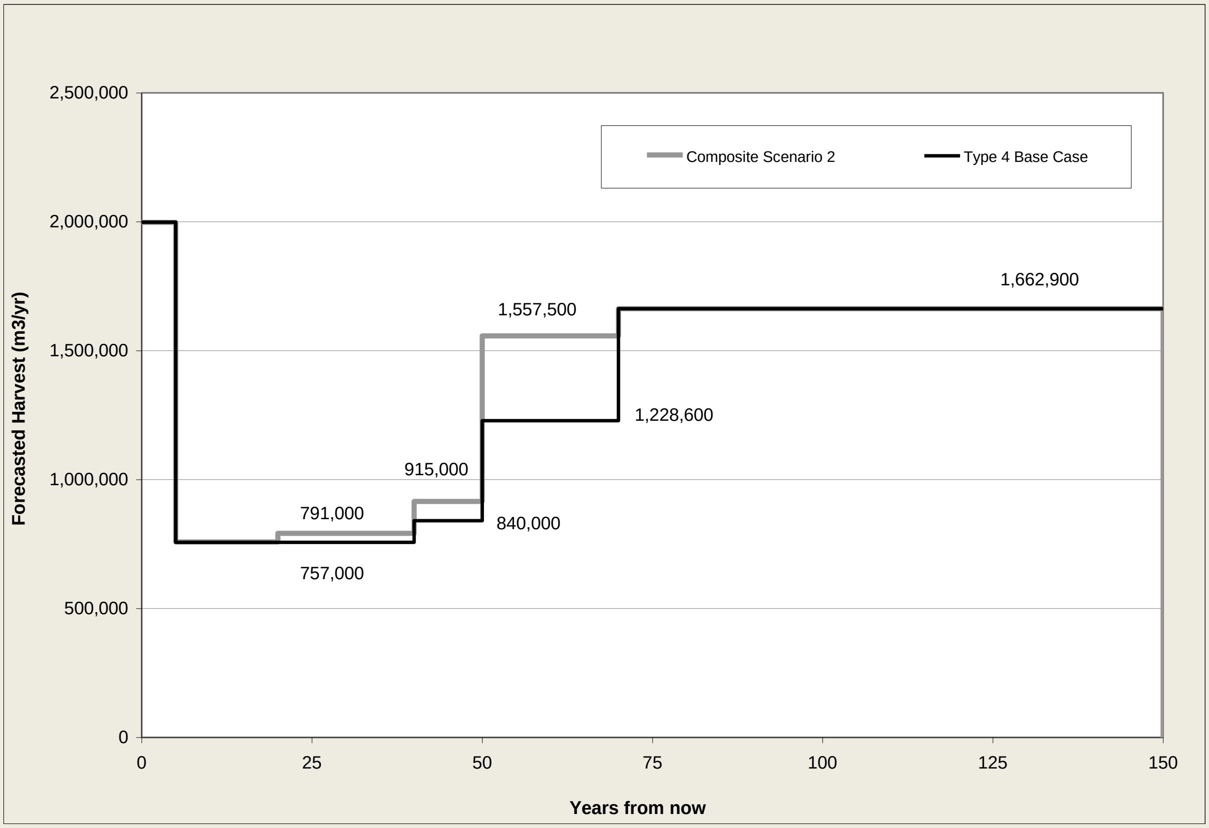


Figure 42: Composite Scenario 2 compared to the base case

Table 21: Annual treatment areas (ha); Composite Scenario 2

Year	Enhanced Reforestation	Fertilize	Rehab	Total
1 to 5	1,126	773	675	2,574
6 to 10	1,022	946	676	2,645
11 to 15	1,015	960	682	2,658
16 to 20	1,002	981	676	2,658
21 to 25	730	1,107		1,837
26 to 30	944	689		1,633
31 to 35	732	560		1,292
36 to 40	912	391		1,303
41 to 45	922	286		1,209
46 to 50	194	40		234

Table 22: Annual budget split by treatment; Composite Scenario 2

Year	Enhanced Reforestation	Fertilize	Rehab	Total
1 to 5	$335,749	$386,489	$1,350,436	$2,072,674
6 to 10	$307,960	$472,998	$1,352,430	$2,133,389
11 to 15	$307,885	$480,185	$1,364,976	$2,153,047
16 to 20	$307,177	$490,632	$1,351,285	$2,149,095
21 to 25	$225,934	$553,588		$779,521
26 to 30	$289,229	$344,475		$633,705
31 to 35	$224,508	$280,205		$504,714
36 to 40	$277,635	$195,580		$473,214
41 to 45	$280,943	$143,226		$424,169
46 to 50	$59,116	$19,968		$79,084

Figure 43 illustrates the harvest forecast by forest unit for Composite Scenario 2. The harvest of fertilized stands starts in year 26 as in the previous scenario. The harvest of rehabilitated dead pine stands and higher density future managed stands starts at year 61. More harvest is predicted to come from rehabilitated dead pine stands than in the previous scenario.

Figure 44 compares the predicted quadratic mean diameter of managed stands between the base case and Composite Scenario 2. As in Composite Scenario 2 the fertilized stands are predicted to have highest mean diameter at harvest, while the higher planting densities result in smaller diameters in enhanced reforestation stands. The same results are also presented in Table 23.

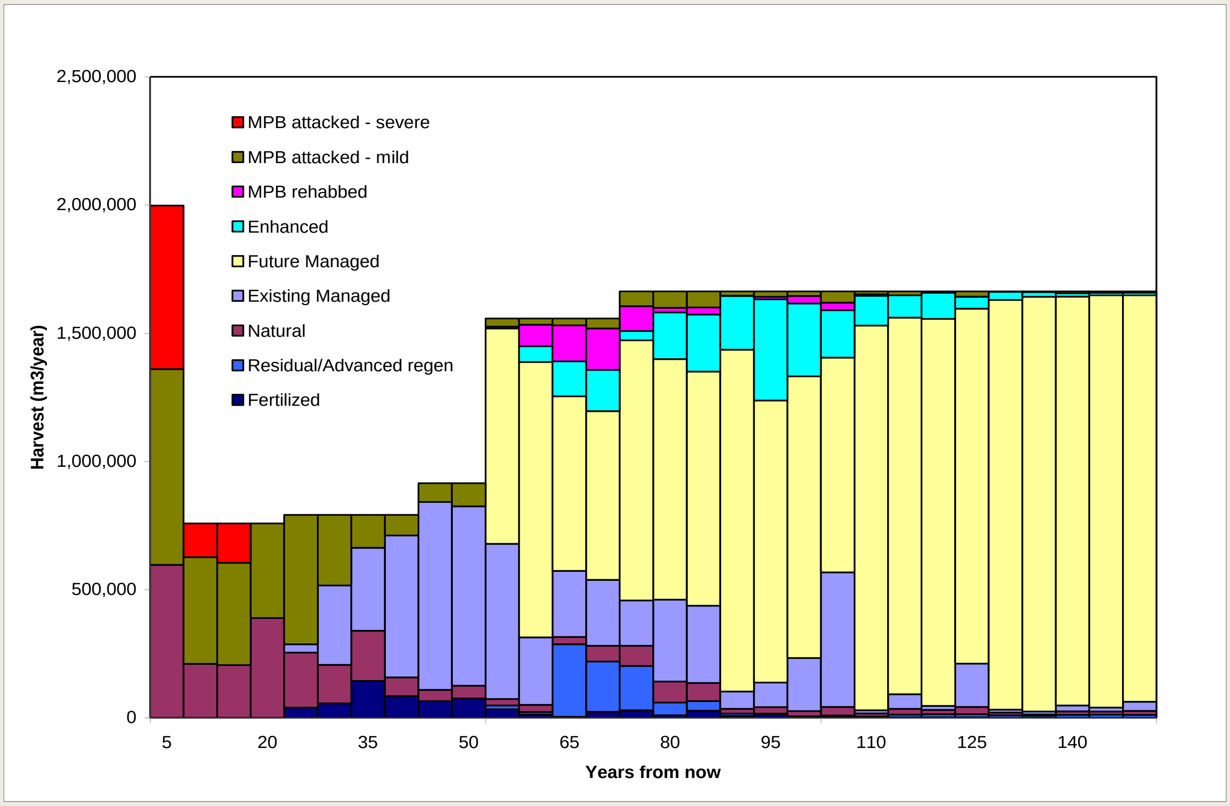


Figure 43: Harvest forecast by forest unit; Composite Scenario 2

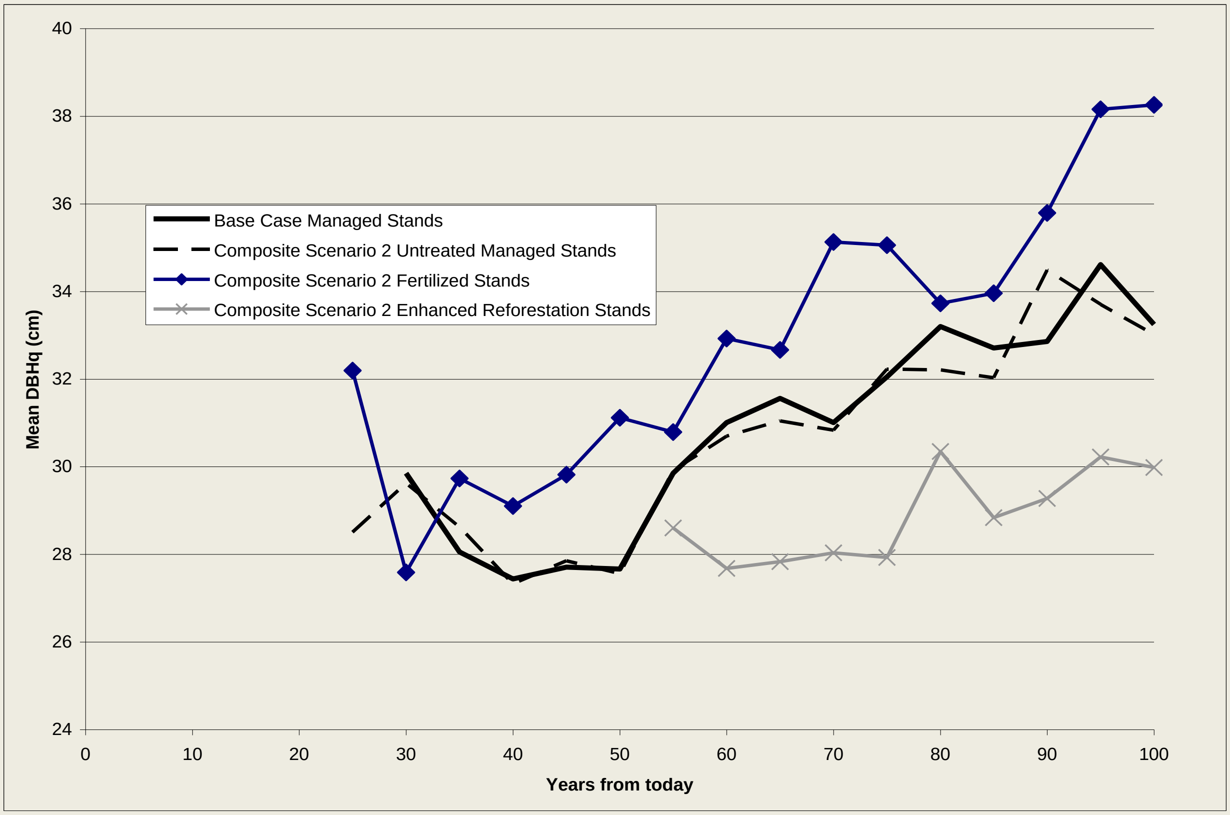


Figure 44: Predicted quadratic mean dbh, managed stand harvest; Composite Scenario 2

Table 23: Predicted quadratic mean dbh, managed stand harvest; Composite Scenario 2

Year	Base Case		Composite Scenario 2					
	Managed Stands		Managed Stands		Fertilized Stands		Enhanced Reforestation Stands	
	Harvest/yr	Mean DBHq	Harvest/yr	Mean DBHq	Harvest/yr	Mean DBHq	Harvest/yr	Mean DBHq
1-5	0		0		0		0	
6-10	0		0		0		0	
11-15	0		0		0		0	
16-20	0		0		0		0	
21-25	0		32,592	28.5	39,994	32.2	0	
26-30	350,127	29.9	309,404	29.6	56,398	27.6	0	
31-35	447,926	28.1	323,557	28.6	143,542	29.7	0	
36-40	647,807	27.4	552,569	27.3	84,579	29.1	0	
41-45	756,351	27.7	732,895	27.9	64,818	29.8	0	
46-50	688,044	27.7	699,555	27.6	75,808	31.1	0	
51-55	1,152,025	29.9	1,445,124	29.9	33,644	30.8	7,792	28.6
56-60	1,171,757	31.0	1,337,167	30.7	12,693	32.9	145,355	27.7
61-65	1,161,865	31.6	938,259	31.0	4,265	32.7	277,170	27.8
66-70	464,530	31.0	914,231	30.8	23,936	35.1	322,926	28.0
71-75	1,438,159	32.1	1,191,354	32.2	29,546	35.1	133,266	27.9
76-80	1,432,678	33.2	1,257,717	32.2	9,741	33.7	199,694	30.3
81-85	1,413,742	32.7	1,214,582	32.0	27,834	34.0	250,350	28.8
86-90	1,604,135	32.9	1,400,404	34.5	7,219	35.8	210,190	29.3
91-95	1,586,979	34.6	1,195,873	33.7	13,437	38.2	404,567	30.2
96-100	1,617,920	33.2	1,305,459	33.0	890	38.3	313,855	30.0

Table 24 shows the treatment areas by BEC for increased planting densities for the first 10 years.

Table 24: Enhanced reforestation; annual areas and costs by BEC zone; Composite Scenario 2

Years	BG (ha)	ESSF (ha)	ICH (ha)	IDF (ha)	MS (ha)	SBPS (ha)	SBS (ha)	Total Area (ha)	Annual Cost ($)
1 - 5	0	355	233	273	231	7	26	1,126	$335,749
6 - 10	0	56	67	429	170	87	213	1,022	$307,960

Table 25 presents the fertilized stands by leading species and BEC for the first 10 years. The same stands were fertilized in this scenario as in Composite Scenario 1 as depicted spatially in Figure 40 above.

Table 25: Fertilization; annual areas and costs by leading species; Composite Scenario 2

Years	Pine	Spruce	Douglas-fir	Total Area (ha)	Annual Cost ($)
1 to 5	642	9	121	773	$386,489
6 to 10	409	314	224	946	$472,998

Table 26 shows the rehabilitated areas by BEC for the first 10 years. The treated polygons are presented spatially in Figure 45.

Table 26: Rehabilitation of dead pine stands; annual areas and costs by BEC zone; Composite Scenario 2

Years	ESSF (ha)	ICH (ha)	IDF (ha)	MS (ha)	SBPS (ha)	SBS (ha)	Total Area (ha)ha	Annual Cost ($)
1 - 5	9	1	426	131	67	41	675	$1,350,436
6 - 10	1	1	464	157	42	12	676	$1,352,430

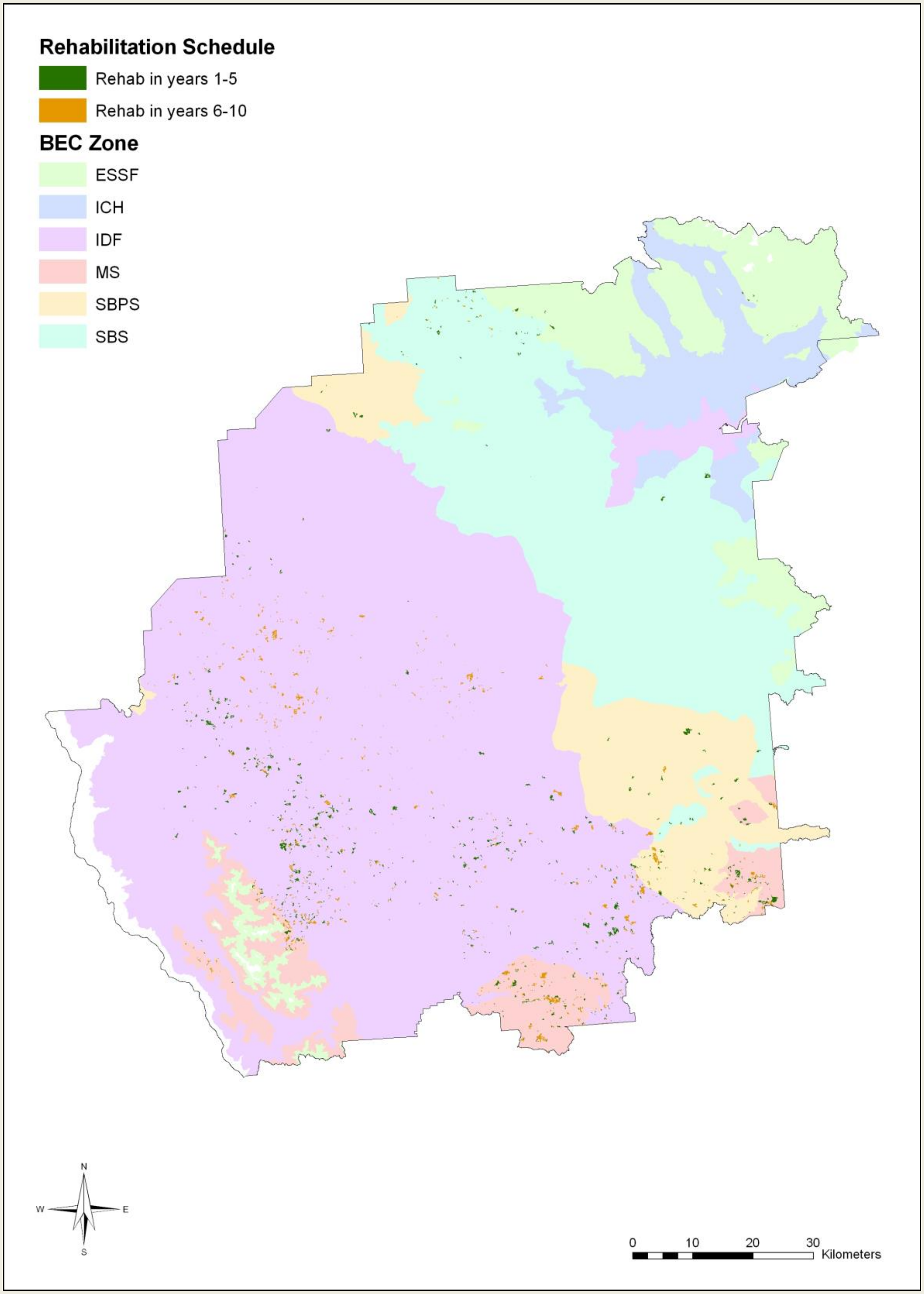


Figure 45: Stands rehabilitated in the model years1 to 10, Composite Scenario 2

4.3 Economic Considerations

The following section provides a brief summary of the stand and forest-level economic impacts of the modelled scenarios. A net present value (NPV) approach was used to compare the present day value of expected future revenues against the present day costs incurred to achieve those revenues. Both analyses use broad-based, simplistic assumptions and methodologies, and the results are provided for context only relative to the estimated yield impacts of the scenarios. A 2% discount rate and a base net economic benefit to the government of $\$25/m^3$ for any incremental volume realized were assumed.

4.3.1 Stand Level

The following assumptions were applied to the different scenarios;

- Rehabilitation
    - Net treatment costs of $2,000/ha assuming knockdown, site preparation and reforestation with applicable assumed future stand criteria. The base analysis assumed that no merchantable timber will be recovered. A sensitivity analysis testing the economic impacts of recovering some merchantable volume was modeled by reducing the net treatment costs to $1,500/ha.
    - New stands are reforested according to the enhanced silviculture strategy (1,600 sph).
    - Harvest of the new stands was assumed to be at 60 years from treatment and would generate revenue of $5,000/ha (200 m^3 /ha at $25/ m^3)
    - Due to the small scale and scattered distribution of the candidate stands, the rehab was not assumed to have any significant impact on reducing the fire hazard.
- Fertilization
    - For each application the cost is $500/ha.
    - Fertilization responses are from TIPSY
    - Existing managed spruce and Douglas fir-leading stands 30 to 40 years old, which have been previously fertilized, are treated twice more (10 and 20 years before harvest) and stands aged 41 to 50 are treated once more (10 years before harvest). The actual average stand attributes were used to initialize the TIPSY yield curves and determine the treatment responses for these stands;
        - Starting 10 years before harvest (1 treatment at 50 years); increased revenue is $175 (7 m^3/ha treatment response times $25/ m^3)
        - Starting 20 years before harvest (2 treatments; at 40 and 50 years); increased revenue is $425 (17 m^3/ha treatment response times $25/ m^3)
    - Existing managed pine-leading stands, which are under prescription and planned for treatment in 2014, are treated four times; at ages 25, 35, 45 and 55 years (40, 30, 20 and 10 years respectively before harvest) and generate increased revenue of $775 (31 m^3/ha treatment response times $25/ m^3) (Note; the actual average stand attributes from the prescriptions were used to initialize the TIPSY yield curves and determine the treatment responses for these stands).
    - Existing managed pine-leading stands 11 to 30 years old are treated three (stands 26 to 30 years old) or four times (stands 11 to 25 years old); at ages (25), 35, 45 and 55 years (40, 30, 20 and 10 years respectively before harvest);

        - Starting 30 years before harvest (3 treatments; at 35, 45 and 55 years); increased revenue is $675 (27 m^3/ha treatment response times $25/ m^3)
        - Starting 40 years before harvest (4 treatments; at 25, 35, 45 and 55 years); increased revenue is $1,150 (46 m^3/ha treatment response times $25/ m^3)
    - Existing managed spruce (Douglas fir)-leading stands 11 to 30 years old are treated three (stands 26 to 30 years old) or four times (stands 11 to 25 years old); at ages (25), 35, 45 and 55 years (40, 30, 20 and 10 years respectively before harvest);
        - Starting 30 years before harvest (3 treatments; at 35, 45 and 55 years); increased revenue is $925 (37 m^3/ha treatment response times $25/ m^3)
        - Starting 40 years before harvest (4 treatments; at 25, 35, 45 and 55 years); increased revenue is $1,150 (46 m^3/ha treatment response times $25/ m^3)
    - Enhanced future stands from spruce, pine and Douglas fir good and very good analysis units treated three times at ages 30, 40 and 50 years old generate similar increased revenue of $700 (28 m^3/ha treatment response times $25/ m^3).

      In a sensitivity analysis the assumed economic benefit is increased by 25% from $25 to $32.25/$m^3$ to simulate the impacts of quality improvement. It is assumed that the incremental volumes in these stands are of higher quality logs. The increased revenues due to higher planting densities are assumed to be $875/ha.

- Enhanced Reforestation
    - The incremental planting cost of $300/ha to increase planting densities by 526s ph to 1600 sph (526 sph times $0.57/tree) will generate increased revenue of:
        - $225 for spruce good to very good analysis units. These are actually about 60% pine and about 30% spruce (9 m^3/ha treatment response times $25/ m^3);
        - $600 for pine good to very good analysis units. These are actually about 75% pine (24 m^3/ha treatment response times $25/ m^3) and,
        - $350 for Douglas fir good to very good analysis units. These are actually about 50% pine and 30% Douglas fir (14 m^3/ha treatment response times $25/ m^3) at a harvest age of 60 years.
    - A sensitivity analysis was completed to estimate the impact of higher quality logs; the net economic benefit is increased by 25% from $25 to $32.25/$m^3$ for stands with increased planting densities to simulate the impacts of quality improvement.
- Dry belt Douglas fir Understory Spacing
    - Modeling was based on $\text{PROGNOSIS}_{\text{BC}}$ with B (minimum basal area >7.5cm) of 18m^2/ha, D (maximum diameter) of 52.5cm and q (diameter class density quotient) of 1.4.
    - With spacing (including planning) costs of $800 to 1200/ha, harvest costs of $29/$m^3$ and future sawlog and peeler values of $50 to 65/$m^3$ and $65 to 80/$m^3$ respectively (depending on whether logging is planned for the midterm or the long term), the results for two stand types which were:
        - An incremental intermediate cut which generated about 79m^3/ha 40 years after spacing and a reduction in the final harvest 70 years after spacing of 14m^3/ha. The net volume increase produced by spacing was 65m^3/ha with a net increase in harvest revenue of $44/$m^3$.

- Rehabilitation of MPB-damaged Managed Pli Stands
  - Modeling was based on a customized spreadsheet approach using TIPSYv4.2 outputs and which incorporated financial analysis (Blackwell, 2009).
  - For Scenario 1 (see Section 3.2.9.2 for the growth and yield assumptions for this analysis), with total rehabilitation of costs of $1,270/ha (including planting costs to a density of 1600sph with genetically improved stock), harvest at a culmination age of 65 years and TIPSYv2 default harvesting costs and lumber and chip prices (less an assumed 10% reduction in the lumber value coming from the open-grown, poor quality stems in the current overstory) resulted in a net increase in harvest volume of 98m^3/ha and $5,275 in harvest revenue.
  - For Scenario 2, and the V2 version of the no treatment option (see Section 3.2.9.2 for the growth and yield assumptions for this analysis), with total rehabilitation of costs of $1,270/ha (including planting costs to a density of 1600sph with genetically improved stock), harvest at a culmination age of 65 years and TIPSYv2 default harvesting costs and lumber and chip prices (less an assumed 10% reduction in the lumber value coming from the open-grown, poor quality stems in the current overstory) resulted in a net increase in harvest volume of 75m^3/ha and $4,968 in harvest revenue.

Table 27 shows the NPV's calculated for various treatments using the above assumptions. Based on stand-level financial analysis the favourable treatments are the rehabilitation of MPB-impacted managed stands, and the rehabilitation of mature MPB-impacted stands assuming that total costs can be kept around $1,500 per hectare. Dry belt Douglas fir understory spacing remains favourable if the costs are between $1,200 and $800 per hectare. The next best treatment is enhanced reforestation with a net loss of about $117 to $231 per hectare. All of the fertilization regimes led to significant negative NPV's mostly due to the small volume responses.

Table 27 Stand-level NPVs for selected treatments

Treatment	Population/Assumptions	Treatment 1	Treatment 2	Treatment 3	Treatment 4
Fertilization	30 to 40 yr old Sx/Fdi stands; prev fert	$(356)	$(624)		
	20 to 30 yr old Pli stands; under Rx				$(1,172)
	11 to 30 yr old Pli stands			$(874)	$(1,002)
	11 to 30 yr old Sx(Fdi) stands			$(736)	$(1,002)
	Increased Density Stands, Quality as Per Future Stands			$(860)	
	Increased Density Stands, Assume Higher Quality			$(748)	
Rehabilitation of Dead Pine Stands	Net Cost = $2,000/ha	$(476)			
	Net Cost = $1,500/ha	$24			
Sx increased Planting Densities	Quality as Per Future Stands	$(231)			
	Assume Higher Quality	$(212)			
Pli increased Planting Densities	Quality as Per Future Stands	$(117)			
	Assume Higher Quality	$(64)			
Fdi increased Planting Densities	Quality as Per Future Stands	$(193)			
	Assume Higher Quality	$(162)			
Dry belt Fdi spacing		$0 to 210			
Rehabilitation of MPB damaged Managed Pli Stands	Scenario 1	$186			
	Scenario 2	$101			

4.3.2 Forest Level

A simplified forest level economic analysis was completed by establishing a net present value for all scenarios. This was done by summing up all the discounted incremental revenues from increased harvest and subtracting the discounted treatment costs from these revenues. The calculation was carried out over a period of 150 years. The discount rate was set at 2% and the assumed net economic benefit to the government for any incremental volume realized was set to $\$25/m^3$.

Rehabilitation created the largest NPV; the incremental volume and value from this treatment are significant later in the planning horizon. Most scenarios produced a positive forest level NPV with the exception of the two more aggressive fertilization regimes and the enhanced reforestation when it was combines with fertilization (Table 28). Composite Scenario 2 produced a significantly higher forest level NPV than Composite Scenario 1; starting the rehabilitation of dead pine stands in the first 5-year period contributed to this.

Figure 46 illustrates the forest level discounted net values (discounted incremental revenues – discounted treatment costs) for the two composite scenarios over the period of 150 years.

Table 28: Net present values; silviculture scenarios compared to the base case

Scenario	NPV ($ Million)
Rehabilitation of Dead Pine Stands	$30.7
Rehabilitation of Dead Pine Stands with Fertilization	$19.5
Fertilization 1	$1.2
Fertilization 2	$(1.4)
Fertilization 3	$(6.5)
Enhanced Reforestation	$17.9
Enhanced Reforestation with Fertilization	$(31.6)
Composite Scenario 1	$7.2
Composite Scenario 2	$24.6

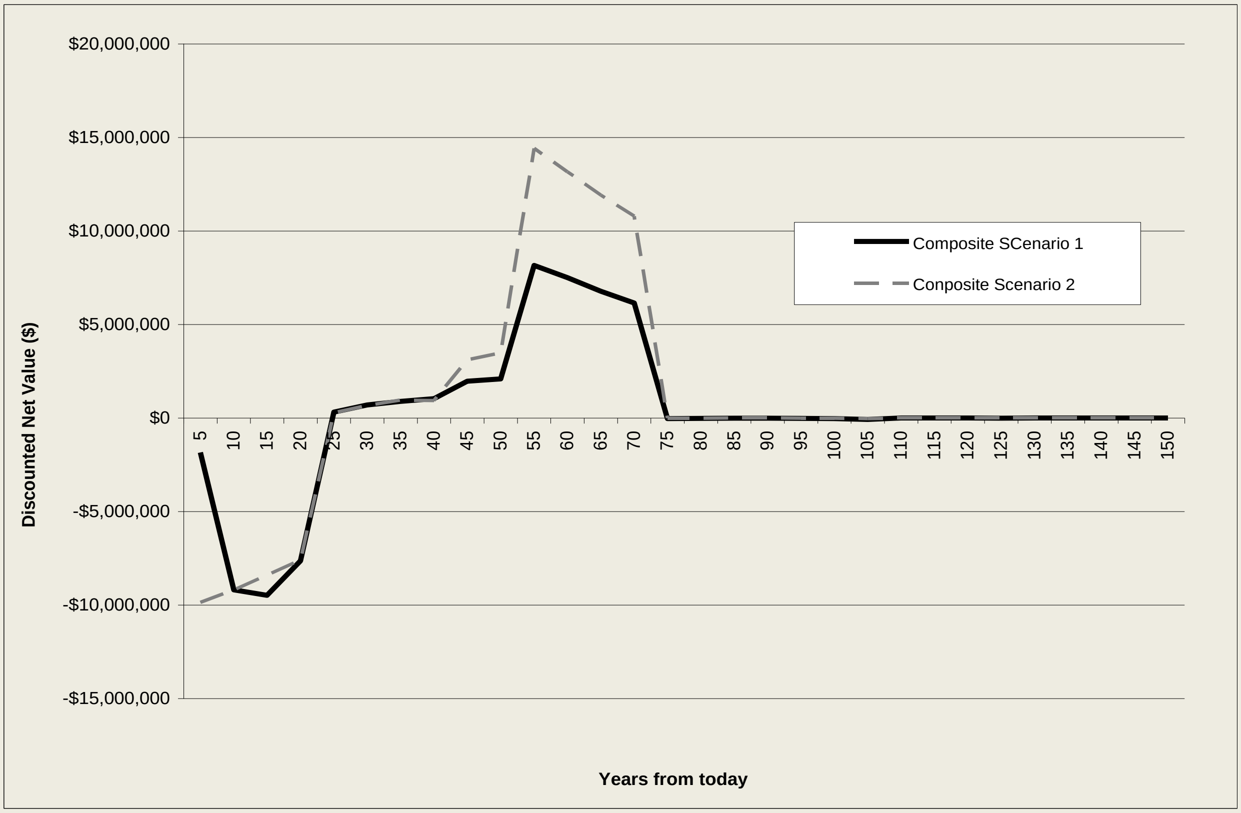


Figure 46: Discounted net values; composite strategies

5 Discussion

The timber supply in the 100 Mile House TSA is constrained by the shortage of merchantable growing stock in the mid term. The shortage of growing stock is caused by the on-going MPB infestation. Spruce beetle is also impacting parts of the TSA; however these impacts are more localized.

Incremental silviculture opportunities in the TSA are somewhat limited. Almost 50% of the THLB is in IDFdk3 where fertilization treatments are not recommended. In other ecosystems, fertilization has shown disappointing results in the past and is not generally considered a high priority in TSA.

Many Douglas-fir leading stands in the IDF were harvested in the past using diameter-limit harvesting. This harvest method created large areas of uneven-aged Douglas-fir forests, many of which are overstocked; and a considerable percentage of the growing stock is now stagnated. Conventional harvesting of these stands is challenging due to small merchantable volumes while reforestation of them has also proven difficult; often these stands are converted to poorly performing pine leading stands.

The IDF Strategy for Williams Lake and 100 House TSAs (Day and McWilliams, 2013) provides direction for the management of these stands. However, uncertainty remains as to the growth and yield of these stands under any potential management strategy.

Rehabilitation of MPB killed pine stands is a potential opportunity to mitigate the late mid-term timber supply and reduce fire risk at the landscape and local levels. However, the TSA licensees and government staff believe that the area predictions for stands that will remain unharvested due decaying timber are not realistic; their view is that most of the forest killed by the MPB will be salvaged and subsequently reforested.

The learning scenarios in this analysis employed a bookend approach; the timber supply impacts were tested by treating all theoretically available areas in the forest estate model regardless of access, financial feasibility or actual condition of the treated stands. This was expected to generate the maximum theoretical treatment impacts. The treatment responses were small relative to the assumed budgets and the size of the treatment areas.

Two composite scenarios were constructed based on stakeholder feedback. The first scenario was designed by the 100 Mile House TSA stakeholder group. It set a modest incremental silviculture target of 600 ha of fertilization per year for the next 5 years at the cost $300,000 per year. The annual fertilization program is set to increase to 1,000 ha per year in the post-salvage period starting 6 years from today. The rehabilitation of dead pine stands will start at year 6 as well and by this time, enhanced basic silviculture will be considered for the silviculture program. The annual budget for the first 5-year period was set at $300,000 and at $2.3 million for years 6 to 10. An additional $50,000 was allocated to Dry belt fir management; this was not modeled in the analysis but will be considered in the final silviculture strategy.

The second scenario increased the annual funding for the first 5-year period to $2.3 million and maintained this budget through years 6 to 10. The funding increase for the first 5 years consisted of rehabilitation of dead pine stands and enhanced reforestation; fertilization treatment areas and costs remained identical to those in the first scenario.

Using a $300,000 annual budget for the first 5 years and $2.3 million for consecutive 5 year periods resulted in a 4.5% increase in harvest between years 21 and 45. The increase was more pronounced between years 41 and 50 at approximately 5.7%. A 15.2% higher harvest level was achieved between years 51 and 70. No increases in the LTHL were observed.

Increasing the annual budget to $2.3 million in the first 5-year period resulted in a 4.5% increase in harvest between years 21 and 45 as in the previous scenario. The increase was 8.9% between years 41 and 50. A 26.8% higher harvest level was achieved between years 51 and 70. No increases in the TLHL were observed.

Based on stand-level financial analysis the favourable treatments are rehabilitation of the MPB-impacted managed stands, and the rehabilitation of mature MPB-impacted stands assuming that total costs can be kept around $1,500 per hectare. Dry belt Douglas fir understory spacing remains favourable if the costs are between $1,200 and $800 per hectare. The next best treatment is enhanced reforestation with a net loss of about $117 to $231 per hectare. All of the fertilization regimes led to significant negative NPV's mostly due to the small volume responses.

A simplified forest level economic analysis showed that rehabilitation of dead pine stands created the largest NPV; the incremental volume and value from this treatment are significant later in the planning horizon. Most scenarios produced a positive forest level NPV with the exception of the two more aggressive fertilization regimes and the enhanced reforestation when it was combined with fertilization. Composite Scenario 2 produced a significantly higher forest level NPV than Composite Scenario 1; starting the rehabilitation of dead pine stands in the first 5-year period contributed to this.

The modelling results are always subject to uncertainty and should be treated with caution. The following should be noted:

- Models cannot assess risk appropriately. For this reason, factors such as fire risk reduction that comes as a side benefit of rehabilitating dead pine stands are not considered by the timber supply model. Another case in point is the option of increased planting densities. In this TSA the growth and yield differences between the base case assumptions and the higher density stands are significant; higher densities provide timber supply benefits in the model results. However, the decision to include this silviculture treatment as an option in the analysis has more to do with building resilient forests and reducing the overall risk of pests and diseases than it has with theoretical improvement in growth and yield.
- Shelf life assumptions of beetle killed timber have a significant impact on the modeled availability of dead pine. If the dead timber decays slower than expected, more harvest will be available in the mid term. The opposite is true, should the shelf life be shorter than modeled.
- This analysis assumed advanced regeneration in many of the dead pine stands. It is not known what the growth and yield of advanced regeneration is or where it exists.
- The current management direction is to use secondary structure where it is adequate. It is not known what the growth and yield of secondary structure is or where it exists.
- In this analysis approximately 60,000 ha of dead pine stands are predicted to remain unharvested. While some of these stands did not get harvested due to biodiversity constraints in the forest estate model, most of them are predicted to remain in the landscape as a result of the decreasing merchantable volume due to shelf assumptions in the analysis. This estimate is subject to uncertainty, as are the spatial locations of these stands.

  The modeled locations of these stands for rehabilitation treatments are theoretical; operational planning is required to identify true candidate stands.
- Approximately 216,000 ha of the THLB in the 100 Mile House TSA consists of stands younger than 51 years old. The harvest of these existing managed stands begins at year 26 and continues throughout the mid term. The growth and yield of these stands is subject to uncertainty; anecdotal evidence suggests that these stands may not be growing as per their modeled yield tables. Studies have found evidence of pests and diseases that may impact the growth rates of these stands.
- The candidate population for fertilization in this analysis consisted of 30,000 ha of existing managed stands (age between 1 and 50). Fertilization schedules suggested by the analysis are theoretical and

have limited practical value; the condition of candidate stands must be known before fertilization treatments are initiated.

- The forest level NPVs are driven by costs, discount rate, time, and the expected incremental harvest volume and the value of this volume. The incremental volumes achieved in this analysis were modest. Changes in analysis assumptions, such as seral stage targets, that increase gains through incremental silviculture have a significant impact on the forest level NPV.

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