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1 Introduction

In November 2013, Nadina Forest District staff and Resource Practices Branch requested Forsite to undertake additional modelling/analysis for the Lakes TSA to explore different assumptions involving fertilization and rehabilitation treatments and to analyze the potential impacts of draft stocking standards intended to address concerns regarding forest health and climate change.

Following various discussions and correspondence, 4 additional modelling runs were proposed:

- Increased Stocking Assumptions
- Reduced Stocking Assumptions
- Updated Multiple-Fertilization Assumptions
- Updated Composite Mix of Strategies @ Budget of $3 M/year (only)

This addendum to the LT4 modelling and analysis report\(^1\) briefly describes the approaches taken to undertake the additional modelling runs and summarizes results for each analysis.

2 Additional Modelling Runs

2.1 Increased Stocking Assumptions

This sensitivity examined impacts on the LT4 harvest flow (current practice) from incorporating the Draft Nadina stocking standards. Changes were only applied to future managed stands since existing managed stands currently reflect existing densities summarized from RESULTS.

Approach

Appendix 1 shows the adjustments made to the base case assumptions (highlighted in yellow) for relevant future managed stand analysis units. These changes involved:

- Increasing establishment densities of PI-leading stands (PI≥50%) within the SBS BEC zone (typically from 1500 to 1600 sph),
- Adding Fdi and Lw to species compositions of Sx- and PI-leading stands on medium and good sites within the SBS BEC zone.

After the revised assumptions were confirmed with Nadina district staff, a new set of TIPSY yield curves were generated. It was also necessary to determine new minimum harvest ages (MHA) for the changed analysis units. The model was then set-up and run to produce the analysis results discussed below.

Results

Compared to the yields used in the Base Case, the changes described above – particularly species composition – generally resulted in lower yields at younger ages and higher yields at much older ages (Figure 1). As well, these new curves caused MHAs to increase by 1-3 years.

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While the harvest forecast for Run 1 (Figure 2) was very similar to the Base Case, it produced a slightly lower (3%) mid- and long-term harvest level. While virtually no Douglas-fir or larch volumes were harvested in the Base Case, 12% and 6%, respectively, were harvested over the long-term in Run 1.

Discussion

The changes to stand composition (more Fd/Lw) resulted in slower growth rates in the first ~70 years of the stand's life. This lengthened MHAs, made less wood available in the mid-term and caused a slight decrease in harvest volume.

It should be noted that the model only reflects the differences in growth rates of the two stand compositions and does not consider differences in the risk of loss/mortality associated with climate change, pests or disease between the two stand types.

Volumes are lower in the long-term because the extra volume produced late in the stand yields is not utilized because stands are harvested earlier. Using the example for AU 3007 (Figure 1), the model elected to harvest stands at 59 years (average), rather than waiting another 20-30 years for more volume. In this case, the harvest forecast is maximized by harvesting less volume more often.
2.2 Reduced Stocking Assumptions

This sensitivity examined impacts on the LT4 base case harvest flow from implementing reduced stocking assumptions in future managed stands to reflect, at least in part, significant levels of mortality observed in young stands due to pine stem rusts on lodgepole pine dominated stands.

**Approach**

Appendix 1 shows the adjustments to the base case assumptions (highlighted in blue) for relevant existing and future managed stand analysis units. These changes involved:

- Increasing the OAF1 from 15% to 30% on Pl-leading stands (Pl≥50%) within the SBS BEC zone. This will apply to both existing and future managed stands.
- Reducing establishment densities on Pl-leading future managed stands from 1500/ha to 1100/ha. This only applied to future managed stands since existing managed stands currently reflect densities summarized from RESULTS.

After the revised assumptions were confirmed with Nadina district staff, a new set of TIPSY yield curves were generated. It was also necessary to determine new MHAs for the changed analysis units. The model was then set-up and run to produce the analysis results discussed below.

**Results**

As expected, increasing OAF1 values by 15% resulted in yield reductions of 13-18% and led to increased MHAs. The reduced establishment densities in future stands contributed to the larger yield reductions.

![Figure 3 Yield curve comparison – example for existing managed stand #2041](image)

Compared to the Base Case harvest forecast, the lower yields configured in Run 2 decreased harvest levels in the mid- and long-terms by 24K m³/yr (13%) and 218K m³/yr (15%) respectively.
Discussion

In this analysis, changing the volumes expected from existing and future managed stand yields (e.g., OAF1) has negative impact on the harvest forecast.

While our approaches for modeling these factors are intended to reflect real world examples, the yield estimates used for this analysis are simple representations of a range of silvicultural practices and biological factors. More work is required to accurately reflect forest health effects on stand dynamics.

2.3 Update Multiple Fertilization Assumptions

This sensitivity examined impacts on the LT4 base case harvest flow from updating the assumptions for multiple-fertilization treatments applied to existing stands. The intent was to increase the area of PI-leading stands to be eligible for treatment.

Approach

Specific adjustments to the base case assumptions included:

- Lowering the site index cut-off for eligible pine-leading stands from SI 19m to SI 15m.

The model was then set-up and run to produce the analysis results discussed below.

Results

The stacked graph in Figure 5 shows that, including multiple applications, areas fertilized ranged between 2,200 ha and 6,000 ha annually. Approximately 400 ha/yr was treated with single fertilization treatments.

Treated areas vary from period to period as stands are: i) treated in a later period, ii) never available for harvesting and remain untreated, iii) harvested without treatment to overcome some other condition (e.g., better to harvest now than wait), or iv) retained and never treated for some non-timber value.

Including multiple applications, approximately 365,000 ha were treated under this fertilization strategy. Moreover, a total of 76,000 ha were treated within the first 20 years; averaging nearly 4,000 ha/yr. This average increased to 5,500 ha/yr between years 30 and 80.
Compared to the results presented in the previous Modelling and Analysis Report (Appendix 2; Slide 1), the revised assumptions in this run resulted in over 135,000 ha (59%) more area treated including 34,000 ha (81%) over the first 20 years.

Figure 6 shows that the budget for the fertilization is maximized between years 16 and 70. This declines sharply afterwards as few existing stands were left to treat (future managed stands were not eligible for treatment in the model).

Compared to the previous analysis (Appendix 2; Slide 2), this run spent over $8.4 M (62%) more on fertilization treatments including an additional $3.4 M (81%) over the first 20 years.

Figure 7 shows a very slight improvement to the harvest flow with multiple-fertilization. The harvest level increased by 17K m³/yr (3%) in the mid-term, 53K m³/yr (5%) in the rise to the long-term and 49K m³/yr (3%) in the long-term.
Figure 7  Harvest flow: Base Case compared to multiple-fertilization strategy

Compared to the previous analysis (Appendix 2; Slide 3), the revised fertilization assumptions produced very little change in the short- or early mid-term, but added 21K m³/yr (1.4%) to the long-term.

Since most of the short- and mid-term harvest comes from natural stands, the incremental volume from fertilization was realized during the climb out of the mid-term trough (Figure 8), similar to the previous analysis. Only a few more stands eligible for treatment contributed to the mid-term harvest level. The incremental volume was not available in time to increase harvest in earlier periods (i.e. ACE² effect). The volume is added at a time when the model is almost exclusively harvesting managed stands as soon as they become available so adding more volume during this period does not support a volume shift into earlier periods.

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² An immediate increase in timber supply resulting from expected future gains. This occurs because incremental volume in the future takes the place of existing stand volume that would otherwise be needed at that time. This effectively allows existing stand volumes to be harvested at a faster rate over the intervening time period.
Figure 8  *Harvest flow: Incremental volume harvested in the multiple-fertilization strategy*

Compared to the previous analysis (Appendix 2; Slide 4), the revised assumptions for fertilization produced over 141K m³ (38%) of incremental harvest volume over the next century - nearly 12K m³ over the mid-term and 55K m³ over the rise to the long-term. This reflects the significant increase in eligible stands available to the model.

**Discussion**

Relaxing treatment eligibility for multiple fertilization to include medium pine stands (SI ≥15 and <19) significantly increased the cumulative area treated (by 135,000 ha). Expenditures for the multiple fertilization treatments reached the maximum $3M/yr level from years 20 to 70.

This also produced an extra 141K m³ of harvest volume from existing managed stands over the next century. Most of the additional volume was harvested after the mid-term for several reasons:

- Most fertilized stands do not meet the minimum harvest criteria for another 30 to 40 years (including the 10 year harvest delay after the last treatment);
- Nothing incent the model to harvest treated stands any sooner;
- The stepped rise in harvest flow between the mid- and long-term appears to dampen any potential ACE effect that might otherwise harvest other eligible stands sooner (stands are already harvested as soon as they are available).

For this analysis, the multiple fertilization treatment was not applied to future managed stands. If it had been, eligible future stands would become merchantable sooner and long-term harvest levels would increase. The magnitude of this increase would depend on the long-term funding level assumed for this particular treatment.

### 2.4 Update Composite Mix of Strategies @ Budget of $3 M/year (only)

This sensitivity examined impacts on the LT4 base case harvest flow from including the composite mix of silviculture treatments, including revised assumptions for fertilization and rehabilitation.

**Approach**

The model was updated to include the revised assumptions described for multiple fertilization (section 2.3), along with the following assumptions:
Limiting rehabilitation to only stands with higher levels of merchantable green volume (i.e., 110-139 m³/ha - no rehabilitation option on stands in low or very low sawlog recovery classes).

The revised approach was first confirmed with Nadina district staff before the model was set-up and run. Ultimately, this scenario was expected to be used for preparing the LT4 tactical plan (separate project).

**Results**

Averaged over the first 15 years, the area of silviculture treatments selected under this scenario (Figure 9) is distributed fairly evenly between rehabilitation (∑ 22,000 ha) and fertilization (∑ 35,000 ha) plus some PCT (∑ 1,000 ha). For the next seventy years, treatments shift primarily to fertilization (∑ 288,000 ha) with a small amount of rehabilitation (∑ 24,000 ha).

![Figure 9](image_url)

**Figure 9**  *Area treated by silviculture treatment under the composite strategy at $3 M/yr*

The revised assumptions generally involved additional area eligible for fertilization and more conservative volumes recovered through rehabilitation. Compared to the previous analysis (Appendix 2; Slide 1), these changes resulted in fertilizing nearly 3 times as much area while rehabilitating about half the area. The ability to access incremental green volume in the mid-term through rehabilitation was a key factor in the previous analysis – and reducing this mechanism made fertilization appear more attractive. To support future fertilization, the model applied five times more PCT but still less than 1,000 ha in total.

Figure 10 shows that besides the third period, the $3M/yr budget assigned to the composite scenario is maximized throughout the short- and mid-term then declines as the area of eligible stands for fertilization decreases. The drop in the third period corresponds with a 50% drop in rehabilitation from the previous period suggesting a lack of appropriate stands to treat over this period.
As expected, a comparison to the previous analysis (Appendix 2; Slide 6) shows a much different distribution of expenditures. In fact, the budget in this analysis was maximized for an additional 3 periods before declining as areas eligible to treat diminished.

The new combination of silviculture strategies improved the harvest flow compared to the base case (Figure 11), particularly throughout the mid-term (+112K m³/yr or 20%) where additional green volume becomes available through the rehabilitation treatments. The rise out of the mid-term is also improved (102K m³/yr or +9%) by gains from fertilization and early rehabilitation of natural stands converted to high-producing managed stands. The increased long-term harvest level (+81K m³/yr or 5%) reflects the additional volume from rehabilitated stands that were otherwise unharvested (i.e., did not meet the minimum harvest criteria in the Base Case).

Compared to the previous analysis, (Appendix 2; Slide 7), new combination of silviculture strategies produced lower gains throughout the mid-term (-48K m³/yr; 6.5%), rise to the long-term (-10K m³/yr; 0.8%) and long-term (-14K m³/yr; 0.9%). This suggests that over the long run, gains added from
fertilization are not as effective as the previous assumptions around recovery of sawlog volumes through rehabilitation (i.e., including low and very low sawlog recovery classes).

Figure 12 shows the unmodified expenditures by treatment activity for the next 20 years for the preferred silviculture strategy at $3 M/yr funding. Rehabilitating MPB-damaged stands continues to be the primary activity to fund over the first decade. Afterwards, expenditures switch favour fertilization as more stands become eligible for treatment closer to harvest. PCT remains a relatively minor funding component over the first decade only.

![Expenditures by activity for the preferred silviculture strategy](image)

**Figure 12**  **Expenditures by activity for the preferred silviculture strategy**

Compared to the unmodified expenditures in the previous analysis, (Appendix 2; Slide 8), this analysis showed a significant shift towards fertilization treatments over the first 20 years; from 2% to over half of the total funding. While rehabilitation was similar in the first decade, the new scenario significantly increased fertilization in the second decade in lieu of rehabilitation (Appendix 2; Slide 9).

**Discussion**

The revised assumptions for this scenario generally involved increasing the area eligible for fertilization and assuming less green volume can be recovered through rehabilitation. Not surprisingly, the composite mix of strategies shifted from a focus on rehabilitation, as in the previous analysis, to a focus on fertilization. These revised assumptions align better with the Nadina district staff's expectations.

The harvest flow was reduced, however, compared to the previous analysis. This occurred because the area rehabilitated dropped in half which, in turn, reduced the volume recovered during the mid-term. The reduction in rehabilitation also reduced relative gains over the long-term, since the untreated area was assumed to never reach the minimum merchantability criteria required to contribute to the harvest flow. Moreover, these non-rehabilitated stands never become future managed stands. This assumption likely underestimates the potential recovery of these stands over the long term.

Compared to the previous analysis, expenditures for the revised composite strategy maintained the maximum $3M/yr level from 2 more decades. Significantly more funds were allocated to multiple fertilization and PCT treatments while funds allocated rehabilitation treatments were reduced by half.

---

3 The preferred strategy in the Lakes Silviculture Strategy was adjusted by adopting the modelling output from the $7 M/yr budget scenario and reducing the budget to $3 M/yr (more likely) by reducing the area treated under rehabilitation.
3 Summary

Increasing stocking standards to adapt to projected trends with forest health and climate change involved increasing establishment densities and/or adding Fdi and Lw for certain future managed stands. The assumptions applied resulted in a slight decrease in the mid- and long-term harvest level as the new regenerating stand volumes were lower at realized harvest ages.

Reducing regenerating stand growth to reflect additional forest health impacts over those assumed in the Base Case involved increasing OAFs and/or reducing establishment densities for certain existing and future managed stands. The assumptions applied decreased harvest levels in the mid- and long-terms by 12% and 14% respectively.

Compared to the previous analysis, increasing the number of eligible stands for fertilization, alone, did little to improve the short- or mid-term harvest levels but allowed for a faster rise out of the mid-term and a 1.4% increase over the long-term.

The revised composite strategy significantly increased the funding allocation for fertilization over rehabilitation treatments. Increasing the area eligible for fertilization and reducing the area eligible for rehabilitation resulted in reallocating approximately half of the funding towards fertilization treatments. However, the increase in fertilization does not completely make up for the opportunities previously assumed for rehabilitation. Compared to the previous analysis the reduced volume available from rehabilitation resulted in a lower (-6.5%) mid-term harvest level.

As a result of this study, Nadina district staff elected to utilize the revised composite strategy to develop the LT4 Tactical Plan (separate project).
## Appendix 1. Revised TIPSY Inputs for Forest Health Runs

Changes to Existing Managed Stand Analysis Units and TIPSY Inputs (bold text; run 1 = yellow; run 2 = blue)

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<th>BEC Group</th>
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Addendum 1 - Modelling and Analysis Report
Lakes – Type IV Silviculture Strategy

March 2014

Addendum 1 - Modelling and Analysis Report

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<td>1,213</td>
<td>35</td>
<td>0.7%</td>
<td>Natural</td>
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<td>2</td>
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<td>Pl</td>
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<td>Sx</td>
<td>10</td>
<td>0.80</td>
<td>0.95</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2038</td>
<td>3011</td>
<td>SBSmc</td>
<td>PLP</td>
<td>G</td>
<td>D</td>
<td>434</td>
<td>2</td>
<td>0.2%</td>
<td>Natural</td>
<td>100</td>
<td>2</td>
<td>3500</td>
<td>Pl</td>
<td>90</td>
<td>Sx</td>
<td>10</td>
<td>0.80</td>
<td>0.95</td>
<td></td>
<td></td>
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<tr>
<td>2039</td>
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<td>SBSmc</td>
<td>PLP</td>
<td>G</td>
<td>O</td>
<td>309</td>
<td>0.2%</td>
<td>Natural</td>
<td>100</td>
<td>2</td>
<td>800</td>
<td>Pl</td>
<td>90</td>
<td>Sx</td>
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<td>0.95</td>
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<td>T</td>
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<td>2</td>
<td>750</td>
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<td>5.9%</td>
<td>Natural</td>
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<td>Pl</td>
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<td>Sx</td>
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<td>PLP</td>
<td>M</td>
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<td>Natural</td>
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<td>3500</td>
<td>Pl</td>
<td>90</td>
<td>Sx</td>
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<td>6500</td>
<td>Pl</td>
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<td>Sx</td>
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<td>0.95</td>
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Notes:
- **BEC Groups:** ESSFmc (ESSFmc/mv1/mv3/mvp/mcp/BFAun); SBSdk (SBSdk/dw3/wk3); SBSmc (SBSmc)
- **Species Groups:** PLP=Pure Pine (Pl, Pa ≥ 80%); PLP=Pine Leading (Pl, Pa ≥ 40% & <80%); SXL=Spruce Leading (Sb, Sw, Sx, Ba, Bl ≥40%); DEL=Deciduous Leading (At, Ac, Dr, Ep ≥40%)
- **Stocking Classes (Total Stems):** A=All; O=Open (0 to <1000 sph); C=Closed (1,000 to <2,500 sph); D=Dense (2,500 to <4,500 sph); R=Repressed (≥4,500 sph)
- **Site Classes (PHR Site Index):** A=All; G=Good (≥19m); M=Medium (≥15m & <19m); P=Poor (<15m)
- **Natural regeneration methods were applied to reflect the spatial pattern of trees at establishment. Stands were actually regenerated using both artificial and natural methods.**
- **As existing managed stands were configured in TIPSY with only natural regeneration methods, genetic gains were not applied.**
- **The analysis units described here do not include criteria that divide units further (e.g., Age class for MPB attacked stands, MPB impact classes, Wildfire impacts).**
## Changes to Future Managed Stand Analysis Units and TIPSY Inputs (bold text; run 1 = yellow; run 2 = blue)

<table>
<thead>
<tr>
<th>FM AU</th>
<th>BEC</th>
<th>Species Group</th>
<th>Site Class</th>
<th>THLB Area</th>
<th>THLB Pct</th>
<th>PHR Spc</th>
<th>PHR SI</th>
<th>Regen Method</th>
<th>Pct</th>
<th>Delay (yrs)</th>
<th>Establish Density</th>
<th>Spc1</th>
<th>Pct1</th>
<th>Spc2</th>
<th>Pct2</th>
<th>Spc3</th>
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<td>3008</td>
<td>SBsdk</td>
<td>PLL</td>
<td>G</td>
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<td>1100</td>
<td>PI</td>
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<td>P</td>
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<td>14</td>
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<td>1500</td>
<td>PI</td>
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</tr>
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</table>

Notes:
- **BEC Groups**: ESSFmc (ESSFmc/mv1/mv3/mvp/mcp/BAF/Aun); SBsdk (SBsdk/dw3/wk3); SBSmc (SBSmc2)
- **Species Groups**: PLP=Pure Pine (Pl, Pa ≥ 80%); PLP=Pine Leading (Pl, Pa ≥ 40% & <80%); SXL=Spruce Leading (Sb, Se, Sx, Ba, BL ≥40%); DEL=Deciduous Leading (At, Ac, Dr, Ep ≥40%)
- **Site Classes** (PHR Site Index): A=All; G=Good (>19m); M=Medium (>15m & <19m); P=Poor (<15m)
- **Planting regeneration methods** were applied to reflect the spatial pattern of trees at establishment. Stands were actually regenerated using both artificial and natural methods.
- **Genetic Gains** were applied accordingly: 7.7% to Pine (all BEC Groups) and 13.2% to Spruce (Only SBsdk & SBSmc BEC Groups)
- **The analysis units described here do not include criteria that divide units further** (e.g., Age class for MPB attacked stands, MPB impact classes, Wildfire impacts)
Appendix 2. **Results from previous analysis compared to results from this addendum**

The following slides compare results from the previous analysis \(^4\) to results from the analysis undertaken in this addendum.

**Slide 1**  **Comparison of area treated under each fertilization regime**

**Slide 2**  **Comparison of expenditures over time for the multiple-fertilization strategy**

Slide 3  Comparison of harvest flows: Base Case compared to multiple-fertilization strategy

Slide 4  Comparison of harvest flows: Incremental volume harvested in the multiple-fertilization strategy
Slide 5  Comparison of area treated by silviculture treatment under the composite strategy at $3 M/yr

Slide 6  Comparison of expenditures over time by silviculture treatment for the composite strategy at $3 M/yr
Previous Analysis

Comparison of harvest flows: Base Case compared to composite strategy at $3 M/yr

Addendum

Comparison of expenditures by activity for the preferred silviculture strategy
### Previous Analysis (unmodified)

**Years 2011-2020**

<table>
<thead>
<tr>
<th>Priority</th>
<th>Treatment</th>
<th>Target Area (ha/yr)</th>
<th>Unit Cost ($/ha)</th>
<th>Target Funding ($M/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rehab</td>
<td>2,310</td>
<td>1,250</td>
<td>2.888</td>
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<tr>
<td>2</td>
<td>Fertilize</td>
<td>190</td>
<td>500</td>
<td>0.095</td>
</tr>
<tr>
<td>3</td>
<td>PCT</td>
<td>20</td>
<td>800</td>
<td>0.016</td>
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**Years 2021-2030**

<table>
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<tr>
<th>Priority</th>
<th>Treatment</th>
<th>Target Area (ha/yr)</th>
<th>Unit Cost ($/ha)</th>
<th>Target Funding ($M/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rehab</td>
<td>2,360</td>
<td>1,250</td>
<td>2.950</td>
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<tr>
<td>2</td>
<td>Fertilize</td>
<td>90</td>
<td>500</td>
<td>0.045</td>
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<tr>
<td>3</td>
<td>PCT</td>
<td>0</td>
<td>800</td>
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</table>

### Addendum

**Years 2011-2020**

<table>
<thead>
<tr>
<th>Priority</th>
<th>Treatment</th>
<th>Target Area (ha/yr)</th>
<th>Unit Cost ($/ha)</th>
<th>Target Funding ($M/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<td>1,570</td>
<td>1,250</td>
<td>1.963</td>
</tr>
<tr>
<td>2</td>
<td>Fertilize</td>
<td>1,930</td>
<td>500</td>
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<td>3</td>
<td>PCT</td>
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<td>0.072</td>
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**Years 2021-2030**

<table>
<thead>
<tr>
<th>Priority</th>
<th>Treatment</th>
<th>Target Area (ha/yr)</th>
<th>Unit Cost ($/ha)</th>
<th>Target Funding ($M/yr)</th>
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</thead>
<tbody>
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<td>1,250</td>
<td>0.600</td>
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*Slide 9*  
*Comparison of target silviculture programs*