FRST 497 GRAD ESSAY FOR UBC FACULTY OF FORESTRY

Mitigating the Mid-term Timber Supply Gap: Potential Silvicultural Solutions in the Prince George TSA

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Abstract

The current mountain pine beetle epidemic (*Dendroctonus ponderosae* Hopkins) (MPB) has affected 17.5 million hectares in British Columbia (BC). In response, the chief forester raised the annual allowable cut (AAC) in several Timber Supply Areas (TSAs) throughout the province, including the Prince George TSA. The AAC uplifts were designed to allow licensees to harvest MPB mortality which would otherwise be worthless if left standing. This had the unwanted consequence of creating a mid-term (11-50 years from now) timber supply gap that will result in lowered AAC's and associated job loss and economic decline.

This paper explores three silvicultural systems that could increase the volume of timber available for harvest in the mid-term. The three systems are: understory retention, pre-commercial thinning (PCT), and fertilization. To determine the potential of these systems to increase mid-term harvest volumes I conducted a literature review and used the Table Interpolation Program for Stand Yields modeling program (TIPSY). Understory retention has some potential to increase volumes, but only by a small amount. The benefits of understory retention are ecological in nature, and include increased biodiversity and forest resilience. PCT and fertilization, either separate or combined, have good potential to increase mid-term harvest volumes. For PCT and fertilization to be effective, it is critical to select appropriate stands.

The minimum height requirements for what is considered suitable understory should be lowered. This will result in less stands being salvage harvested, and will increase the ecological diversity and resilience of pine-leading stands. There may also be some associated increases in mid-term harvest volumes. PCT and fertilization should be used in conjunction in stands that will benefit most from these treatments. This will increase available mid-term harvest volumes. If done properly, the risk associated with spending money on silvicultural treatments is acceptable.

Key Words: Mid-term timber supply, silviculture, mountain pine beetle, pre-commercial thinning, fertilization, understory retention, Prince George

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Introduction

Logging has a long and storied history in British Columbia (BC). What began in the 1800's as an unregulated free-for-all has matured into a highly regulated system that employs over 14,000 people and was worth more than 1.8 billion dollars in 2009 (BCStats, 2010). BC harvest levels on public forest land are based on the principles of sustainable yield. According to this principle, no more trees should be harvested within a given period than the land is capable of growing within that period. The volume that is cut every year within a timber supply unit is restricted by the annual allowable cut (AAC), which is determined by the chief forester at least every ten years. There is some variability allowed in the harvest in regards to the AAC; licensees can and do cut under the AAC based on market factors. The AAC is the result of applying policy decisions to an (estimated) supply of timber determined through numerous timber supply analyses (Williams, 1993). The AAC reflects societal values, environmental considerations, operability restriction, as well as the long run sustainable yield (LTSY). The Chief Forester also has leeway to increase (or decrease) the AAC in response to natural disturbances such as wildfire and insect attacks. In the northern and southern interior forest regions, there have been significant and long lasting (since 2002) uplifts in the AAC to capture mortality due to the mountain pine beetle (MPB) (*Dendroctonus ponderosae* Hopkins) epidemic. In the Prince George (PG) Timber Supply Area (TSA), for example, the AAC has been increased from 5.7 million m^3 to 14.9 million m^3 (Pousette & Hawkins, 2006). While the short term benefits of AAC uplifts include job creation and increased tax revenues for municipal and provincial governments, the long term effects will be a significant fall-down of future harvest levels and future revenues. When the un-harvestable mortality is included, reduction in future AAC's is estimated to be as much a 60% of the former LTSY in places like the Quesnel TSA (McGarrity & Hoberg, 2005).

This paper will explore potential silvicultural systems of increasing volume growth of stands in the PG TSA today so that the volume harvested during the projected mid-term timber supply (MTTS) gap may be increased. The silvicultural systems that will be studied are understory retention, thinning, and fertilization. I conducted a literature review and used the Table Interpolation Program for Stand Yields modeling program (TIPSY 4.2) to ascertain the viability and effectiveness of the proposed silvicultural systems.

Background information

History of the mountain pine beetle epidemic

The current MPB epidemic began in the 1990's, and has since become the largest infestation ever recorded in Canada (Natural Resources Canada, 2008). The cumulative volume killed has reached 726 million m^3 over 17.5 million hectares in BC (MoFR, 2011a). The reason for the current level of infestation is a combination of anthropogenic and environmental causes. The beetle prefers mature lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm.) trees of a certain diameter (MoFR, 2011a). Starting in the early 20th century, humans in BC began a system of fire suppression that resulted in many unnatural stands of mature (>80 years) lodgepole pine of the perfect size (>20 cm diameter at breast height [dbh, 1.3 m]) for MPB attack. The stands are considered unnatural because lodgepole pine forests normally burn down at somewhat regular intervals of 100-150 years.

At the same time as the start of the epidemic, many of the even-aged mature pine stands were drought-stressed due to drier and hotter summers, making the trees more susceptible to attack by the MPB. Cold weather is a main factor in the control of MPB populations (MoFR, 2011a). Consistent temperatures of colder than -40° Celsius are required over the winter to kill beetle larvae. Early fall and late spring cold is important as well; temperatures of -25° Celsius are cold enough to kill beetle larvae before their natural antifreeze (glycerol) builds up to sufficient levels (MoFR, 2011a). The frequency of these extreme cold events is on the decline, due in part to climate change (Barber, 2007). When all these factors are taken into account, it is not surprising that the current epidemic has reached such large proportions. The impacts of an infestation of this magnitude are far-reaching and severe. The current epidemic extends from Fort St. John to the north, Terrace to the west, the United States border to the south, and beyond the Alberta border to the east. The effects on BC's commercial timber supply are significant and affect short, medium, and long term timber supplies.

Timber supply

Timber supply is defined by the Forest Service of BC Forest Analysis Branch as the available timber on the timber harvesting land base (THLB) of a given area. Timber supply is divided into three future time periods for this paper: short-term supply (0-10 years from now), mid-term timber supply (11-50 years) and long-term supply (from 51 years until the end of the rotation).

In many areas in the province that historically harvested mainly old-growth timber, there has already been a fall-down in AAC that has resulted in lost jobs and mill closures. Furthermore, more people are required to harvest old growth, and as companies' transition into second growth and managed stands there is usually an associated increase in efficiency and mechanization. This has been especially apparent on coastal BC where large old-growth trees required many men to harvest, and should not be confused with the fall-down associated with increased AAC's in the interior of BC.

In the interior, the fall-down is due to the timber supply gap that is the direct result of successive years of MPB salvage harvesting. This gap spans several decades and is roughly estimated to begin in 10 years and last for 40 years. These numbers are rough estimates as the industry is constantly changing and the THLB may increase as harvesting and milling technology improve.

Why is mid-term timber supply important?

There was 49 million m^3 harvested on public land in BC in 2009, and 70% came from the interior (BCStats, 2010). There are dozens of mills in the interior, including the biggest sawmill in the world owned by Canfor in Houston, BC, capable of producing 1.4 million m^3 of lumber annually. Many rural communities depend on logging to support a significant part of their population. This issue was brought to light when the Babine Forest Products mill in Burns Lake, BC, burned down on January 20th, 2012. The mill provided 250 jobs in a community of 3,600, and it is uncertain whether or not it will be rebuilt. The uncertainty stems from the projected fall-down in the area and a lack of guaranteed timber supply. It will be tough to find investors willing to spend the estimated $80 million that it will cost to rebuild the mill if there is only enough timber to keep the mill running at capacity for the next 5 years.

Logging contributes a substantial portion of income in some BC Interior Communities (Table 1).

Table 1. Income and employment from logging in four BC interior TSAs. (McGarrity & Hoberg, 2005)

TSA	Area	Income (%)	Employment (%)
Prince George	Prince George District	30	29
	Fort St. James District	54	57
	Vanderhoof District	41	43
Merritt	Merritt TSA	25	24
Lakes	Lakes TSA	43	43
Quesnel	Quesnel TSA	-	45

Extent of the MTTS problem in the Prince George TSA

To explain the extent to the MTTS problem, the PG TSA will be used as an example (Figure 1). The PG TSA is central to the MPB epidemic and there are 19 lumber mills in the area that are running at full capacity processing salvaged timber. The TSA covers 7.97 million hectares and includes the cities of Price George, Fort St. James, and Vanderhoof. There is 3.09 million hectares in the THLB. Many of the pine leading stands were fire established 40 or more years ago, and there has been heavy mortality within these stands. The MPB epidemic peaked between 2004 and 2006, but new mortality continues especially in the Fort St. James Forest District (Snetsinger, 2011a). I reviewed the AAC's in the Ministry of Forests' "Prince George TSA Rationale for the AAC Determination" for the last 15 years, and the AAC for the PG TSA increased significantly in 2002 and 2004 before decreasing slightly in 2011 (Figure 2).

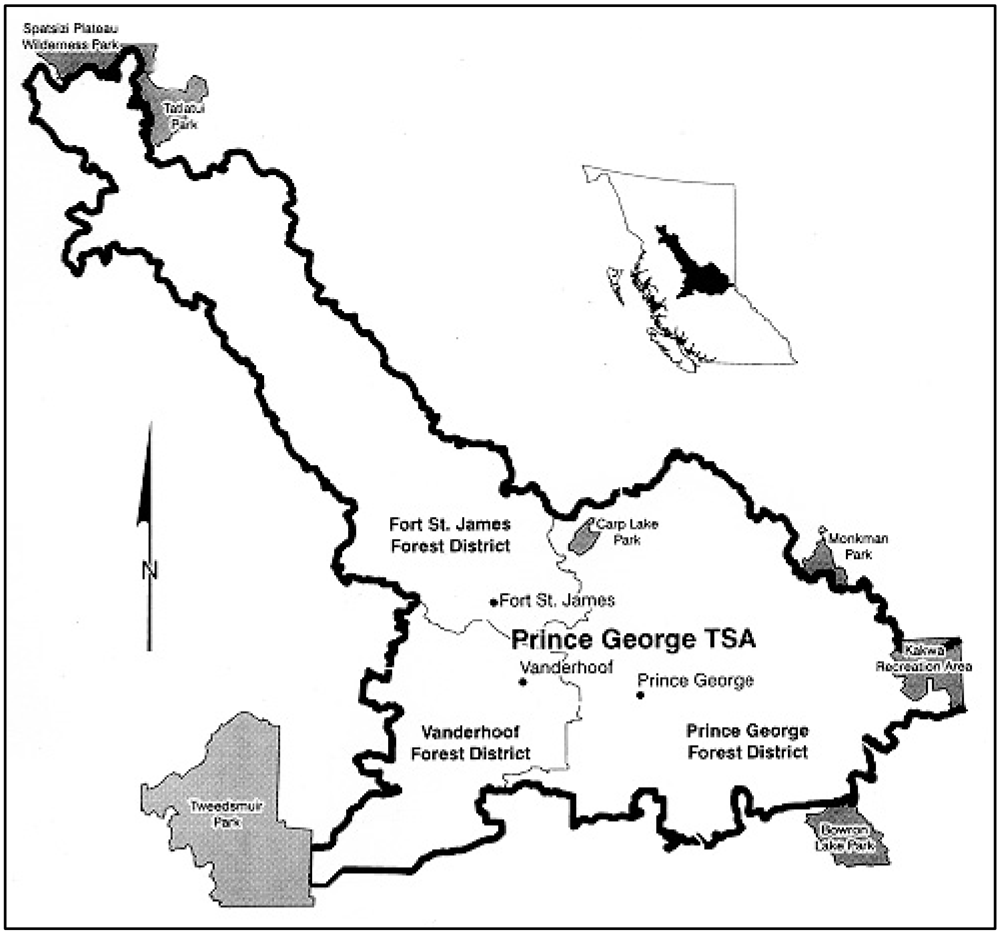

Figure 1. The Prince George TSA (MoFR, 2011b)

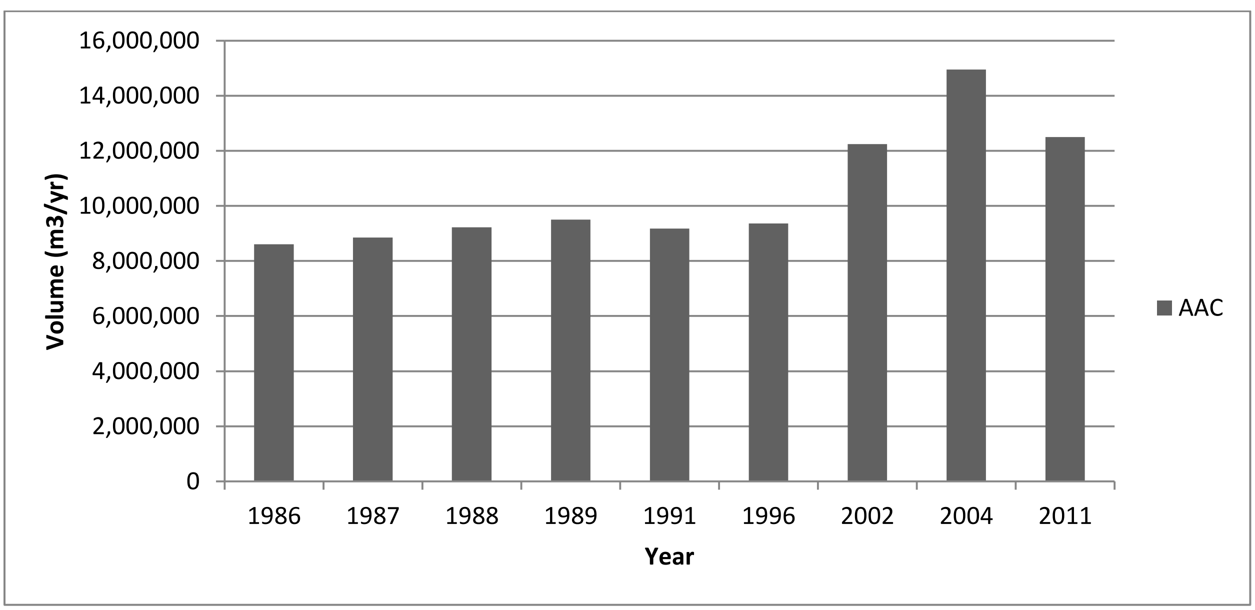

Figure 2. Prince George TSA AAC levels 1986-2011 compiled from the respective PG TSA AAC rationales. First AAC uplift due to MPB was in 2002

The AAC was relatively stable from 1986 to 1996. The AAC during this time reflected the LTSY and pine salvage was not a major determinant of cut levels. The AAC was lifted after 2002 to harvest stands that would help stop the spread of the beetle. The MPB epidemic reached a peak in 2004, as did the AAC. The second uplift was to allow licensees to harvest the volume needed to capture the majority of the MPB mortality. It has since declined to 12.5 million m^3, which is still 25% higher than the 1996 level.

Based on the PG TSA Timber Supply Analysis Public Discussion Paper (2010), the pine-leading stands (i.e. stands in which lodgepole pine comprises 70% or more of the total volume) damaged by MPB are estimated to either be completely salvaged, or have degraded beyond what is salvageable, in the next 12 years. At this point, only spruce- or cedar-leading stands will be available for harvest, which brings the mid-term harvest level down to 4.3 million m^3. This is projected to last for 40 years, before the harvest is increased to 6.5 million m^3 to account for pine stands that are reaching maturity. Around the year 2060 the projected harvest will increase again to the LTSY which is about 9 million m^3.

Within the next decade, the harvest levels in the PG TSA will drop 71%. In an area that relies on logging for 43% of its employment and 41.7% of its income, the fall-down will be drastic and have far reaching effects. The best way to efficiently assign resources to mitigate this potential problem is to accurately assess the problem through provincial forest inventories.

Status of the PG TSA forest inventory

The PG TSA has a comprehensive forest inventory that includes timber, wildlife, disturbances, operability, recreation, and more. The Vanderhoof Forest District (VFD) has a vegetation resource inventory (VRI) that was completed in 2003. The Fort St. James and Prince George Forest Districts (FSJFD and PGFD) have VRI data that was completed in 2007. The VRI is the standard inventory for all Crown-managed TSA and TFL lands in BC. It consists of two major components: estimation of vegetation characteristics from aerial photographs, and statistically-based ground sampling to confirm photo-based estimates (MoFR, 2008). The importance of up to date inventory cannot be understated. The rate that trees are still being killed by the MPB means that the VRI must be an ongoing investment. Only with accurate information can forest managers in the PG TSA correctly allocate resources for silvicultural investment.

Current efforts at MTTS mitigation by the BC Government

Partitioning the AAC

The chief forester, Jim Snetsinger, has been managing the AAC in the PG TSA, and around the province, to minimize the effects of the mid-term timber supply gap. His main strategy for this has been partitioning the AAC to ensure that the harvest is focused on pine-leading stands where possible. Snetsinger said: "the partition is aimed at maintaining the opportunity to continue salvaging pine while protecting non-pine stands needed to support mid-term harvest levels" (Snetsinger, 2011b). This policy will focus harvesting on stands that are facing imminent MPB attack or have already been attacked. For example, in the PG TSA, 70% of volume harvested since 2005 has been pine (MoFR, 2010a). This will ensure that there will be enough non-pine-leading stands remaining to maintain some level of harvesting though the mid-term.

The Land Based Investment Strategy

The BC government has undertaken a large scale program called the Land Based Investment Strategy (LBIS). The LBIS is a multi-faceted approach that includes the Forest Investment Account (FIA) and the Forests for Tomorrow (FFT) programs. The mandate of the FFT is to plant 13 million seedlings a year in areas of catastrophic disturbances, such as MPB or wildfire killed areas (MoFR, 2010b). The main priority for the LBIS is fertilization, spacing and brushing in the Lakes, Quesnel, Prince George and Williams Lake TSAs, and the goal is to mitigate the reduction in the mid-term timber supply. The stated performance measure is an annual timber volume gain of 7.1 million m^3 from silviculture investments. Other categories for investment include tree improvement, forest health, fish passage, ecosystem restoration, and fuel management. The LBIS is an ambitious project and will hopefully meet its goals for volume increases and a 2% return on investment.

Proposed silvicultural methods for mitigating the MTTS gap

It is clear from the above background information that certain areas of the province will be facing a shortage of fiber supply in the coming years. This shortage will last for over 40 years and will have severe consequences for the forestry-dependent communities that dot the interior of BC. Every tree that will be harvested in the mid-term has either started growing already or will in the next decade; in order to lessen the impact of the timber supply gap certain silvicultural methods must be employed. These strategies will be discussed in detail below.

Understory retention

The understory, or secondary structure, as defined in Coates *et al.* (2006), includes all seedlings, saplings, sub-canopy, and canopy trees that will likely survive a mountain pine beetle attack. For this report, only the understory of pine-leading stands will be discussed. The understory in these stands is generally composed of species not susceptible to MPB attack, this being due to the shade-intolerance and seed dispersal techniques of lodgepole pine. Where pine is present in the understory it is likely too small to be attacked. Greater value may be gained by choosing not to harvest pine-leading stands where there is significant secondary structure.

Secondary structure has many benefits other than providing mid-term timber supply, these include:

1. hydrology-
    - increases transpiration, and snow and rain interception (Uunila, Guy, & Pike, 2006);
    - MPB attacked forests have increased overland and spring flows (Uunila, Guy, & Pike, 2006);
2. biodiversity-
    - increased genetic diversity of future forests (Burton, 2006);
3. wildlife habitat-
    - habitat for certain species that prefer secondary structure for forage and cover (Burton, 2006);
4. overall forest resilience-

- increased capacity for a forest to resist change and to recover from major disturbances (Burton, 2006).

How is the understory retained under current logging practices?

As of July 25th, 2008, the Forest Planning and Practices Regulation (FPPR) section 43.1 requires:

> *"'Targeted pine leading stands', at least 5 hectares in size, with an adequate stocking density of suitable secondary structure to be excluded from cut blocks or harvested in a manner that protects an 'adequate stocking density' of 'suitable secondary structure', unless the regulation or the district manager provides an exemption from doing so."*

The secondary structure must consist of trees identified in an approved forest stewardship plan (FSP) as preferred or acceptable, and they must be of good form and vigor. If the minimum number of well-spaced trees (i.e. trees that are greater than 1.6 m apart) is 700 stems per hectare (sph), then the minimum height to be eligible for retention is 6 m. If there are at least 900 sph then the minimum height is 4 m. These regulations only apply to pine-leading stands and secondary structure may not be identified or retained in other stand types.

How much understory should be retained?

More secondary structure should be retained in the interior of BC to help increase the volume available in the mid-term. To be available for harvest, trees must have at least 12.5 cm top diameter. This may change is the future with improved technology and recovery in sawmills. Understory trees typically release 2-3 years after the death of the over story, so the understory would need to be 10-20 years old to be available during the mid-term (Coates *et al.* 2006). Another way to asses understory potential is by basal area. If the basal area of pine-leading stands is 5-10 m^2/ha then they have to potential to contribute to the MTTS (Coates *et al.* 2006). Twenty-five to thirty percent of pine-leading stands in north central BC meet these criteria.

In Coates *et al.* (2006), the authors identified which biogeoclimatic ecosystem classification (BEC) zones were most likely to have sufficient understory. The best candidates were the sub-boreal spruce – moist cool, and dry warm subzones (SBSmc, and SBSdw). The SBSmc had a median density of 2000-4000 sph and comprises 12% of the PG TSA. The SBSdw has a median density of 700-1000 sph and comprises 12% of the PG TSA. The worst candidate for understory growth was the sub-boreal spruce – dry cool subzone (SBSdk), as it had <400 sph of suitable understory. The SBSdk subzone only amounts to 2% of the PG TSA.

Stands throughout the TSA should be prioritized for retention based on their ability to contribute to the mid-term timber supply. The height guidelines for what constitutes suitable secondary structure should be lowered from 6 m to 4 m for stands with 700 sph, and from 4 m to 2 m for stands with 900 sph. This will increase the number of stands that are not eligible for logging in the PG TSA and will increase the timber available for harvest during the mid-term. Some of these stands (especially in the SBSmc, and SBSdw subzones) may have harvestable volumes in the range of 200-300 m3/ha in the next 25-40 years (Coates *et al.* 2006).

In a paper titled "Silviculture Strategy for the Prince George Timber Supply Area", Bradley (2008) modeled advanced regeneration in pine-leading stands against the base case scenario where these stands were harvested (Figure 3). The base case assumed that the AAC remained at 14.9 million m^3 for ten years. However, since this paper was published, the AAC has been decreased to 12.5 million m^3. The results were that the mid-term harvest can be increased by only 100,000 m^3/yr (1.4%) compared to the base case. The advanced regeneration is not available for harvest until the end of the mid-term, but the increase in harvestable volume can be spread out over the duration assuming there are mature trees to harvest. Advanced regeneration is assumed to be 10 years old at the time of release.

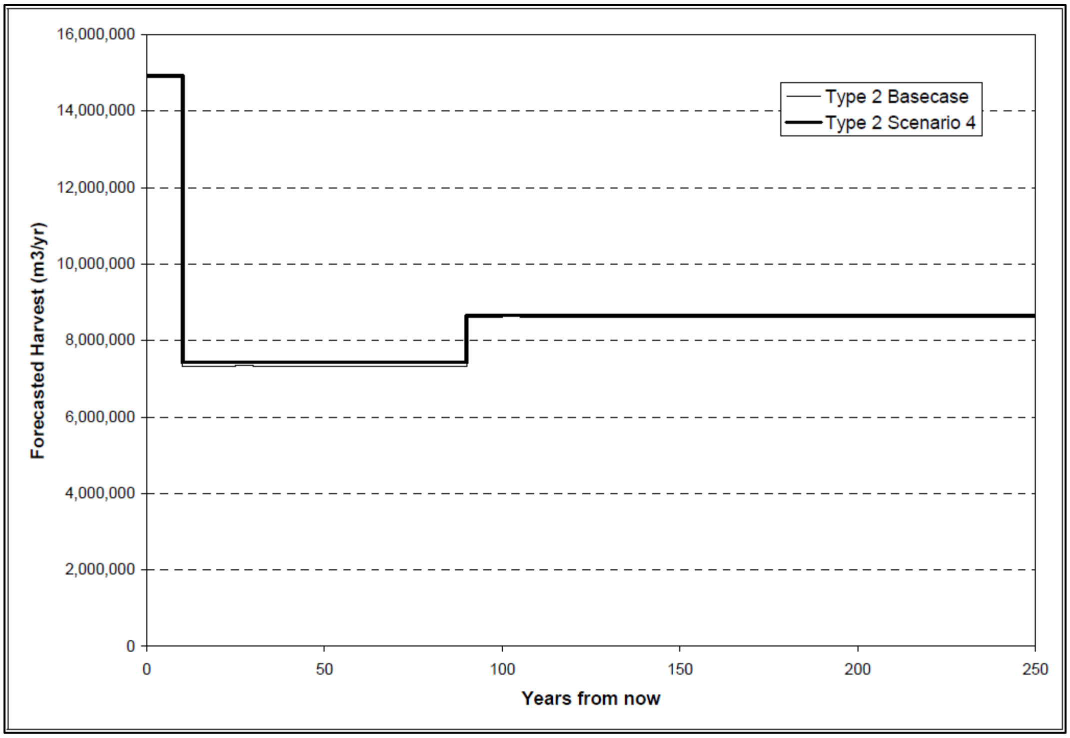

Figure 3. Advanced regeneration (Scenario 4) compared to the base case. In the graph, the base case is a thin line just beneath the thicker line of Scenario 4 between 10 and 90 years (Bradley, 2008)

Thinning

What is thinning?

Thinning falls into two major categories: pre-commercial thinning (PCT, also called juvenile spacing) and commercial thinning. PCT acts on the AAC by speeding up the age at which a stand can be considered operable. The growth in the stand is shifted to the remaining trees, allowing species selection, drop in rotation age, and a reduction in mortality due to competition. Usually the trees selected for harvest during the thinning operation are not of commercial size or species. PCT can lead to an increase in the merchantable volume of a stand, and some stands may be available for harvest in 25-45 years (Weetman & Mitchell, 2005). PCT can also allow for earlier commercial thinning opportunities. In commercial thinning the goal is to remove some valuable timber while leaving trees that will respond well to release. The remaining trees will have improved growth and will be of better form than if the stand had been left alone until harvest. This type of treatment is very dependent on markets for fiber, and may not be used if no market is available for the thinned material. Commercial thinning can distribute a harvest over time and therefore relieve the effects of timber supply shortages caused by age class gaps. Unfortunately, this type of silvicultural treatment is seldom used in industrial forestry due to high logging costs and low timber values.

Due to time constraints (i.e. the mid-term is 11-50 years from now) and cost restrictions (i.e. thinning is expensive relative to clearcutting), PCT is the only viable thinning treatment for increasing MTTS.

What stands would respond best to PCT?

When considering which stands would respond best to a PCT treatment, a careful analysis of risk is necessary. For example, if a lodgepole pine stand is thinned what is the risk that the stand will be killed by a future MPB outbreak? The BC Forest Service has published a set of guidelines called "Field Guidelines for the Selection of Stands for Spacing" (1996). A suitable stand has the following characteristics (applicable to lodgepole pine, white spruce [*Picea glauca* (Moench) Voss], and Engelmann spruce [*Picea engelmannii* Parry ex Engelm.]):

- Tree height is greater than free-growing but less than 10 m,
- The live crown ratio is ≥30%,
- The height to diameter ratio is <100,
- The total stems per hectare is ≥2500, and
- The site index (SI) is ≥15 m.

If all the above conditions are met then the next step is to assess forest health. The root diseases armillaria (*Armillaria ostoyae* Peck) and tomentosus (*Inonotus tomentosus* P. Karst) are of major concern, and increase the risk of loss in a stand beyond what is acceptable for PCT investments. Pine and spruce are highly susceptible to armillaria. Spruce is highly susceptible to tomentosus, while pine is only moderately susceptible (Allen *et al.* 1996). Both diseases are prevalent in the PG TSA.

If stands are healthy enough to consider PCT treatment, which species make the best candidates? There is considerable research that correlates stand vigor due to thinning with a decreased susceptibility to MPB attack and blue stain fungus infection

(Whitehead & Russo, 2005; Waring & Pitman, 1985; Mitchell, Waring, & Pitman, 1983). There will be a relative overabundance of spruce available for harvest in the mid-term due to the mountain pine beetle, so pine-leading stands may be the best choice for PCT. PCT treatments on pine would not be risk-free however. There is evidence that as the climate warms lodgepole pine may be increasing susseptable to a variety of pests and pathogens (Heineman *et al.* 2010). Thinning treatments should be focus on managing the density of very dense or repressed pine-leading stands in the PG TSA. These stands should be carefully analyzed to minimize the risks of damage associated with pine.

How would thinning lodgepole pine help with the MTTS gap?

Lodgepole pine naturally regenerates in very dense pure stands following major disturbances, and densities of 50,000-100,000 sph are not uncommon in the northern interior of BC (Armit, 1966). When growing at such high densities, the competition for growing space (light, water, and nutrients) can cause stands to stagnate, and height and diameter growth slows to the point where the rotation age of a stand may be delayed for many years. This is a problem for stands that are projected to reach maturity during the mid-term.

In an experiment conducted by Johnstone & Thienen (2004), in the Vanderhoof Forest District in the SBSdw subzone, it was shown that thinning can have dramatic results on the height, diameter and volume growth, and merchantability of a repressed stand of lodgepole pine. Very dense stands (average 80,000 sph) were thinned to 500, 1000, 1500, 2000, and 2500s ph. The largest growth response occurred on higher productivity sites, and all thinning densities experienced significant increases in growth. Lower densities were observed to have the best diameter growth response (Figure 4) and all post-treatment densities experienced increased height growth compared to the control (Figure 5). Overall volume growth per tree was highest in the lowest density stands, and decreased incrementally with increasing densities (Figure 6). The highest density per hectare would be found at the higher residual densities.

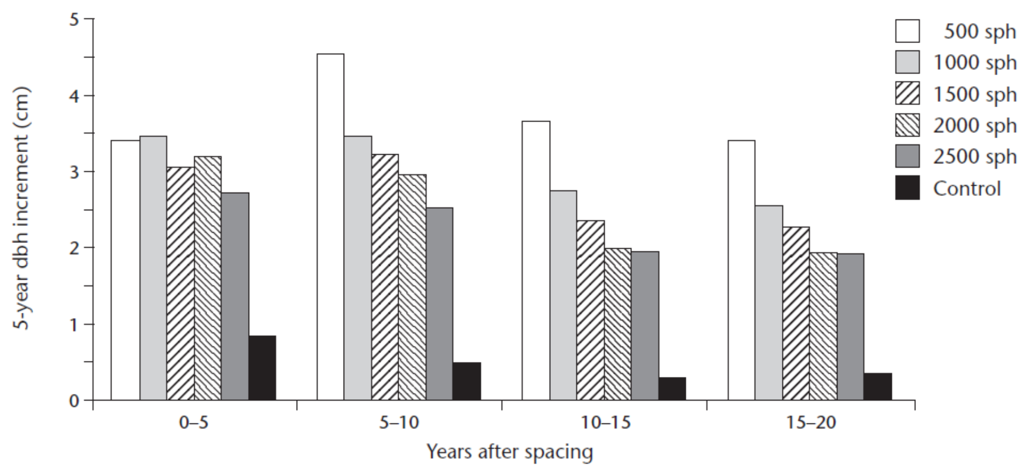

Figure 4. Periodic diameter growth following spacing of lodgepole pine (Johnstone & Thienen, 2004)

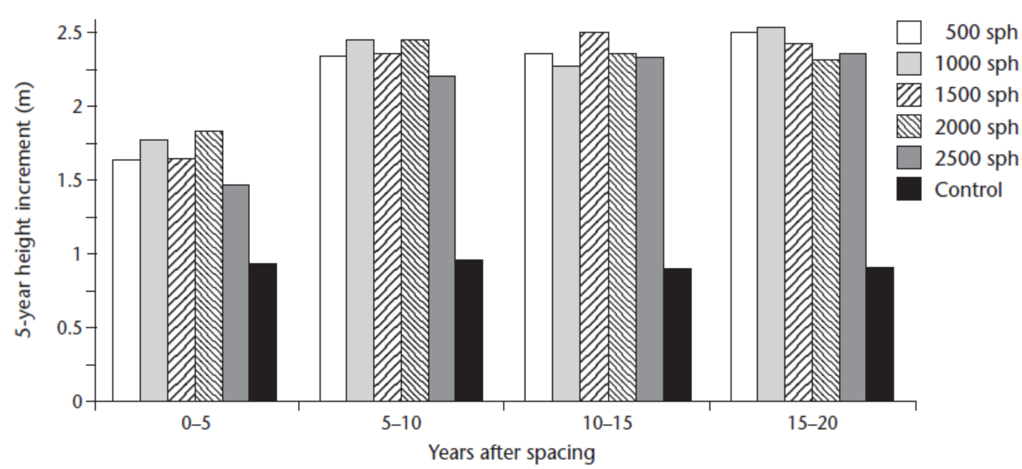

Figure 5. Periodic height growth following spacing of lodgepole pine (Johnstone & Thienen, 2004)

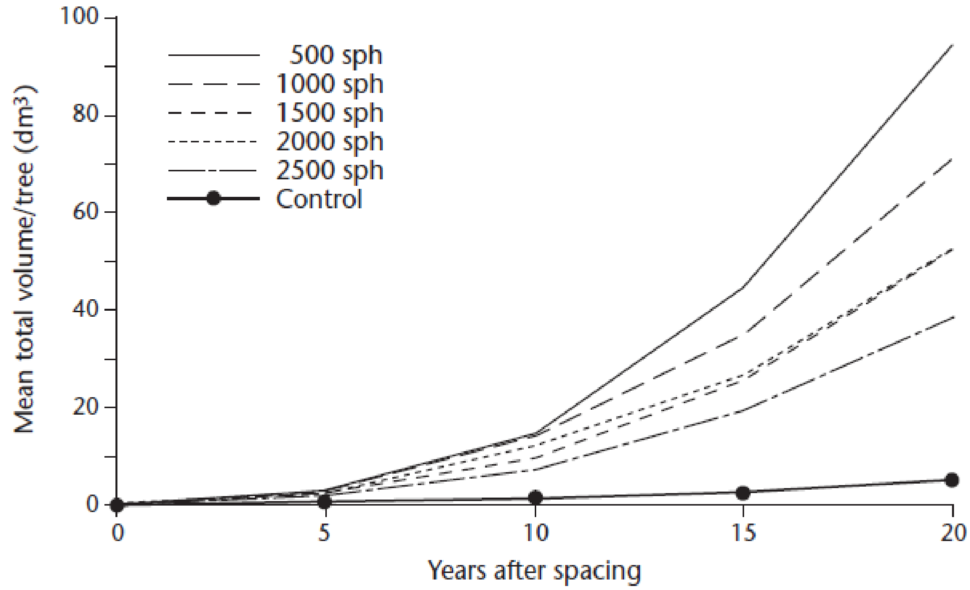

Figure 6. Individual-tree total volume development following spacing of lodgepole pine (Johnstone & Thienen, 2004)

When prescribing PCT, a balance must be found between optimal spacing for tree form, maximizing space for crown development, and total volume increase per hectare. This balance will vary according to BEC zone and site series. Thinning has the added benefit of allowing species selection and the removal of diseased or malformed trees. PCT, if applied to the appropriate stands, could help increase the volume available for harvest during the mid-term and could alleviate pressure on forestry dependent communities. PCT can be combined with fertilization to further increase the volume growth of a forest.

Fertilization

What is fertilization?

Fertilization refers to the periodic application of nitrogen (N) to a forest. There can be serious N deficiencies in interior lodgepole pine and spruce stands, and large reductions in rotation length and a sustained growth response are possible with repeated fertilization of young stands of both species (Brockley & Simpson, 2004). Increases in mean annual increment of 30% are possible (Weetman & Mitchell, 2005; Brockley R. , 1996), and it is the most proven method of increasing the harvest volume and speeding up the operability of a stand (MoFR, 2007). There is a strong correlation between leaf area and annual volume growth. When N is limiting in an ecosystem, fertilization can greatly increase the leaf area of a tree and therefor can increase the annual volume growth (Brockley R. , 2005).

N can be applied to a forest either on the ground or through aerial spraying. Aerial spraying is the most common and cost effective method of application. Fertilization is often used in combination with PCT to maximize the results of both treatments. Figure 7 clearly shows the potential results of fertilization on a well-spaced interior spruce trial. There is a great potential for fertilization to help alleviate timber supply gaps in the mid-term.

Figure 7. Pictures of unfertilized spruce (left) and fertilized spruce (right) (MoFR, 2007)

What stands would respond best to fertilization?

The 2008 report on the silvicultural strategies for the PG TSA clearly outlines the current fertilization strategies for the region. Candidate stands were limited to spruce-leading stands (i.e. >60% spruce) between the ages of 41-100 years old on sites with a SI between 15 and 24. Bradley is of the opinion that the risk of fertilizing pine-leading stands is too great given the current MPB epidemic.

Given that the MPB epidemic peaked in the VFD and PGFD in 2004 and the FSJFD in 2006, there is potential for fertilizing pine-leading stands. Fertilizing trees 15-80 years old can increase mid-term harvest volumes (Figure 8). Like spruce, fertilizing pine will have the greatest effect on stands with a site index ≥15. The relative effect of fertilization decreases on sites that are too rich, so sites above SI24 should not be included. Dense, repressed stands of pine that are thinned should also be fertilized. The thinned stands should not be too widely spaced or the N can be lost to competing vegetation (Brockley R. , 2005).

It has been shown that fertilization can increase the chances of stem breakage from snow due to increased foliage levels and a corresponding increase in snow interception (Teste & Lieffers, 2011). To mitigate this problem, thinned stands should be allowed to stabilize for 2-3 years before fertilizer applications in areas with heavy snowfalls.

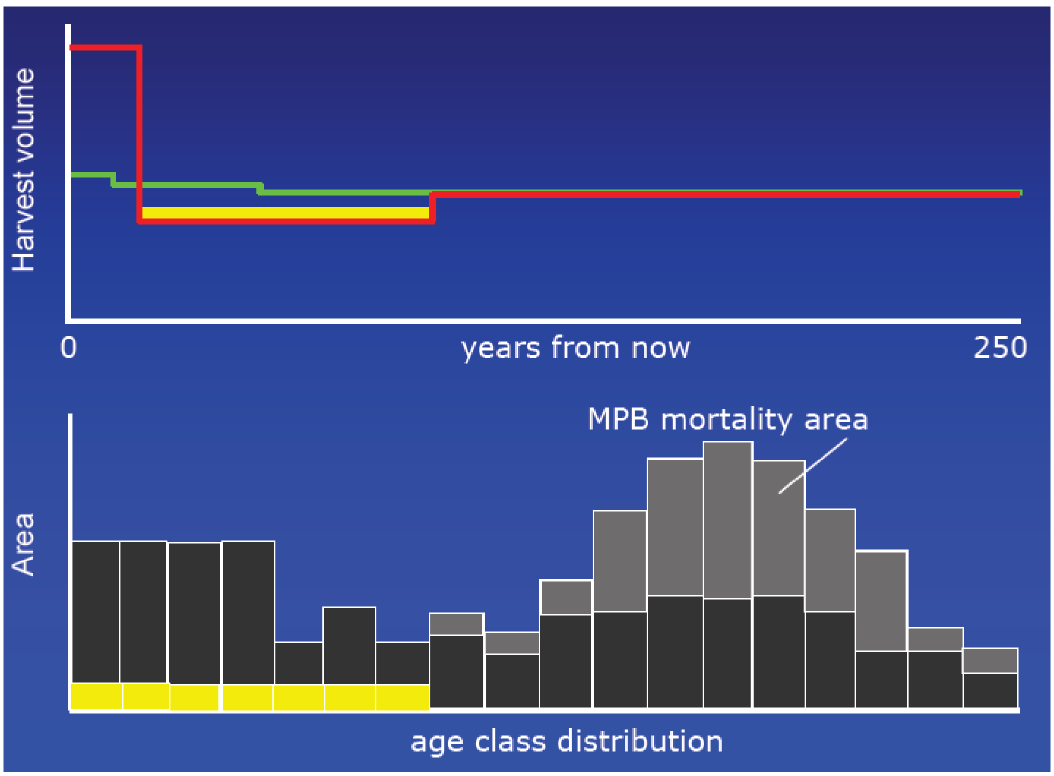

Figure 8. Fertilizing 15-to 80-year-old stands (in yellow) can increase harvest volumes 10–60 years from now (Brockley R. , 2011)

How would fertilization help with MTTS gap?

Bradley (2008) used TIPSY to evaluate potential growth in spruce-leading stands in the PG TSA (Figure 9). Bradley found that potential gains from fertilization are significant, and the relative increase in volume is greatest for natural stands.

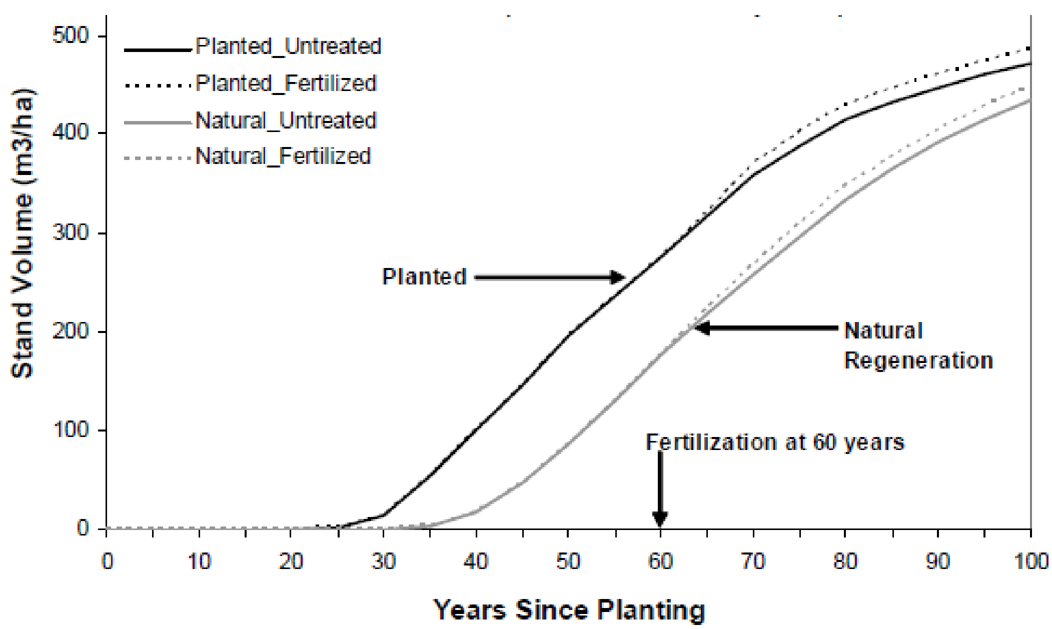

Figure 9. Comparison of yield tables for planted and natural stands. The assumptions are 100% white spruce; 1600sph; SI20; fertilization at 25, 35 and 45 years (Bradley, 2008)

The potential for mitigating the MTTS gap with N fertilization should not be limited to spruce, but should also include stands of pine as well. Using TIPSY, I obtained volume over age curves for three simulated stands (Figure 10). The input conditions are as follows: naturally regenerated stand with 10,000 sph in the PGFD, SI 20, thinning was done at age 25 to a density of 1600 sph, fertilization with nitrogen at 25, 35 and 45 years of age.

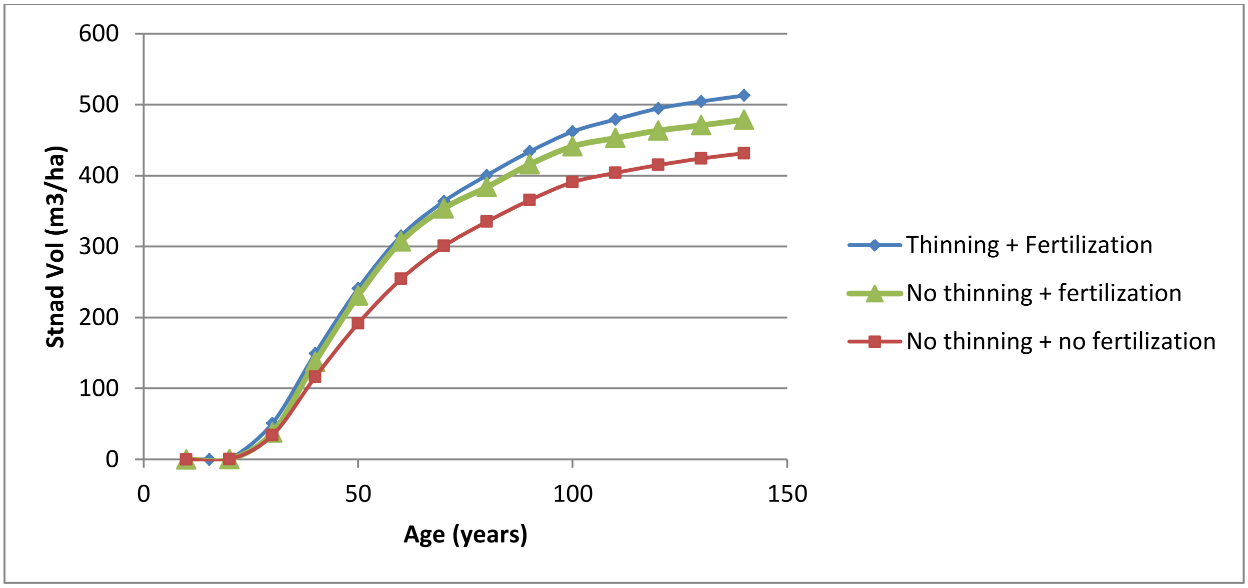

Figure 10. Volume over age curves for three simulated stands from TIPSY 4.2

If harvested at age 80, a stand with no treatments will have 335 m^3/ha, compared to 384 m^3/ha for a fertilized stand and 400 m^3/ha for a thinned and fertilized stand.

The TIPSY economics section states that fertilization costs, on average, $353/ha in the PGFD. This is a significant addition to the silviculture costs for an area and may be a major factor in the reluctance of licensees and the government to increase fertilization treatments.

Discussion and Recommendations

The problems that have been caused by the pine beetle epidemic will be long lasting and severe. The loss of the mid-term timber supply and the associated fall-down in AAC will result in extensive job loss and economic decline in forestry dependent communities throughout the interior of BC (Martin, 2011). However, there are some potential silvicultural strategies that could help mitigate this problem. The following is a list of suggestions for increasing the volume available for harvest in the mid-term:

1. continue to update the provincial forest inventory–
    - more information is needed on the true extent of the MPB epidemic;

- better inventory allows forest managers to better allocate resources for silvicultural investment;

2. lower height requirements for what constitutes suitable secondary structure–
   - from 6m to 4m for stands with 700sph, and from 4m to 2m for stands with 900sph or more;
   - this will result in less salvage harvest in the short-term but will benefit forest health and ecology;
3. pre-commercially thin suitable pine-leading stands–
   - inter-tree competition in overly dense pine-leading stands results in stagnation and productivity losses;
   - PCT will transfer growth to remaining trees which will increase crown size and correspondingly, growth and yield;
4. fertilize pine and spruce with nitrogen–
   - fertilizing will increase the vigor, growth rate and volume of stands while at the same time decreasing the rotation age;
   - fertilization can be combined with PCT to increase the effectiveness of each treatment.

Conclusion

In the last decade, BC has lost 30,000 forestry jobs and 50 mills have either closed or are sitting idle (Kozak & Halseth, 2010). While the factors causing this decline are numerous and cannot be attributed to the MPB epidemic alone, loss of mid-term timber supply will undoubtedly exacerbate the problem. In this tough economic climate it is difficult to justify investing money in silviculture in BC. This is short-sighted and will only cause further declines in revenue from forestry in the future. While there are risks associated with silvicultural investments in lodgepole pine, the potential impacts on rural communities outweigh these risks. PCT and fertilization, either separate or combined, have good potential to help alleviate timber supply shortages in the mid-term. Combining PCT and fertilization will have the most benefit, but will also have the highest monetary costs. Due to risks associated with stem breakage due to snow, if both treatments are used, fertilization should follow PCT by several years.

Understory retention does not have as much potential as PCT and fertilization to alleviate mid-term timber supply shortages, but there are other benefits to the forest beyond economics. These include benefits to hydrology, biodiversity, habitat, and forest resilience. The negative impacts of understory retention will be felt by the licensees in the form of reduced short-term harvest levels.

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