Report for the Chief Forester
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Abundance of Secondary Structure in Lodgepole Pine Stands Affected by the Mountain Pine Beetle

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Introduction

The magnitude and extent of the current mountain pine beetle outbreak in British Columbia requires thoughtful planning to recover value from the impacted timber while maintaining other values and reducing impacts to future timber supplies.

In order to make informed decisions about management of stands and landscapes affected by the pine beetle we need better information on the abundance and extent of structure in lodgepole pine stand types. We currently have limited information on the abundance of seedlings and saplings (**understory trees**) in pine-leading stand types. This information is difficult to obtain from traditional inventory data. Understory trees in pine-leading stands are generally dominated by species not susceptible to the mountain pine beetle, or if they are pine, are too small to be attacked, and hence will survive the epidemic. In addition to understory trees, non-pine sub-canopy and canopy trees can contribute to structure in pine-leading stand types. Collectively, we will call seedlings, saplings, sub-canopy and canopy trees that will likely survive a pine beetle attack "**secondary structure".**

Secondary structure in lodgepole pine-leading stand types contributes to ecological processes, hydrologic recovery, visual quality and wildlife habitat after mountain pine beetle attack. These are major topics on their own and we will not directly address them in this report. Of primary concern in this report is how secondary structure may help to mitigate projected mid-term (15-50 years from now) timber supply shortages. Current projections suggest sharp drops in mid-term supply in all analysis units affected by the pine beetle. This report represents the first step in determining if secondary structure in pine-leading stand types can help mitigate mid-term timber supply short falls, by identifying the abundance and extent of secondary structure in these stand types. We also project future development of three stand types with good secondary structure using VDYP7 and SORTIE-ND.

The information in this report can assist in making decisions about harvesting and rehabilitation priorities for stand affected by the mountain pine beetle. We specifically address the following questions in this report:

1. How abundant is secondary structure in pine-leading stands?
2. Is secondary structure similar across biogeoclimatic units (SBSdk, SBSdw2, SBSdw3, SBSmc2 and SBSmc3) in pine-dominated stands?
3. Can stands with good secondary structure reasonably be expected to reach harvestable volumes in the mid-term?

Methods

Datasets used in this project were drawn from mature and older pine stands in the Nadina, Vanderhoof and Prince George Forest Districts of north central BC (Table 1). Known younger stands were removed from the dataset. Meeting these criteria were 1,211 sample plots from 7 different research projects in pine stands across all biogeoclimatic units in north central BC where detailed data were collected on tree composition and sizes (Table 1).

Study objectives and data format varied among the individual research projects. Data from each sample plot were broken into tree layers: established seedlings (10 cm to less than 1.3 m tall), saplings (0.1 to <7.5 cm DBH), sub-canopy trees (7.5 cm to <15.0 cm DBH) and canopy trees (15.0 cm DBH and greater). Understory data was summarized for conifers only whereas sub-canopy and canopy tree data include both conifer and broadleaved species.

To be considered a pine-leading stand and included in the dataset sub-canopy and canopy tree composition (measured by percent basal area) had to be greater than 50% lodgepole pine. In total, 1083 of the 1211 plots were found to be pine-leading. Of the 1083 pine-leading plots, 83% contained at least 70% pine. A total of 949 plots fell in the five Sub-Boreal Spruce (SBS) biogeoclimatic units (SBSdk, SBSdw2, SBSdw3, SBSmc2 and SBSmc3) that are the focus of this report (Table 1).

The collated data came from studies established at different time periods relative to attack by the mountain pine beetle. Some plots were established prior to beetle attack (most NIVMA data), some during active attack and some after the dominant attack period. This posed no problems for identifying non-pine secondary structure. For pine, only established seedlings and saplings contributed to secondary structure; all live pine sub-canopy and canopy trees were removed from the database for the purpose of calculating secondary structure. This may be overly conservative; however, it reduces the risk of overestimating secondary structure and provides a better portrayal of non-pine secondary sub-canopy and canopy structure.

In order to estimate whether secondary structure in pine-leading stands can reach harvestable volumes in the mid-term we used the individual tree, spatially explicit stand dynamics simulator SORTIE-ND (http://www.sortie-nd.org) and the Ministry's natural stand yield model VDYP7 (http://www.for.gov.bc.ca/hre/gymodels/GY-Model/about.htm) to project the future composition and growth of three stands that currently have moderate to good secondary structure (Table 2). These stands were from the Vanderhoof Forest District (DeLong data, Table 1) and were either under active attack or just through the dominant attack period. Some larger diameter pine trees were alive at the time of sampling (Table 2), however these trees were not included in the model simulations. As a conservative measure, at the start of the model simulations all live pine 12.5 cm DBH and greater were killed, as few larger pine trees are found alive in older attacked stands.

SORTIE-ND model simulations used actual plot data to create stand conditions similar to each individual sample plot. The simulations included snag dynamics, where pine snags block light, deteriorate and fall over time (FSP Project Y051161). The VDYP7 simulations used the species composition of each sample plot as starting conditions. The current point (or age) that each sample plot represented on a VDYP7 yield curve was estimated based on the basal area of the secondary structure in each stand at the start of the simulation (see results and clearcut equivalency of secondary structure). VDYP7 yields were then projected for the next 60 years.

Initial basal areas of secondary structure in the three simulated stands were: stand 8 = 6.81, stand 11 = 6.43 and stand 18 = 13.92 m^2/ha.

Results

To make our results readily interpretable for operations, we have chosen to present cumulative percent of stocking above specific density thresholds as a means of conveying the abundance of understory trees (seedlings and saplings) and cumulative percent of basal area above specific basal area thresholds for conveying secondary structure of combined sub-canopy and canopy trees.

Understory, sub-canopy and canopy trees

To illustrate the data, we have selected a minimum threshold of 1000 stems/ha to represent a stocking level that should result in full site occupancy by understory trees. Approximately 40% of sample plots in pine-leading stands across sub-boreal spruce biogeoclimatic units exceeded the 1000 stems/ha threshold for understory trees (Fig. 1). Understory tree abundance varied among biogeoclimatic units (Figs. 2-4). Understory trees were least common in the SBSdk unit with a little over 20% of plots exceeding 1000 stems/ha (Fig. 3). The SBSmc2 and SBSmc3 had the highest percentage of plots exceeding 1000 stems/ha (60-80%), followed by the two SBSdw variants (42-55%) (Fig. 3). Median density of understory trees was much higher in the SBSmc2 unit than other units; half the plots sampled exceeded 4000 stems/ha (Fig. 4). Species composition of understory trees also varied considerably by biogeoclimatic units (Table 3).

Sub-canopy and canopy tree secondary structure followed similar patterns to the understory trees except for the SBSmc3 biogeoclimatic unit (Fig. 5). Structure was least abundant in the SBSdk and most abundant in the two SBSdw variants and in the SBSmc2. Sub-canopy and canopy tree basal area of non-pine trees was much lower in the SBSmc3 than in the SBSmc2, although the two variants had similar high understory abundances. Tree species composition of sub-canopy and canopy trees also varied by biogeoclimatic units (Table 4), but not as much as the understory tree layer (Table 3).

We think pine-leading stands with 5-10 m^2/ha or more of secondary structure basal area have the potential to contribute to mid-term timber supply (Coates and Hall 2005). Across north central BC, about 20-35% of pine-leading stands meet this criteria. The percent of pine-leading stands meeting this minimum threshold varied considerably by biogeoclimatic unit, reaching a high of 40-60% in the SBSdw2 (Fig. 5). Apparently, in the SBSdw2, 44% of this structure is black spruce (Table 4). In the other biogeoclimatic units black spruce is minor or absent in the sub-canopy and canopy tree layer (Table 4).

This report does not address the species suitability of secondary structure (understory trees and sub-canopy and canopy trees) nor its release potential. These are important issues for timber quality, value and future volume production, and for Timber Supply Review. These issues need to be addressed elsewhere. During field sampling for this project we observed that understory trees released 2-3 years after mountain pine beetle attack.

Clearcut equivalency of secondary structure

We calculated the basal area of all saplings, sub-canopy and canopy trees in each sample plot (live pine trees >7.5 cm DBH were excluded, see methods). We then used TIPSY to determine basal area development of an average (mesic) spruce plantation in the Nadina and Vanderhoof Districts (Fig. 6). Based on the basal area – age relationship in figure 6 we then assigned a clearcut equivalence age to each sample plot (Fig. 7). This allows secondary structure to be quantified in terms of how long it would take a typical spruce plantation to reach basal areas equivalent to those found in pine-leading stands. The assignment of a clearcut equivalence age does not imply future performance of these stands will follow that of a managed spruce plantation. Across the Nadina, Vanderhoof and Prince George Forest Districts about 60% of pine-leading stands have secondary structure equivalent to or better than a 20 year old spruce clearcut (Fig. 7). Close to 30% of pine-leading stands were equivalent or better than a 30 year old spruce clearcut (Fig. 7).

Clearcut equivalency, however, varied widely by biogeoclimatic unit (Fig. 8). In the SBSdw variants and the SBSmc variants, 75 to 85% of pine-leading stand types had secondary structure equivalent to or better than a 20 year old spruce clearcut (Fig. 8). Five to 10% of pine-leading stands in three of the five biogeoclimatic units were equivalent to or better than a 40 year old clearcut (Fig. 8). Stands with good secondary structure were rarer in the SBSdk subzone where only about 30% of stands were equivalent to or better than a 20 year old spruce clearcut (Fig. 8).

Projection of future status of three stands

We used plot data from three stands with average to good secondary structure as starting conditions for the SORTIE-ND stand dynamics simulator and the natural stand model VDYP7. Results from these simulations clearly show that such stand types can contribute harvestable volume in the mid-term, with many stands supporting volumes of 200-300 m^3/ha within 25 to 40 years (Fig. 9).

Conclusions based on preliminary analysis

1. Pine-leading stands have considerable variability in secondary structure across north central BC. Approximately 20-30% of these stands have sufficient secondary structure today to reasonably expect a mid-term harvest opportunity if simply left unsalvaged.
2. Approximately 40-50% of pine-leading stands in north central BC have sufficient understory densities to be stocked without further silvicultural intervention. We have insufficient data to predict if they would be considered stocked with well-spaced acceptable species. Such understory trees, if protected, may reduce rotations by 10-30 years compared to complete salvage and planting.
3. Approximately 20-25% of pine-leading stands in north central BC had poor secondary structure. These stands are prime candidates for total salvage and planting.
4. The north central BC percentages listed in points 1-3 varied by biogeoclimatic unit. Secondary structure was by far the lowest across the SBSdk subzone compared to other biogeoclimatic units. Stands with good secondary structure in the SBSdk may have high value from an ecological and habitat perspective. It would make sense to concentrate harvesting elsewhere in the SBSdk, in the many stands where secondary structure is low.
5. Opportunities for understory retention were highest in the SBSmc and SBSdw variants, depending on species preferences.
6. The SBSmc2 has an excellent combination of understory stocking and minimum thresholds of overstory basal area that can release and provide mid-term harvest opportunities.
7. There appears to be considerable potential to reduce the impact to mid-term timber supply and enhance biodiversity values, hydrologic recovery, visual quality and wildlife habitat by strategically protecting certain pine-leading stand types from immediate harvest and/or protecting secondary structure during salvage operations.

Future Analysis

In a future report, we will undertake stand- and landscape-scale modeling to examine different silvicultural strategies that might mitigate mid-term timber supply and contribute to biodiversity, hydrologic recovery, visual quality and habitat objectives. In addition, we will undertake a more refined examination of understory tree abundance by biogeoclimatic unit, inventory type and broad site type.

Our intent, at that time, is to provide the following information:

1. A more refined examination of the abundance of secondary structure by biogeoclimatic unit, inventory type and broad site type or site series (pine lichen, mesic or circum-mesic sites).
2. Analysis of how well the major inventory types reflect the amount of secondary structure in pine-leading stands, and in particular, the amount of live non-pine basal area of sub-canopy and canopy trees.
3. Identification of representative structural types found in pine-dominated stands.
4. Detailed projection of expected future growth of the representative structural types using VDYP7 and, possibly, the spatially explicit individual tree model SORTIE-ND.
5. An estimate of the proportion of area in combinations of biogeoclimatic unit, inventory type and broad site types that will contribute to timber supply in 20, 30, 40, 50 and 60 years from the present.
6. An examination of the effect of different silvicultural strategies on mid-term timber supply (using the Morice and Vanderhoof Forest District as examples), utilizing the landscape-scale SELES modeling platform.

Acknowledgments

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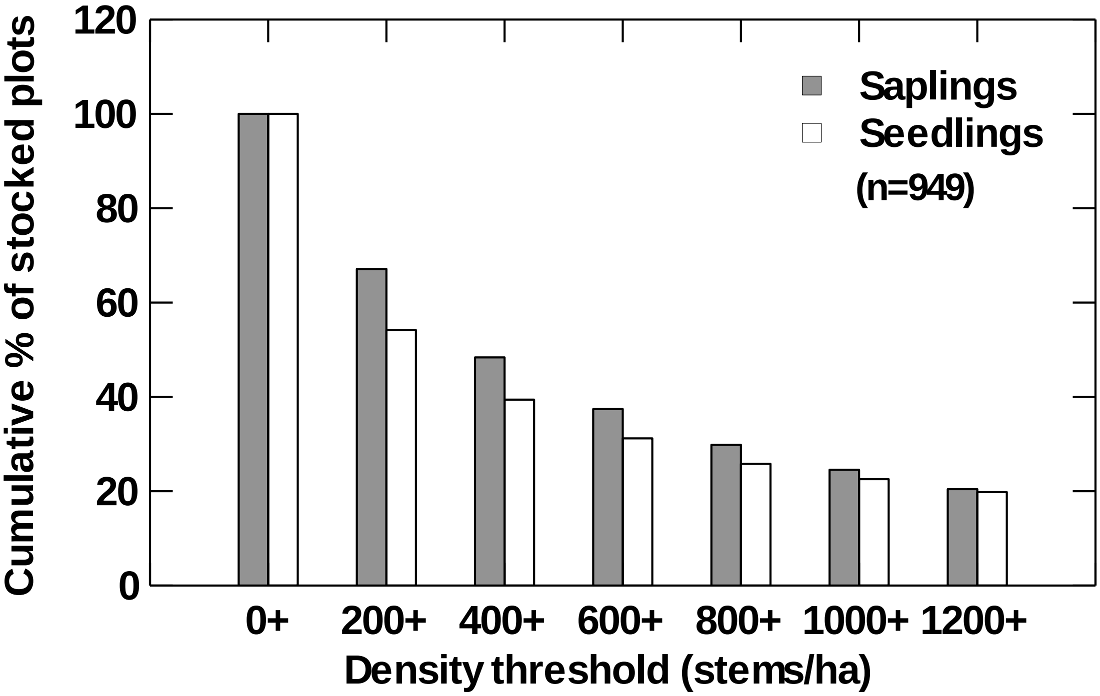
References

Coates, K.D. and Hall, E.C. 2005. Implications of alternate silvicultural strategies in Mountain Pine Beetle damaged stands. Technical Report For Forest Science Program Project Y051161. Bulkley Valley Centre for Natural Resources Research and Management, Smithers, BC. 31p.



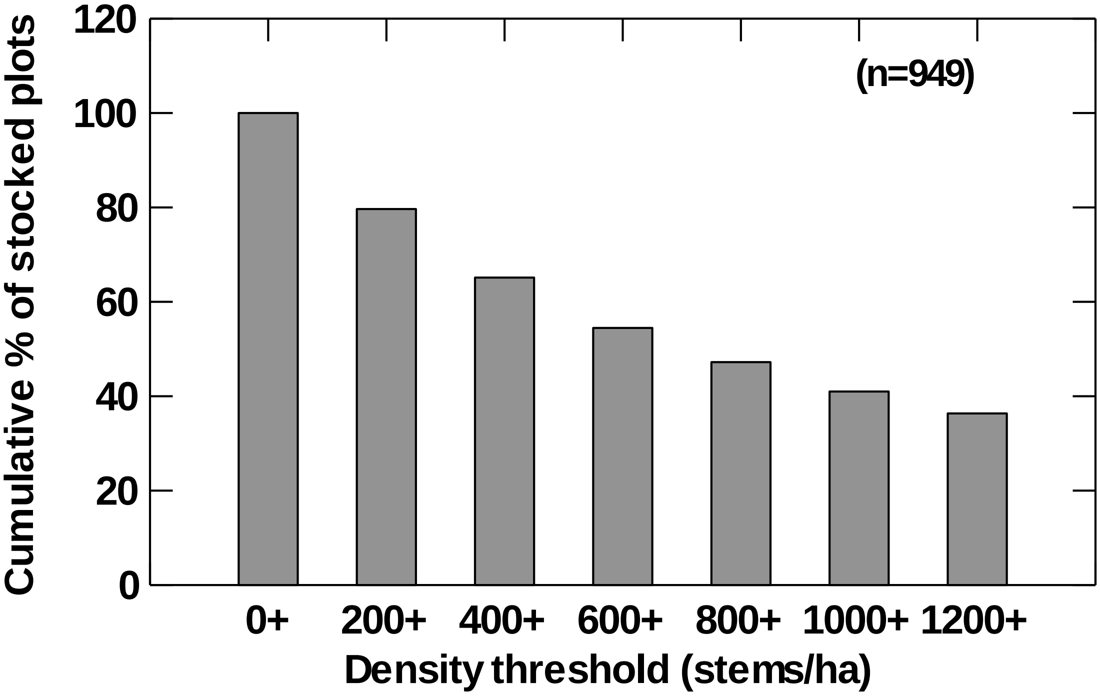


Figure 1. Cumulative percentage of plots in pine-leading stands across north central BC with density of seedlings (10 cm to <1.3 m tall) and saplings (≥1.3m tall and <7.5 cm dbh) separated (top graph) and seedlings and saplings combined (bottom) above specified density thresholds.

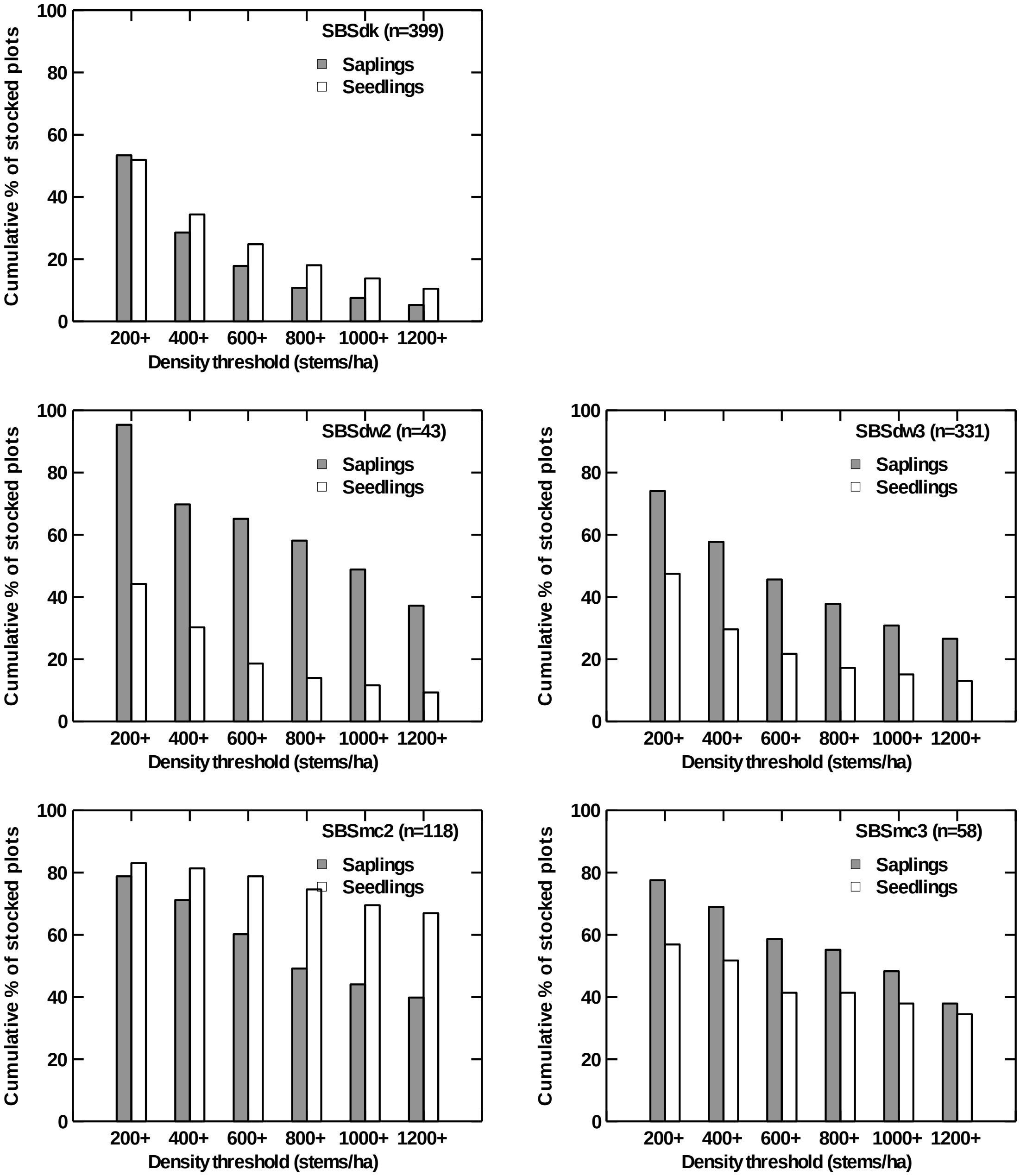


Figure 2. Cumulative percentage of plots with density of seedlings and saplings above specified density thresholds by biogeoclimatic unit.

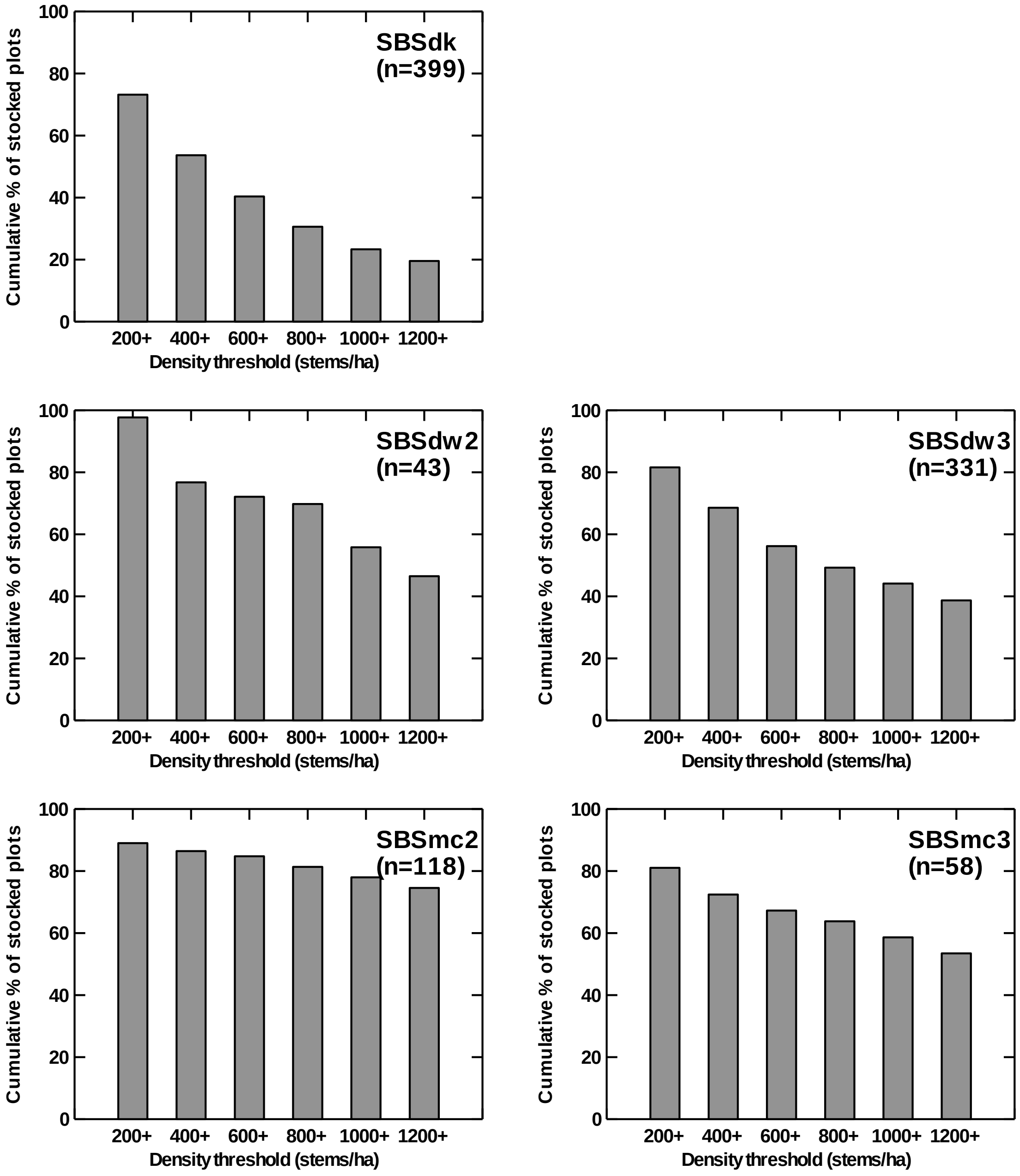


Figure 3. Cumulative percentage of plots with understory trees above specified density thresholds by biogeoclimatic unit.

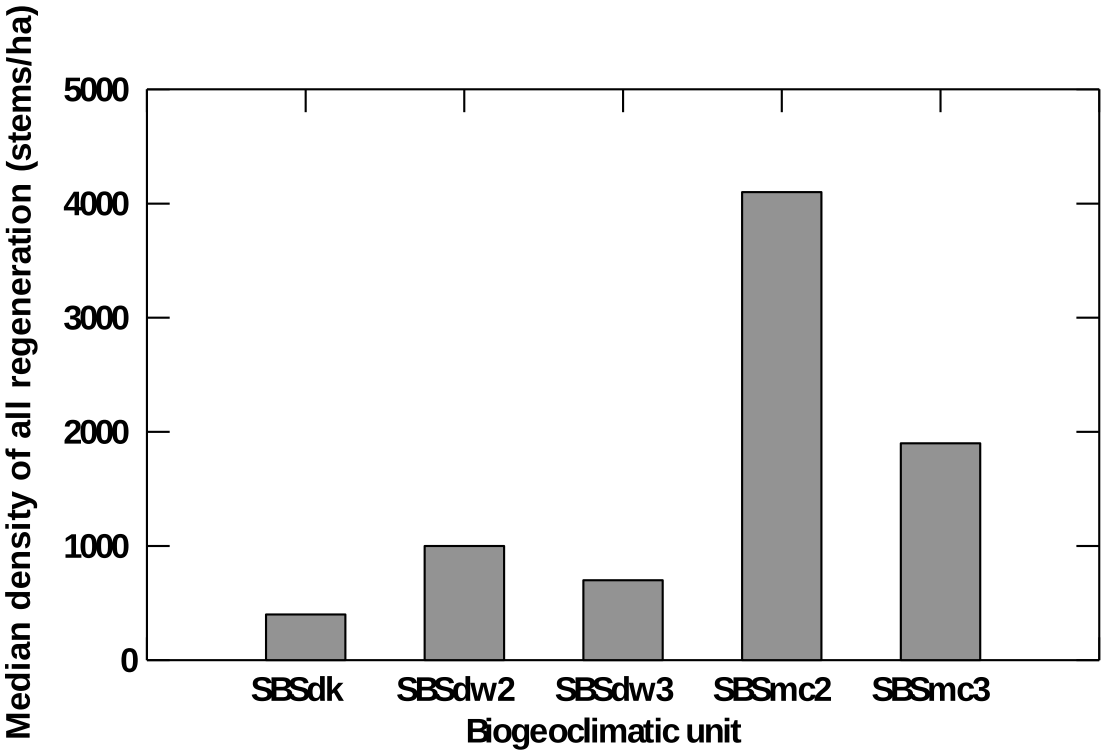


Figure 4. Median density of seedlings and saplings in pine-leading stands by biogeoclimatic unit. The median represents the middle number in the distribution of densities from the sample plots. For example, in the SBSdw2, the median was about 1000 stems per hectare meaning 50% of the pine-leading stands in the SBSdw2 had more than 1000 stems per hectare while the other half had lower densities.

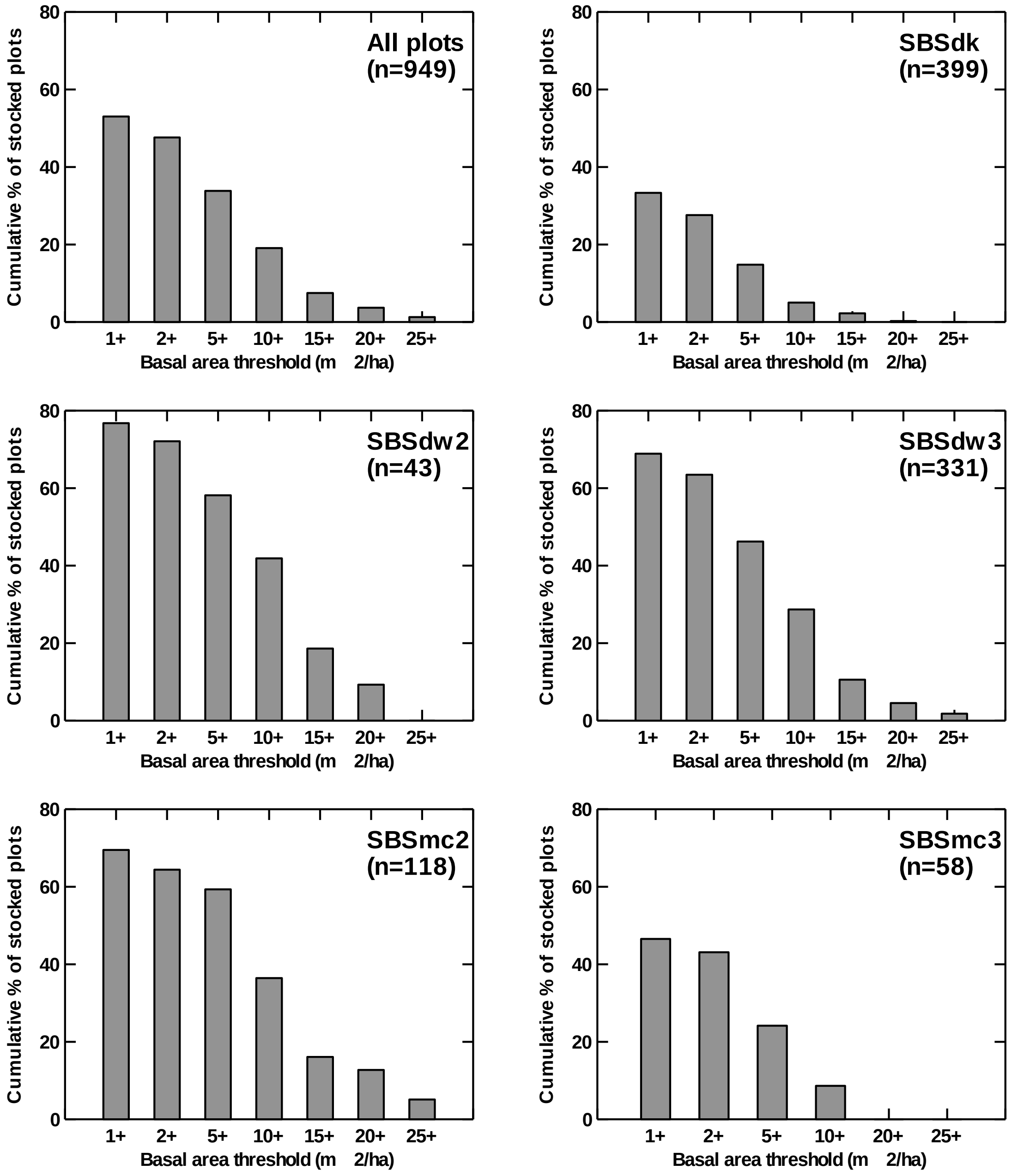


Figure 5. Cumulative percentage of plots with basal area of non-pine sub-canopy and canopy trees (7.5 cm DBH and greater) above specified basal area thresholds in pine-leading stands across north central BC (all plots) and by biogeoclimatic unit.

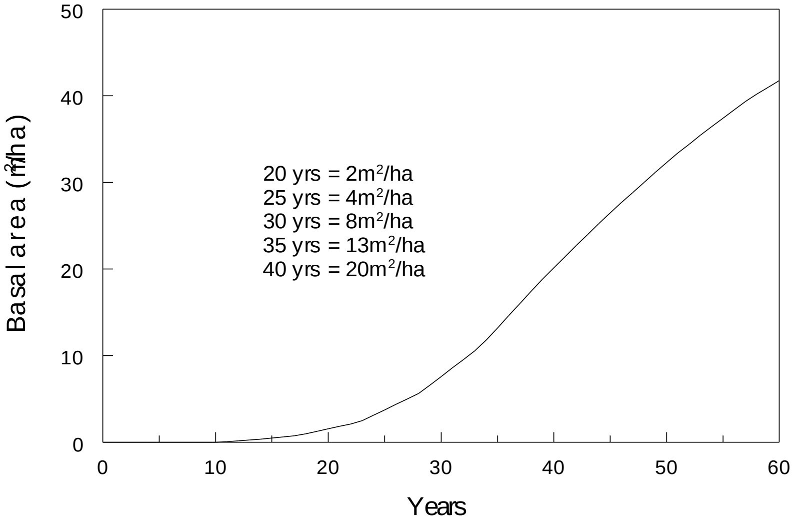


Figure 6. Basal area over time of an interior spruce plantation on a mesic site in the Vanderhoof or Nadina Districts (TIPSY, site index 19.6 m, 1,600 stems/ha).

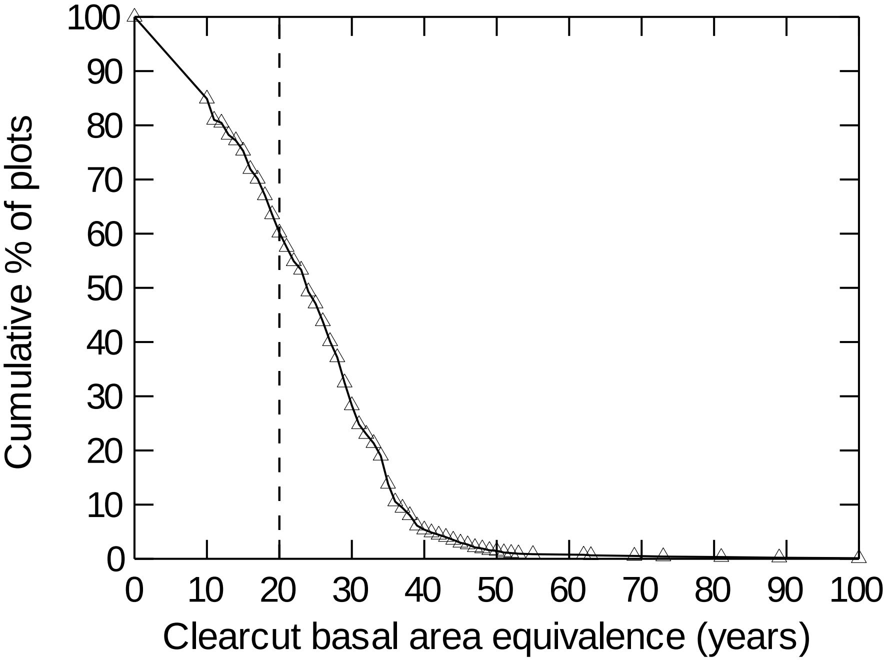


Figure 7. Cumulative percent of plots in pine-leading stands across north central BC that had the equivalent basal area of a developing clearcut. The basal area of secondary structure in each plot was assigned the number of years it would take a spruce plantation to reach that basal area (Fig. 6). About 60% of pine-leading stands have secondary structure equivalent to or better than a 20 year old spruce clearcut (dashed vertical line).

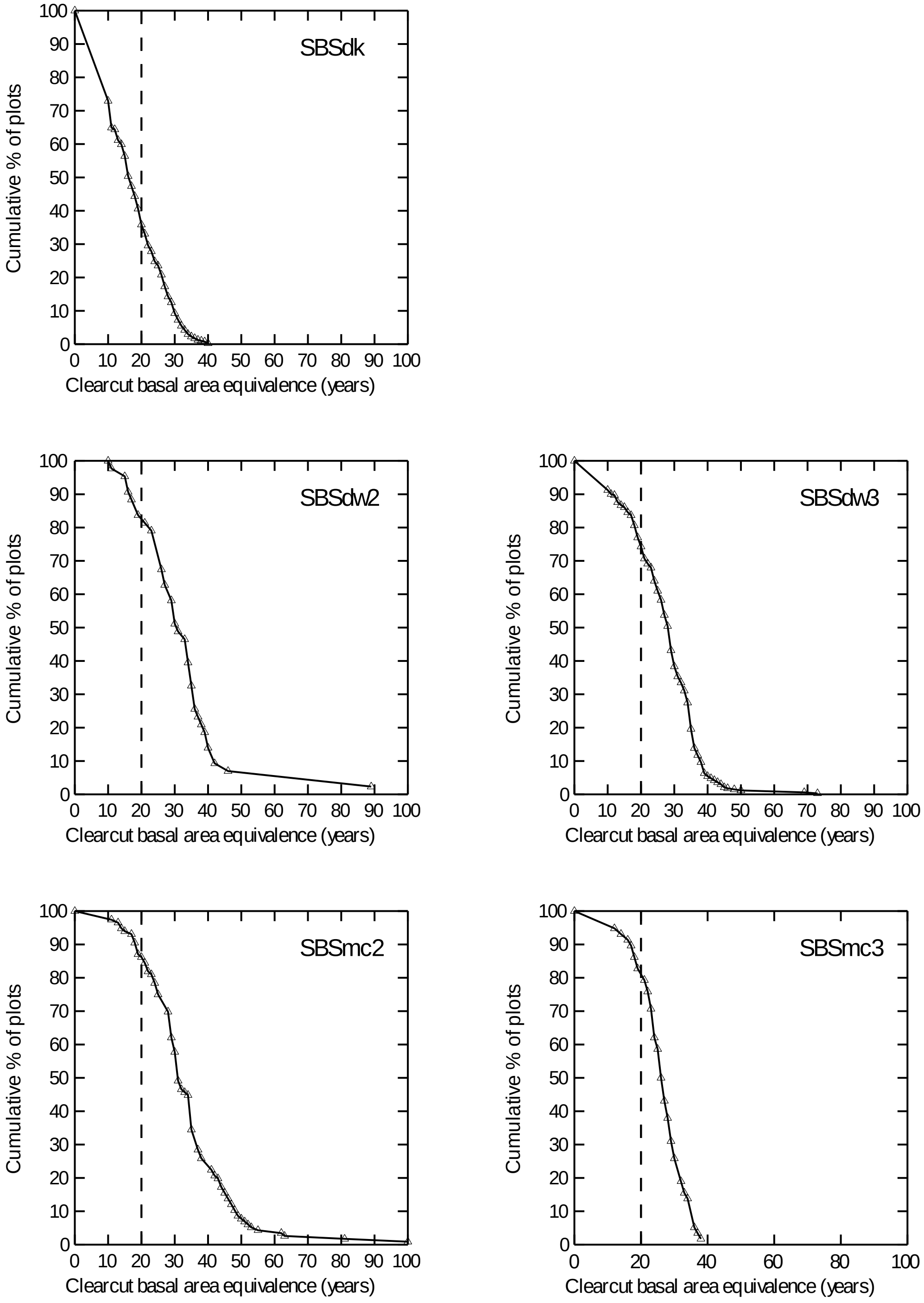


Figure 8. Cumulative percent of plots in pine leading stands that have the equivalent basal area to a developing clearcut by biogeoclimatic unit in north central BC. The basal area of secondary structure in each plot was assigned the number of years it would take a spruce clearcut to reach that basal area (Fig. 6). The dashed vertical line indicates the percentage of plots with secondary structure equivalent to or better than a 20 year old clearcut. The proportion of stands at a given age of clearcut equivalency varies widely by subzone.

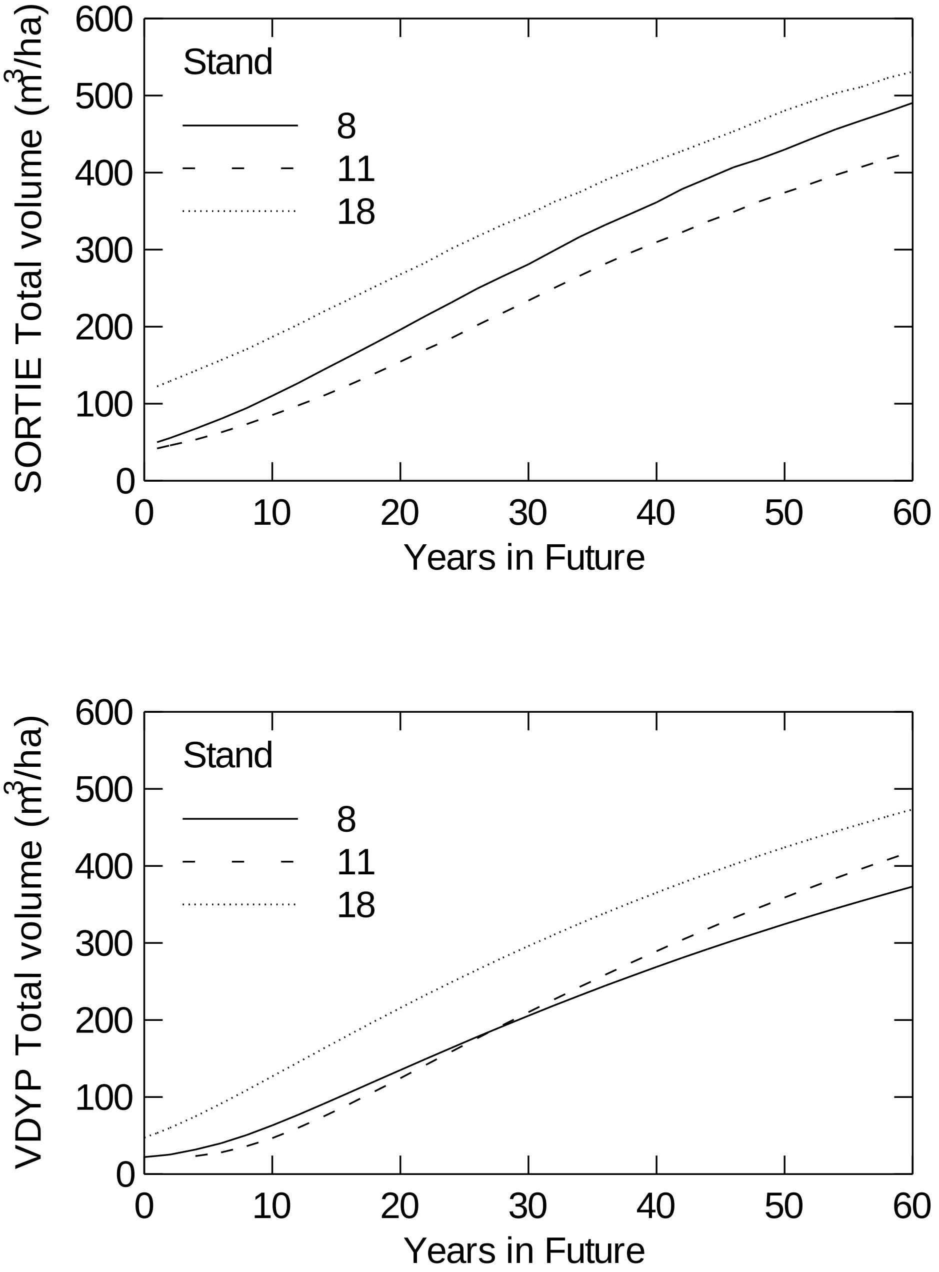


Figure 9. Projected volume over time as predicted by the SORTIE-ND simulation model (top) and the natural stand model VDYP7 (bottom) for three pine-leading stands with good secondary structure (Table 2). Volumes that could be considered commercially viable accrue within as little as 20 years. Initial conditions were: **stand 8**, clearcut equivalency 29 yrs, had a mixed overstory of spruce and pine and no advanced regeneration; **stand 11**, clearcut equivalency 26 yrs, had a complex understory and a sparse overstory of spruce and subalpine fir; **stand 18**, clearcut equivalency 35 yrs, had abundant advanced regeneration under a spruce and pine overstory. See methods section for initial basal area of secondary structure and details on model simulations.

Source	Total Number of Plots	Pine – leading Plots[1]	Subzone	Plots used in analysis	Funding source and Experimental details
Burton	233	185	SBSdk SBSdw3 SBSmc3	50 111 24	FSP Y061184 http://www.bcfsp.com
Cichowski & Williston	59	59	SBSdk SBSmc2	7 24	FSP Y061134 http://www.bcfsp.com
Coates	93	86	SBSdk SBSmc2 SBSmc3	19 62 5	FSP Y061148 http://www.bcfsp.com
Delong	18	18	SBSdk SBSdw3 SBSmc3	6 6 5	FSP Y061072 http://www.bcfsp.com
Hawkins	347	274	SBSdw2 SBSdw3 SBSmc3	35 211 23	MPBI Project 8.23 http://mpb.cfs.nrcan.gc.ca/
NIVMA	186	186	SBSdk SBSdw2 SBSdw3 SBSmc2 SBSmc3	14 8 3 32 1	http://www.nivma.bc.ca/
Rakochy	303	303	SBSdk	303	MPBI Project 8.23 http://mpb.cfs.nrcan.gc.ca/ CFS, BLNDC, and Alcan
TOTALS	**1211**	**1083**		**949**	

Table 1. Sources of data, by researchers or organization, used in the analysis including total plots, total pine-leading plots, and plots located in SBS subzones used in this analysis. Further information about each study can be found at the web site of the funding organization.

[1] pine-leading plots had >50% of sub-canopy and canopy basal area of lodgepole pine.

Plot	DBH class (cm)	Subalpine fir #/ha	Interior spruce #/ha	Lodgepole pine #/ha	Lodgepole pine snags #/ha
8 (mixed canopy and sparse Advanced regeneration)	Seedlings	0	0	0	0
	0-2	0	100	0	0
	2-4	0	0	0	0
	4-6	0	0	0	0
	6-8	0	0	0	0
	8-10	0	75	0	0
	10-12	0	25	0	0
	12-14	0	75	25	25
	14-16	0	50	0	50
	16-18	0	100	0	200
	18-20	0	25	0	100
	20-22	0	0	25	150
	22-24	0	0	25	75
	24-26	0	25	0	125
	26-28	0	0	0	50
	28-30	0	0	0	25
	30-32	0	0	0	50
	32-34	0	0	0	50
11 (complex understory and sparse canopy)	Seedlings	0	200	100	100
	0-2	200	0	100	100
	2-4	0	400	700	700
	4-6	200	100	0	0
	6-8	200	100	0	0
	8-10	25	25	0	0
	10-12	0	25	0	0
	12-14	0	0	0	0
	14-16	0	0	0	0
	16-18	0	0	0	0
	18-20	0	0	0	0
	20-22	0	25	0	0
	22-24	0	0	0	0
	24-26	0	0	0	0
	26-28	0	0	0	0
	28-30	0	0	0	0
	30-32	0	0	0	0
	32-34	0	0	0	50
	34-36	0	25	0	25
	36-38	0	0	0	100
	38-40	0	0	0	50
	40+	0	0	0	100
18 (complex understory and canopy layers)	Seedlings	300	200	0	0
	0-2	300	200	0	0
	2-4	0	0	0	0
	4-6	0	0	0	0
	6-8	0	25	0	0
	8-10	0	75	0	25
	10-12	0	50	0	0
	12-14	0	75	0	0
	14-16	0	25	25	25
	16-18	0	0	25	50
	18-20	0	0	0	50
	20-22	0	100	0	50
	22-24	0	25	25	25
	24-26	0	25	0	50
	26-28	0	0	0	100
	28-30	0	0	0	75
	30-32	0	0	0	50
	32-34	0	0	0	50
	34-36	0	25	0	25
	36-38	0	25	0	50
	38-40	0	0	0	0
	40+	0	0	0	50

Table 2. Initial starting conditions for three stands used in SORTIE-ND and VDYP7 simulations to project future status over time.

Table 3. Percent of Total Stems

Subzone	SBSdk			SBSdw2			SBSdw3			SBSmc2			SBSmc3		
	Seedlings		Saplings	Seedlings		Saplings	Seedlings		Saplings	Seedlings		Saplings	Seedlings		Saplings
Species	(%)		(%)	(%)		(%)	(%)		(%)	(%)		(%)	(%)		(%)
Pl	P	27.2	26.5	P	25.6	30.7	P	9.6	25.9	P	4.6	5.6	P	1.9	20.0
Sx	P	34.6	55.8	P	25.6	41.7	P	11.7	28.2	P	6.6	14.7	P	8.7	12.8
Bl	U	15.8	14.6	U[1]	3.0	3.4	U[2]	30.9	21.4	A	88.0	79.4	A[3]	75.4	18.1
Sb	A[4]	22.4	3.1	U[5]	4.9	3.5	U[6]	43.8	20.2	U[7]	0.8	0.3	A[8]	14.0	49.1
Fd	P	0.0	0.0	P	40.9	20.7	P	4.0	4.3	U	0.0	0.0	U	0.0	0.0
Total		100	100		100	100		100	100		100	100		100	100

Table 3. Percent distribution of understory tree species composition by biogeoclimatic unit in north central BC. Pl= lodgepole pine; Sx=interior spruce; Bl=subalpine fir; Sb=black spruce; Fd=Douglas-fir. P= Preferred species; A= Acceptable; U= Unacceptable. After harvest, in a free growing stand, 600 of 700 well spaced trees / ha must be of the preferred species and 100 well spaced trees / ha are allowed to be of acceptable species. These criteria require careful assessment for suitability in unsalvaged MPB damaged stands.

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[1] Acceptable only on SBSdw2/08 & 10 sites
[1] Acceptable only on SBSdw3/06 - 09 sites
[1] Acceptable on SBSmc3/01, 07 & 08 sites
[1] Acceptable on SBSdk 03 and preferred on SBSdk 09 & 10 sites
[1] Acceptable only on SBSdw2/07 & 11 sites
[1] Acceptable only on SBSdw3/06 and preferred on SBSdw3/10 sites
[1] Acceptable only on SBSmc2/03 and preferred on SBSmc2/07 & 12 sites
[1] Acceptable only on SBSmc3/04-06 and preferred on SBSmc3/09 sites

Table 4. Percent of Sub-Canopy and Canopy Basal Area

Subzone	SBSdk	SBSdw2	SBSdw3	SBSmc2	SBSmc3
Species	(%)	(%)	(%)	(%)	(%)
Sx	82.5	50.3	46.5	46.8	86.6
Bl	1.6	0.2	7.2	52.1	2.4
Sb	0.0	44.0	14.1	0.0	0.0
Fd	4.7	4.4	28.7	0.6	4.9
At	11.2	1.0	3.5	0.5	6.1
Ep	0.0	0.1	0.0	0.0	0.0
Total	100	100	100	100	100

Table 4. Percent distribution of sub-canopy and canopy basal area by tree species and by biogeoclimatic unit in north central BC. Sx=interior spruce; Bl=subalpine fir; Sb=black spruce; Fd=Douglas-fir; At=trembling aspen; Ep=paper birch.

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[1] Acceptable only on SBSdw2/08 & 10 sites
[2] Acceptable only on SBSdw3/06 - 09 sites
[3] Acceptable on SBSmc3/01, 07 & 08 sites
[4] Acceptable on SBSdk 03 and preferred on SBSdk 09 & 10 sites
[5] Acceptable only on SBSdw2/07 & 11 sites
[6] Acceptable only on SBSdw3/06 and preferred on SBSdw3/10 sites
[7] Acceptable only on SBSmc2/03 and preferred on SBSmc2/07 & 12 sites
[8] Acceptable only on SBSmc3/04-06 and preferred on SBSmc3/09 sites