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A Comparison Between Managed-stand Yields of Lodgepole Pine in British Columbia and Sweden

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EXECUTIVE SUMMARY

Sweden has operationally planted and experimented with lodgepole pine for over 70 years. It has often been said that intensive forest practices in Sweden have resulted in levels of productivity which are far superior to that shown by second-growth stands of lodgepole pine in British Columbia. Translations of publications from Sweden allows a preliminary comparison of permanent sample plot data and computer model outputs between the two countries. Key findings include:

1) The range in site productivity, and particularly the upper limit is very similar between the two countries;
2) The amount of standing cubic volume at a particular stage of development is also very similar between BC and Sweden;
3) Yields produced for one similar silvicultural regime by two very different computer models (TASS in B. C. and the model of Elfving, 1990 for Sweden) are quite similar for standing volume, culmination of mean annual increment, and, especially, total production. TASS predicts about 2 cm greater average diameter even though mortality rates of the Swedish model was higher before and after thinning.

The comparisons suggest that second-growth stands of lodgepole pine are probably already achieving the yields that are reported in Sweden. The future second-growth forests of interior BC will compete very well with other countries in temperate regions once repressed wild stands are converted to well-managed conditions.

Reference:

Goudie, J. W. 1996. A comparison between managed-stand yields of lodgepole pine in British Columbia and Sweden. p. 51-63. January 24,25, 1996, Smithers, BC, Tollestrup, P. (ed.). Northern Interior Vegetation Management Association, Prince George, BC.

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INTRODUCTION

As evidenced by a series of editorials and letters to the editor earlier this year in Victoria, a perception exists in the general public and with foresters in government and industry that lodgepole pine (*Pinus contorta* ssp. *latifolia* [Engel.] Critch.) forests in BC are not attaining the productivity of those in Sweden, even though Sweden has more northerly latitudes. Figure 1 shows the relative position of the two counties as well as the distribution of lodgepole pine. The arctic circle (60^0 latitude) at BC's most northern border approximately bisects Sweden Seed collected from BC is generally planted at more northerly latitudes in Sweden. There have been no direct comparisons of the species' performance made between the countries. The translation of Swedish publications has made a first-approximation quantitative comparison of yields possible.

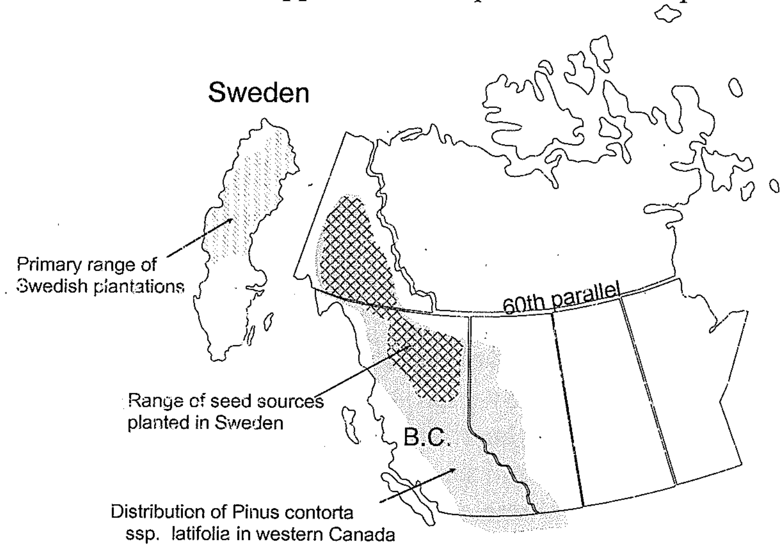

Figure 1. Distribution of Pinus contorta ssp. latifolia in Sweden and western Canada.

Over the last several years, staff of the Forest Productivity and Decision Support (FPDS) section of Research Branch have obtained permanent sample plot (PSP) and stem analysis data to facilitate the production of managed stand yield tables for all important timber species in British Columbia. Over 12,000 permanent sample plots have been collected and consistently summarized, comprising close to 40,000 plot measurements and literally millions of tree records from 17 different sources. Almost 1900 of these are lodgepole pine plots collected from sources in British Columbia, Alberta and Sweden.

An attempt was made to obtain additional data and managed stand information from European sources since in general, they have been intensively managing native and exotic species (particularly BC lodgepole pine) for a much longer period of time than in western Canada. Two reports from Swedish sources which listed yields from not only permanent sample plots but also model output arose from that effort (Elfving 1985 and Elfving 1990). The reports were translated and the published plot summaries and model output were keypunched and graphed to compare to sources in BC

SITE QUALITY

The first question asked of the data was "How does the range of site quality in Sweden compare to British Columbia?". The measure of site productivity most easily compared between such wide geographic distances is site index. Figure 2 shows the dominant height-breast height age trajectories of the sixty-two Swedish PSPs found in the publications. Note that the lower and upper range of site index are about 15 and 25 m at breast height age 50. The current Ministry of Forests site index curves (Goudie 1984, Thrower *et al.* 1991) are also shown in Figure 2 and conform to the plot trajectories up to index age 50. The growth of older plots may be underestimated. The question about the range of sites can not be fully answered by the small amount of data shown because we do not know if the Swedish PSPs reflect the true range of sites upon which lodgepole pine is planted in Sweden. The range of sites is better compared through the use of unbiased inventory information. However, it is not unreasonable to assume that, if the PSPs are preferentially located in well-growing stands, the upper limit of the data approximates the upper limit of site quality (25 m).

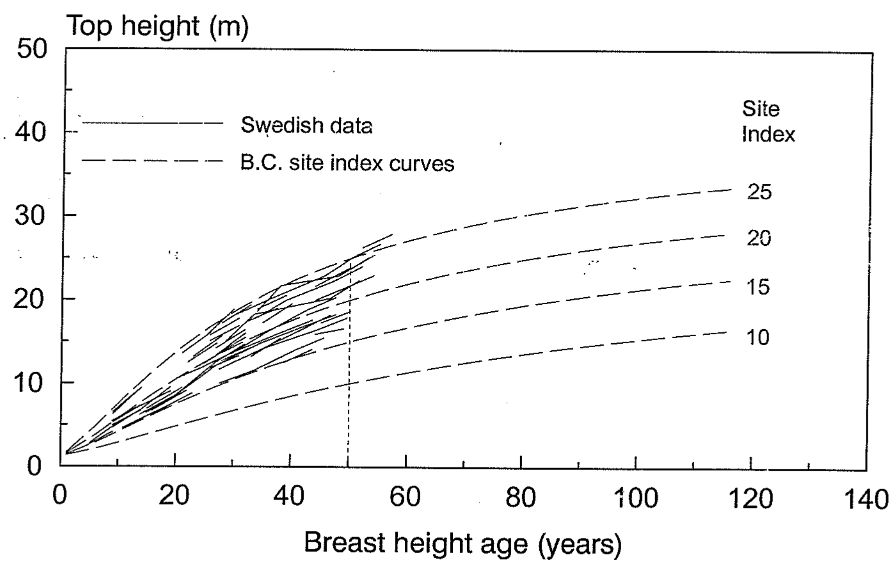

Figure 2. Swedish lodgepole pine PSP data compared to BC site index curves.

The range in site index of lodgepole pine PSPs in BC is about 13 to 28 m for 579 plots in the database. The lower limit is likely higher than the BC inventory would reflect because the inventory includes both very unproductive areas and an unknown quantity of repressed stands in which excessive density has reduced dominant height growth below the site potential. PSPs are usually subjectively located to avoid such areas. The upper limit of site index is again probably realistic assuming the logic on PSP placement holds in B. C.

A reasonable interpretation of this comparison is that the range (and especially the upper limits) are similar in the two countries. This is not surprising because the latitudinal ranges of the two countries overlap by about one-third and the growing season is probably similar because Sweden is influenced by a warm off-shore current.

The site curves are very similar between the two locations. Figure 3 shows two versions of BC curves (Goudie 1984 wet and dry sites) compared to curves developed by Elfving (1990) from the PSP data shown in Figure 2. The only areas of appreciable departure are well beyond the Swedish data base (above 25m site index and older than 70 years).

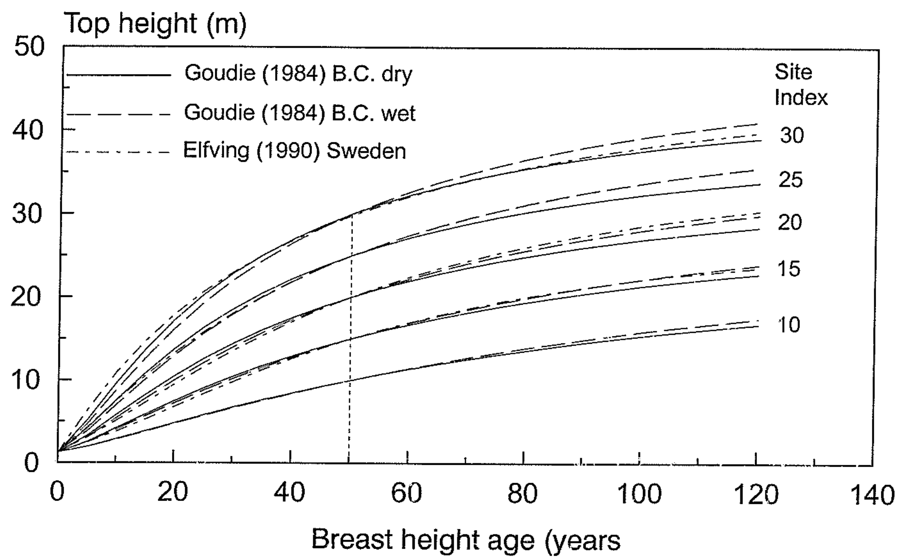

Figure 3. Swedish site index curves compared to BC site index curves.

VOLUME PRODUCTIVITY

The next question we asked of the data was "Do the plots in Sweden show a greater volume for a given density and stage of development (as indicated by dominant height)? This question again could not be directly answered because initial stand conditions and management histories are largely unknown and probably vastly different between the datasets. We can draw some tentative general inferences from an analyst's viewpoint.

Figure 4 shows the total volume of the Swedish plots related to dominant height. Using dominant height rather than age usually removes most of the variability due to differences in site quality between widely-diverse geographic areas. The Swedish plots are all plantations, probably established with about 3000 stems/ha. An unknown number have been thinned before the PSP were installed while others have been thinned since the measurement sequence began (note the eight plots that decline in volume). The oldest plots are about 65 years old and a few are approaching 28 m in dominant height. These are the oldest plantation data we have located for lodgepole pine.

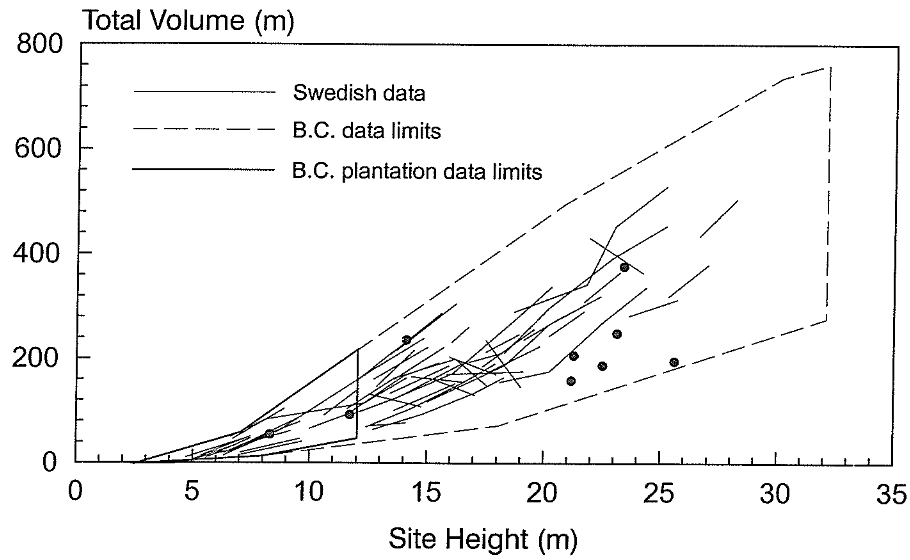

Figure 4. Swedish lodgepole pine PSP data compared to range of plots in BC

Figure 4 also shows the range of lodgepole pine PSP data in BC Note that all the plantation data in B. C. fall between 0 and 12 m of top height at the lower left of the graph while the rest of the data are from wild stands with little or no management activity. The BC data completely bracket the Swedish data and that they have a very similar overall shape. The wider range of the BC data reflects the greater variation in density in the wild stands compared to the plantations of Sweden. We can tentatively conclude that Swedish plots do not have excessive volumes relative to top height.

MODEL COMPARISONS

The Swedish researchers used the PSP data shown in Figures 2 and 4 to generate a relatively simple growth and yield model which included stand-level height growth and basal area growth equations (Elfving, 1990). The Tree and Stand Simulator (TASS, Mitchell 1975, Goudie 1980) is an individual tree model whose growth equations are based on stem analysis data collected for five species in several projects over the last two-to-three decades. The lodgepole pine version of TASS has been calibrated to PSP data from BC and Alberta. A coded version of the Swedish model has not yet been obtained so we simply entered the published yield tables generated by the model into a dataset and designed a TASS run to mimic the yield table as nearly as possible. Table 1 shows the data used in the following comparison.

While it is interesting to compare two lodgepole pine models whose basic construction and PSP database are vastly different, it should be remembered that this is a preliminary comparison of only one regime. Any conclusion made should be viewed as tentative if not speculative. A more comprehensive comparison of model performance may occur if a coded version of the Swedish model was obtained and evaluated for a number of regimes.

Number of Live Stems. Figure 5 shows the development of number of live stems vs. site height. Initial planting density in TASS was iteratively varied until the stem count matched the Swedish starting conditions within 15 trees per ha. An automated thinning rule in the Swedish model reduced the stems to 855 per ha at 16.4 m of site height. A tree selection algorithm in TASS that considers the spacing and vigour of each tree compared with its immediate neighbours was used to reduce the stand density to the same post-treatment density as the Swedish model.

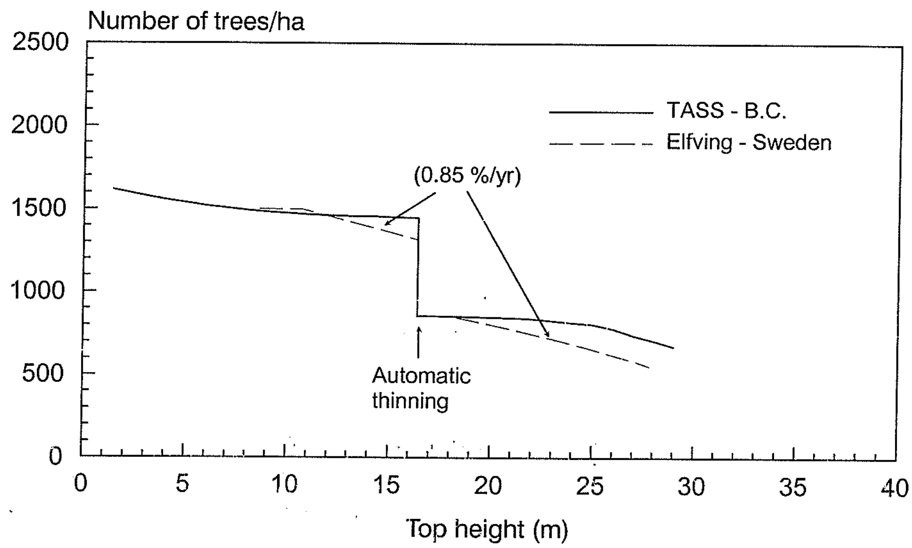

Figure 5. Comparison of Swedish model to TASS projections for managed lodgepole pine on site index 20 m (number of live stems vs top height).

The natural mortality trends are considerably different in the comparisons shown in Figure 5. The relatively simple Swedish routine removes a constant 0.85 percent of the trees per year, regardless of the stand density. The TASS algorithm is more dynamic in that suppressed trees are removed when a measure of their "vigour" status is reduced to a limiting value. TASS shows considerably lower mortality rates (higher carrying capacity) before and after thinning.

Quadratic Mean Diameter. Figure 6 shows that TASS generates average diameters which are about 2 cm larger than the Swedish model despite the lower mortality rates. The thinning routine utilized in TASS removed a higher proportion of small stems than the Swedish model as witnessed by the lower d/D ratio (0.904 vs 0.923). Nonetheless, the trends of the two models before and after thinning are very nearly parallel.

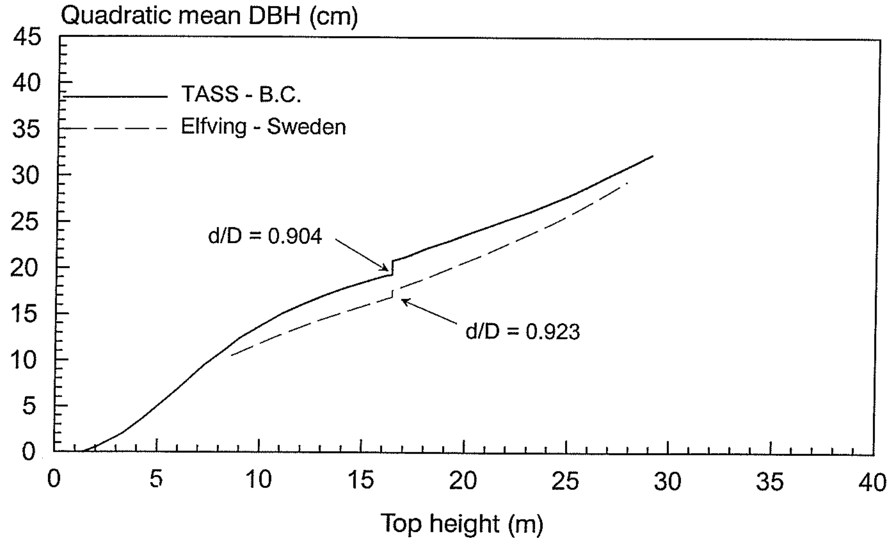

Figure 6. Comparison of Swedish model to TASS projections for managed lodgepole pine on site index 20 m (quadratic mean DBH vs top height).

Total Volume: The trends in total volume are shown in Figure 7. The Swedish yields were adjusted from outside to inside bark using a ratio generated by equations produced by Eriksson (1988). The greater total volume before and after treatment predicted by TASS reflects the differences in carrying capacity shown in Figure 5 and diameter growth rates in Figure 6. Another explanation of the differences in standing volume at the later stages of development may be the paucity of Swedish PSP data beyond 22 m of height. The Swedish model is a stand-level regression-based model which often do not extrapolate well beyond the range of data available. More dynamic individual tree models such as TASS tend to be more realistic beyond known datasets.

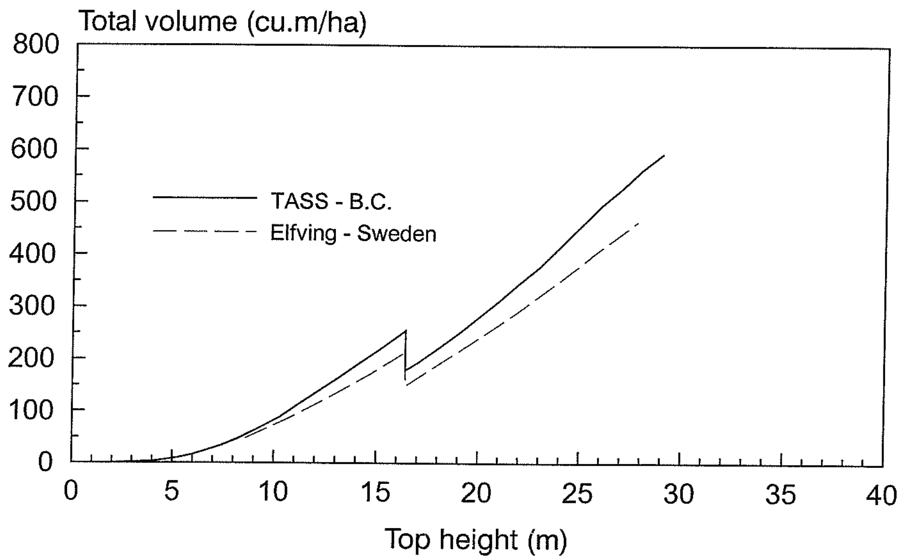

Figure 7. Comparison of Swedish model to TASS projections for managed lodgepole pine on site index 20 m (total stem volume inside bark vs top height).

Mean Annual Increment. Figures 8 and 9 show that the two models predict similar total volume maximum mean annual increments for site index 20 m. If thinning volumes are excluded (Figure 8) culmination of MAI is within 2% (4.68 vs 4.78 m^3/ha/yr for Swedish model and TASS, respectively) and it occurs within five years (83 vs. 88). If thinning volumes are included, the maximum values are 5.47 m^3/ha/yr at 76 years for the Swedish model and 5.79 m^3/ha/yr at 70 years for TASS. The close correspondence in culmination of mean annual increment between two very different models calibrated to data from widely varying geographic regions is quite important, but perhaps not surprising. It reflects the similarity of the data to which each model is calibrated and suggests that the basic biology of this species is similar if grown in temperate forest regions of similar conditions under similar silvicultural regimes.

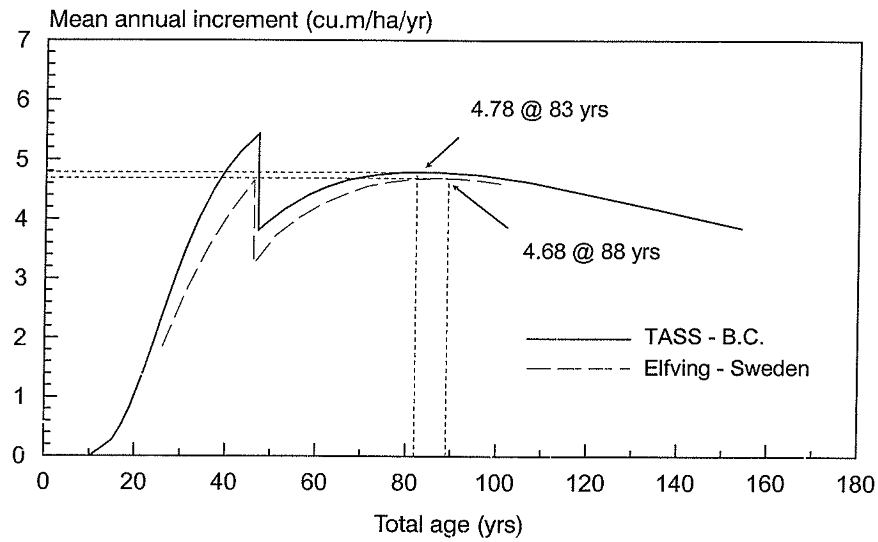

Figure 8. Comparison of Swedish model to TASS projections for managed lodgepole pine on site index 20 m (mean annual increment vs age). Volume expressed is total stem volume inside bark excluding thinnings.

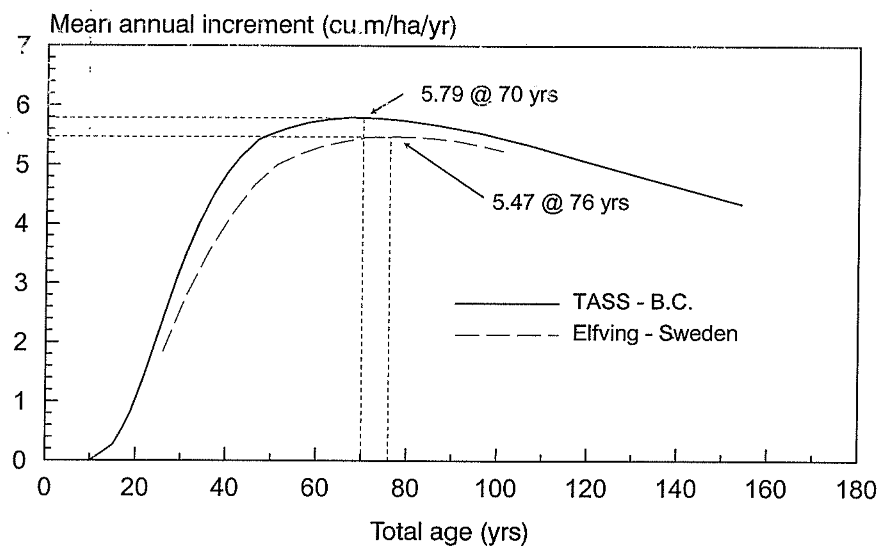

Figure 9. Comparison of Swedish model to TASS projections for managed lodgepole pine on site index 20 m (mean annual increment vs age). Volume expressed is total stem volume inside bark including thinnings.

Total Production. This contention is further supported by Figure 10 which shows the trajectories of total production, defined as the cumulative amounts of total volume inside bark for trees which are standing live, removed in thinning or lost to mortality. This measure compensates somewhat for the variability caused by differences in thinning algorithms and mortality models. Note that the two models are virtually identical for most of the simulation, indicating that for a given site quality and silvicultural regime, the basic production rates are similar between Sweden and B. C.

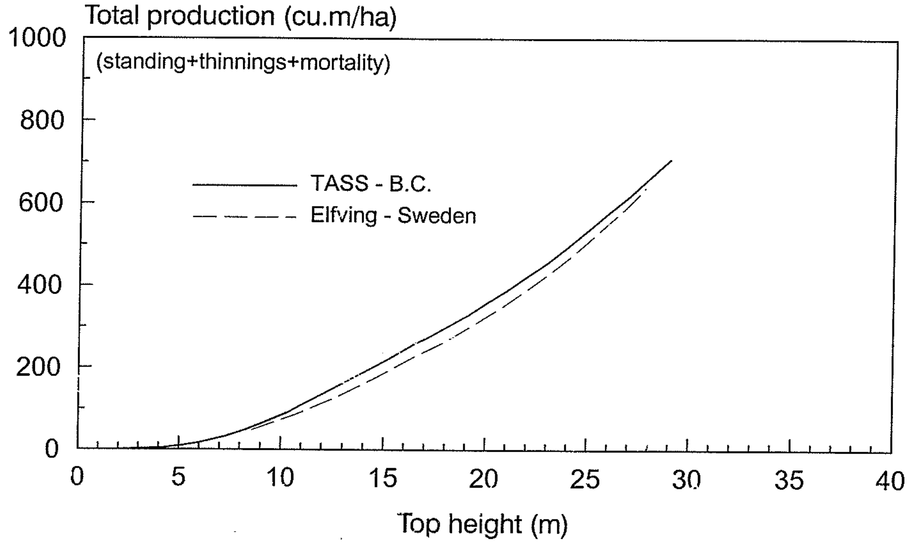

Figure 10. Comparison of Swedish model to TASS projections for managed lodgepole pine on site index 20 m (total stand production vs. top height). Volume expressed is total stem volume including all thinnings, mortality and standing live trees.

SUMMARY

Collecting and summarizing the large amounts of PSP data now on file has required a large investment of time and effort. However, it is beginning to produce information which is potentially a very valuable asset in the decision making process. In this case, our best information suggests that our second-growth stands probably already are achieving the yields that are being reported in Sweden. The lodgepole pine forests of BC will be very competitive once repressed fire-origin stands get converted to vigorous second-growth forests that are managed in a sound ecological, silvicultural and financial manner.

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Table 1. Yields generated by a) Swedish model and b) TASS simulation

a)

Total Age (yrs)	Top Height (m)	Number of stems per ha	Total stem volume/ha (inside bark)		Mean annual increment (m^3/ha/yr)		Quadratic mean DBH (cm)
			Gross	Live	Excl. thinnings	Incl. thinnings	
---Swedish model---							
26	8.6	1500	48	48	1.85	1.85	10.5
31	10.7	1500	86	86	2.77	2.77	12.5
36	12.7	1436	129	127	3.53	3.53	14.2
41	14.6	1375	177	170	4.15	4.15	15.6
46	16.4	1316	226	214	4.65	4.65	16.9
46	16.4	855	226	149	3.24	4.65	17.6
51	18.0	855	266	190	3.72	5.00	18.9
56	19.4	819	307	225	4.02	5.18	20.2
61	20.7	784	347	259	4.24	5.31	21.4
66	21.9	751	388	291	4.41	5.40	22.6
71	23.0	719	428	323	4.55	5.46	23.7
76	24.0	688	466	351	4.62	5.47	24.7
81	24.9	659	504	378	4.67	5.47	25.7
86	25.7	631	540	403	4.69	5.44	26.7
91	26.5	604	575	426	4.68	5.40	27.7
96	27.2	578	608	446	4.64	5.32	28.6
101	27.8	554	640	464	4.59	5.24	29.4

□

Table 1. Yields generated by Swedish model and TASS simulation (cont.)

b)

Total Age (yrs)	Top Height (m)	Number of stems per ha	Total stem volume/ha (inside bark)		Mean annual increment (m^3/ha/yr)		Quadratic mean DBH (cm)
			Gross	Live	Excl. thinnings	Incl. thinnings	
TASS							
8	1.4	1617	0	0	0.00	0.00	0.0
10	2.0	1601	0	0	0.00	0.00	0.5
13	3.3	1571	2	2	0.15	0.15	2.0
15	4.2	1552	4	4	0.27	0.27	3.5
17	5.1	1535	9	9	0.53	0.53	5.2
19	6.0	1519	16	16	0.84	0.84	6.9
22	7.3	1501	32	32	1.45	1.45	9.5
24	8.2	1490	47	46	1.92	1.92	11.0
26	9.0	1481	63	62	2.38	2.38	12.4
29	10.3	1471	90	89	3.07	3.07	14.1
31	11.0	1467	110	108	3.48	3.48	15.0
34	12.1	1461	139	137	4.03	4.03	16.1
37	13.2	1457	168	166	4.49	4.49	17.1
40	14.2	1456	195	194	4.85	4.85	17.9
43	15.2	1451	222	221	5.14	5.14	18.6
46	16.1	1449	248	246	5.35	5.35	19.2
47	16.4	1447	257	255	5.42	5.42	19.2
47	16.4	854	257	179	3.81	5.43	20.8
49	17.0	854	271	193	3.94	5.49	21.2
53	18.0	852	299	221	4.17	5.60	22.1
58	19.2	850	332	255	4.40	5.71	23.0
62	20.0	846	358	281	4.53	5.76	23.7
67	21.0	845	389	312	4.66	5.80	24.5
73	22.0	839	424	346	4.74	5.78	25.3
79	23.0	828	457	378	4.78	5.75	26.1
87	24.0	815	496	416	4.78	5.66	27.0
96	25.0	805	536	455	4.74	5.53	27.9
107	26.0	778	579	494	4.62	5.33	29.0
119	27.0	738	619	527	4.43	5.07	30.1
135	28.0	708	664	563	4.17	4.73	31.2
154	29.0	673	708	593	3.85	4.34	32.3