UNDERSTANDING THE UNDERSTORY: DILEMMA AND OPPORTUNITY

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INTRODUCTION

This paper focuses on the management of understory white spruce (*Picea glauca* (Moench) Voss.) in the Manitoba Lowlands Section (B.15), Boreal Mixedwood Section (B.18a), and Lower Foothills Section (B.19a) of Rowe (1972) (Fig. 1). These sections constitute over 130 000 km^2 of productive forest land, about one-third of the regional total. These lands are well-located with respect to transportation systems, communities, and power, so they can be readily exploited, managed, and protected. They are also among the most productive forest sites in the region, with gross mean annual increments of unmanaged stands commonly in the range of 2-6 m^3/ha (Corns and Annas 1986; Kabzems et al. 1986).

With recent increased utilization of aspen (*Populus tremuoloides* (Michx.) in the region, these sites are becoming increasingly important as a source of commercial hardwoods in addition to their traditional role as a source of softwoods, especially white spruce. This situation poses new management challenges and presents new opportunities, particularly where both species occur together with white spruce as a high-value understory.

The long-term supply of commercial white spruce from mixedwoods can only be maintained or increased by successful establishment, growth, and protection of regeneration. In the intervening 60-80 years, white spruce supplies must come from existing stands, and any increases in supply must come from judicious management intervention in these stands.

This paper addresses costs, risks, and success in establishing and growing new white spruce plantations on mixedwood sites in the region to date and assesses the potential of understory stands as an interim source of white spruce growth and yield.

INVENTORY

Current Status and Future Needs

Current regional inventories of spruce-aspen mixedwoods are based on low intensity sampling and are unsuited as a source of detailed information on age, species mixture (especially aspen-poplar proportions) and the amount, size and distribution of white spruce understory.

Figure 2 shows the volume of wood currently inventoried in hardwood (H), mixedwood (HS, SH), and softwood (S) classes[1] in the region and clearly shows the relative importance of mixedwoods, particularly in Alberta.

The extent of the mixedwood resource tends to be underestimated because understories, particularly in H and HS stands, are not inventoried. Recent surveys in the region have found spruce understories in significant amounts in up to 80% of stands inventoried as H and HS, depending on fire and logging history and site and climate conditions. The amount of understory therefore merits serious consideration in white spruce management planning.

Until recently, white spruce understory was viewed somewhat like money in the bank on a long-term, low interest deposit with final yield to be realized after slow natural succession. In the future we may be increasingly faced with the situation of H and HS stands being scheduled for hardwood harvest, thereby jeopardizing understory spruce.

FUTURE WOOD SUPPLY

Role of Plantations

In the past, white spruce plantations on mixedwood sites have been established by both planting and seeding, usually following mechanical scarification of cutovers with substantial aspen residuals or by conversion of young aspen stands, mainly of fire origin, by mechanical clearing and planting. Costs of such work now ranges from \$300 to \$1000 per hectare for initial plantation establishment.

Recent literature reviews and surveys (Johnson and Gorman 1977; Johnson 1986; Drew 1987) and consultations with regional field staff indicate that while most

[1] H = 75%+ hardwood, HS = 51-75% hardwood, SH = 51-75% softwood, and S = 75%+ softwood.

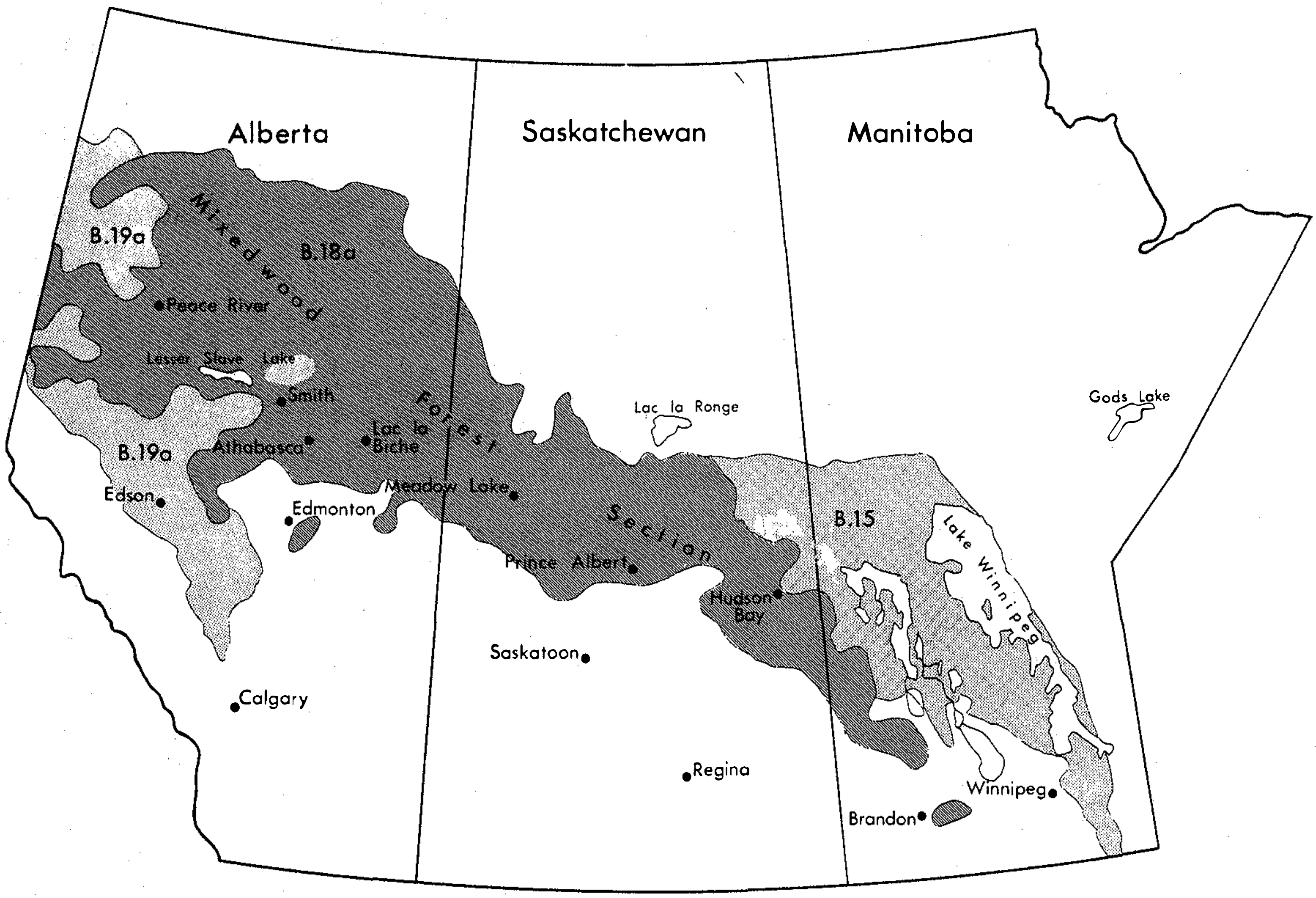

Figure 1. The boreal forest in the prairie provinces: sections B.15 (Manitoba Lowlands), B.18a (Mixedwood), and B.19a (Lower Foothills) of the Boreal Forest Region (Rowe 1972).

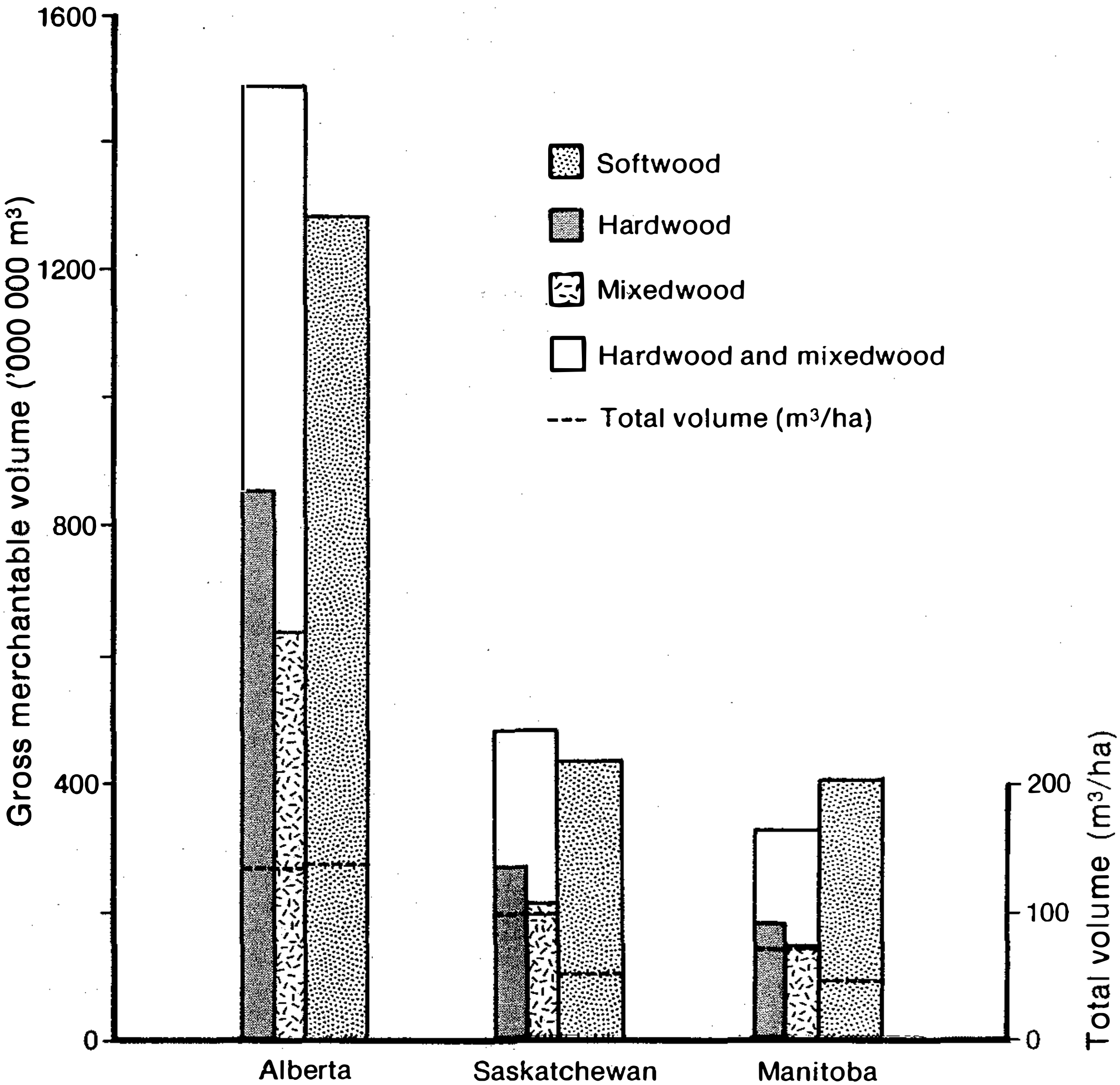

Figure 2. Gross merchantable timber volumes by major cover classes in Alberta, Saskatchewan, and Manitoba.

spruce plantations on mixedwood sites initially meet minimum stocking standards, they are tending to regress due to competition from brush and grass and damage by hares. The result is that up to two-thirds are reverting to mixedwood or hardwood status, with a subsequent loss in softwood growth potential. There is a critical need for effective tending of newly established plantations and no tools are available for achieving this economically. For example, recent reports on herbicide availability and outlook for Canada (Castrilli and Vigod 1987; Reynolds 1988) and for the world (Patosaari 1987) suggest that availability of such tools is unlikely to increase in the short term and that other means of competition control must be sought.

Success of spruce regeneration and tending on mixedwood sites may improve as utilization standards for all species increase and as markets develop for aspen and poplar. This will reduce the problems of heavy residual slash loads and standing residuals that are currently impediments to silviculture, but competition control measures will still be critical.

Given the costly, risky, and mainly unsuccessful history of white spruce regeneration on mixedwood sites to date, it seems that the future supply of commercial white spruce is dependent on existing sources, which are primarily understory stands occurring naturally in association with aspen and poplar.

Role of Understory Stands

A Tending and Harvesting Scenario

In an attempt to improve our understanding of understory management we developed a tending and harvesting scenario that assumes that both aspen and spruce will be grown on the same land base. Beginning with separate stand types rated HS and SH, we could harvest aspen under the following conditions: aspen overstories aged 60, 70, and 80 years; understory white spruce ranging from 40 to 50 years; and from 1200 to 2000 stems per hectare at 2.5 cm or greater diameter at breast height (dbh). As well, all spruce over 25 cm dbh could be harvested, leaving a range of viable understory white spruce from 200 to 1000 stems per hectare and between 2.5 and 25 cm dbh. Sixty years later each stand could be harvested for all species and options for future management considered. Figure 3 illustrates the procedure.

This scenario does not necessarily imply a sustained yield policy for white spruce on the land base concerned. Its main function is to avoid waste by realizing the growth and yield potential of existing understory spruce in a given stocking range, while utilizing aspen. The subsequent issue of land base assignment, whether hardwood or softwood or possibly hardwood and softwood, in the next rotation is not addressed here. Of course, options other than aspen harvest may exist in cases where there is no aspen demand or where aspen is old or decadent or where white spruce has priority over aspen.

The feasibility of this scenario was assessed on the basis of field interviews with management foresters and by compiling sample plot data for aspen stands with spruce understories (MacLeod and Blythe 1953). Data from 38 plots were analyzed in groupings representing HS stands (51–75% aspen) and SH stands (51–75% white spruce) by hardwood age classes 60, 70, and 80 years, and the average number of understory white spruce stems was plotted for each of the six classes. A number of assumptions were then applied to determine a probable range of remaining viable residuals after the aspen were harvested. Assumptions included the following:

- all spruce over 25 cm dbh harvested to reduce windthrow;
- harvest everything over 25 cm dbh with 25% mortality caused by harvesting (Froning 1980);
- harvesting mortality of 25% as only loss;
- all spruce taller than 8 m blown down after harvest;
- all spruce over 8 m blown down and and 25% mortality caused by harvest;
- in all cases trees less than 3 m in height (2.5 cm dbh) are overgrown by aspen suckers following harvest (Johnson 1986).

The application of these assumptions to previously plotted diameter distributions of understory white spruce by age and stand type indicated that in each case, a range of viable residuals after harvest, from 200 to 1000 stems per hectare, was possible. If greater losses occurred (for example, from excessive logging damage or blowdown), this scenario would not apply. Diameter distribution curves were derived representing 200, 400, 600, 800, and 1000 viable residual white spruce and based on the shape of the average diameter distribution curve for each of the six stand type and age classes. Figure 4 illustrates the diameter distribution for HS stands with aspen aged 60 years.

This diameter distribution was the basis for subsequent growth and yield modeling.

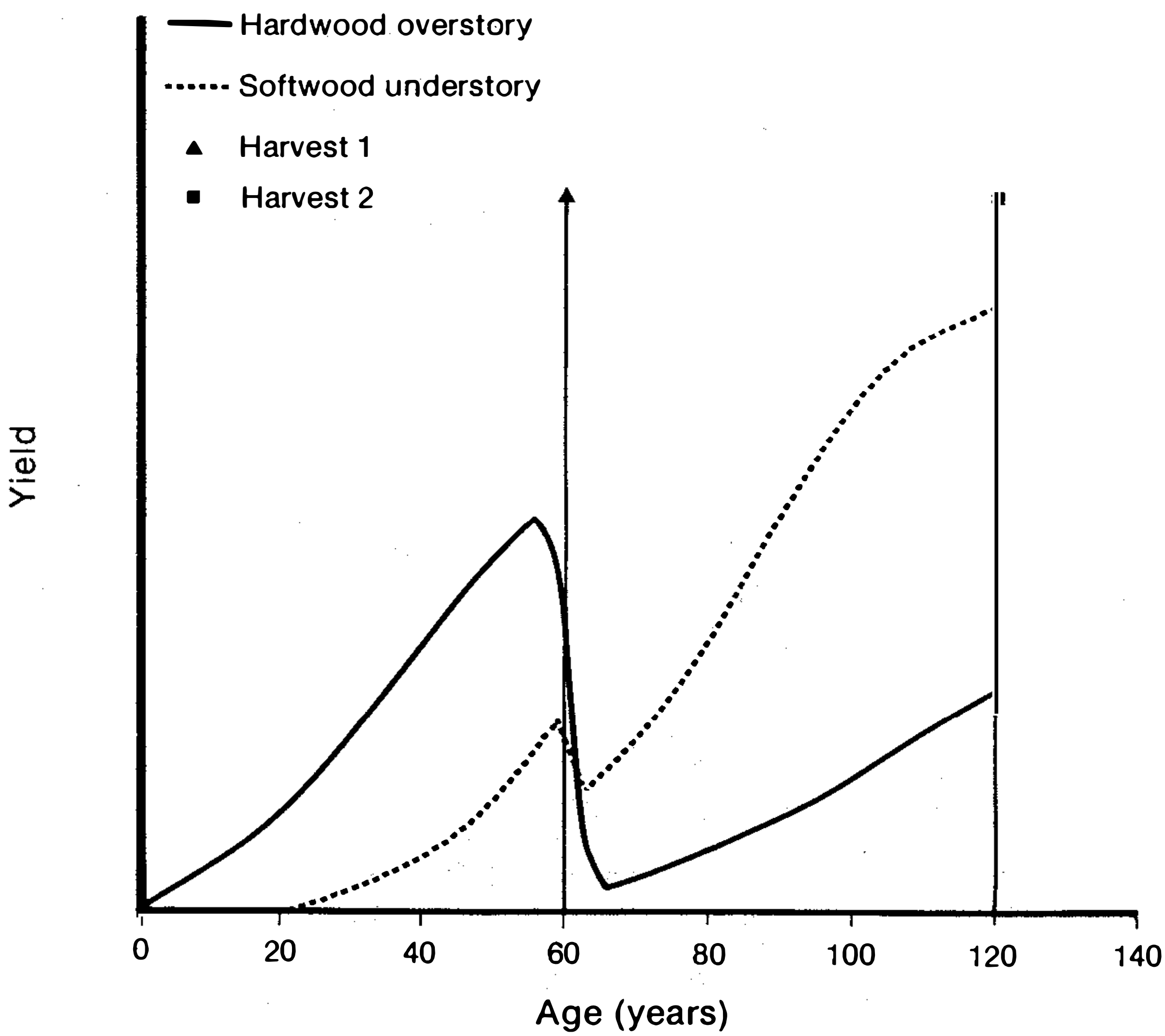

Figure 3. Generalized two-stage tending and harvesting scenario.

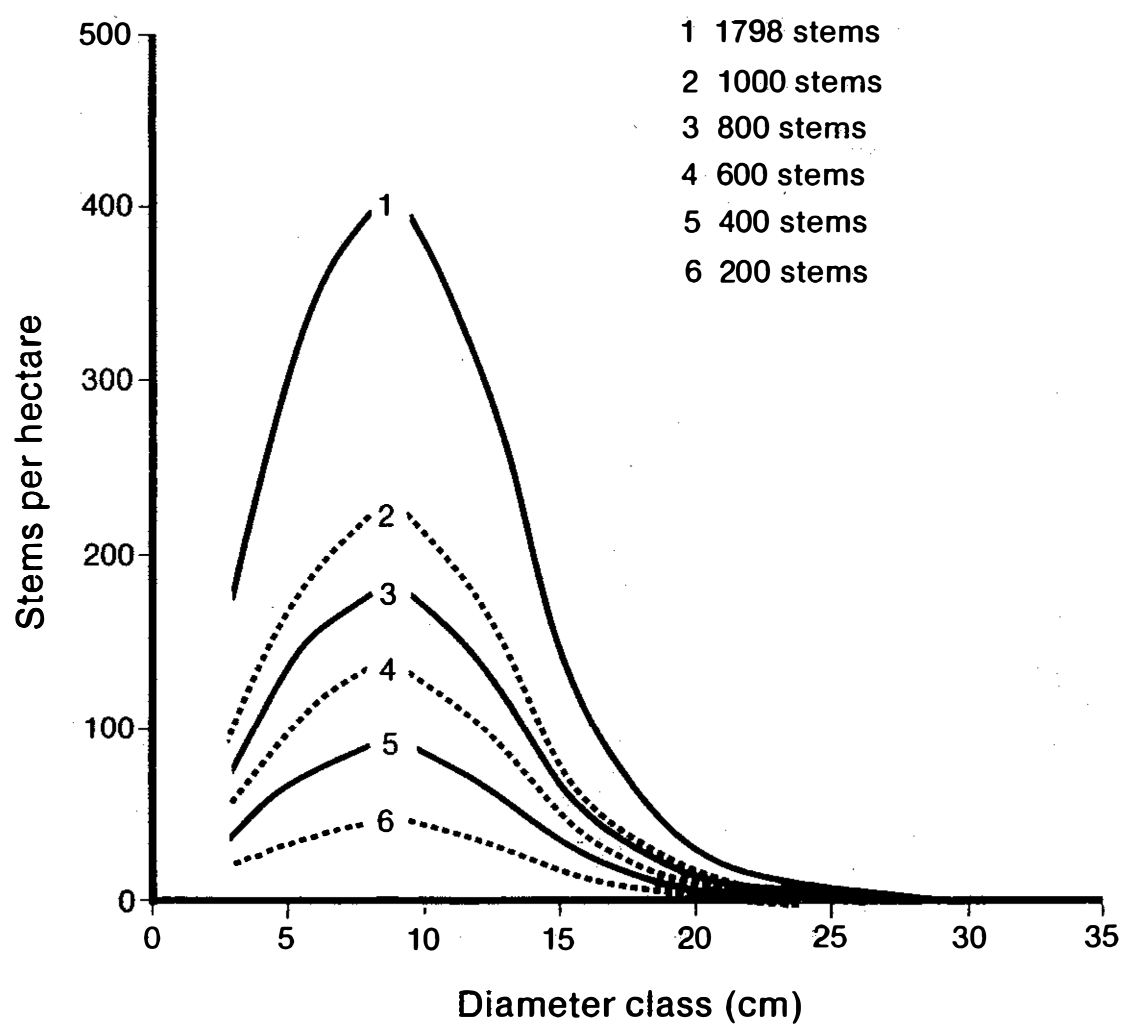

Figure 4. Diameter distribution curves for viable white spruce understory in HS stands (51–75% hardwood) with overstory aged 60 years.

Growth and Yield Projections

We used several in-house data sources as well as published information to derive yield estimates for residual spruce stands after the aspen component had been harvested.

We described initial conditions by dbh distributions (stand tables) and heights for each diameter class. The residuals we considered were between the 2.5-cm (1-in.) and the 23-cm (9-in.) dbh classes. We ignored trees smaller than the 2.5-cm class as they could be overtaken by aspen suckers; trees in the 25-cm (10-in.) dbh class and over were harvested. Figure 4 shows one such stand table with smoothed values.

We made the following assumptions in our growth and yield estimations:

- poplar as well as aspen were utilized;
- at the time of aspen harvest the average age of the spruce was 40 years;
- it took 5 years after the aspen harvest for the spruce to recover, for which period no increment was considered; after this period, fully released growth was applied;
- as there were unstocked areas after harvest, especially at lower spruce densities, aspen suckers filled in these openings to the extent shade tolerance would permit;
- the aspen understory following harvest had no significant impact on the growth of spruce understory;
- with crown closure of the dominant spruce, the aspen was crowded out;
- aspen yield, if any, was simply a complement of spruce yield that may be expected in mixed stands on similar sites in this region (Johnstone 1977).

We estimated the growth and yield of spruce with STEMS (Stand and Tree Evaluation and Modeling System), an individual tree distance independent growth model developed in the Lake States for species including white spruce (Belcher et al. 1982). We calibrated the model's performance to the point of crown closure using growth information of individually released spruce trees from a Canadian Forestry Service study established about 35 years ago in the Slave Lake Forest (Yang 1988).

We also ensured that our yield estimates thus obtained were reasonable in comparison with yields of white spruce plantations growing on sites of similar productivity (Berry 1987) and with yields of natural, fully stocked spruce-aspen stands in this region (Johnstone 1977).

Our yield forecasts with the STEMS model for medium-good productivity sites (Site Index = 24 m at reference age 70 years) for two mortality scenarios were for either no spruce mortality during the 40- to 100-year period or for increasing mortality rate with increasing stand density (Figs. 5 and 6; Table 1). Main results were as follows:

- maximum merchantable yield for spruce of about 550–590 m^3/ha at 100 years for the 600, 800, and 1000 trees/ha densities;
- predicted yield at 100 years about 10% lower for stands with 400 trees/ha and about 30% lower for stands with 200 trees/ha;
- for the two most dense stands (1000 and 800 trees/ha), final harvest 20 years earlier (at age 80) might give somewhat higher returns in terms of mean annual increment (MAI) but not necessarily in value increment;
- spruce mortality during the 60-year release period resulted in somewhat greater mean dbh for all stands. At higher densities where mortality was also greater, predicted yield was 5–10% lower than in stands without mortality. At the two lower densities—400 and 200 trees/ha—there was lower mortality and yield effects were negligible.

From these forecasts we may conclude that as few as 600 spruce trees/ha may ensure just about maximum merchantable volume yields at a 100-year rotation, and stands with 400 trees/ha can yield within 10% of the maximum yield. At densities below 400 trees/ha, loss in yield will accelerate. Some loss, as shown for 400 trees/ha may be acceptable, because saving fewer trees means reduced harvesting costs; whereas trying to save more than 300–400 trees/ha is likely to increase harvesting costs in an exponential fashion.

These forecasts showed negligible mortality impact on yield at higher densities. Trees in such stands fully occupy the area soon after harvest, and mortality among smaller trees would only ensure continued rapid growth of the remaining trees.

In addition to volume yield, other considerations such as knot size, proportion of juvenile wood, and specific gravity of the wood produced may also be important in developing treatment prescriptions for this

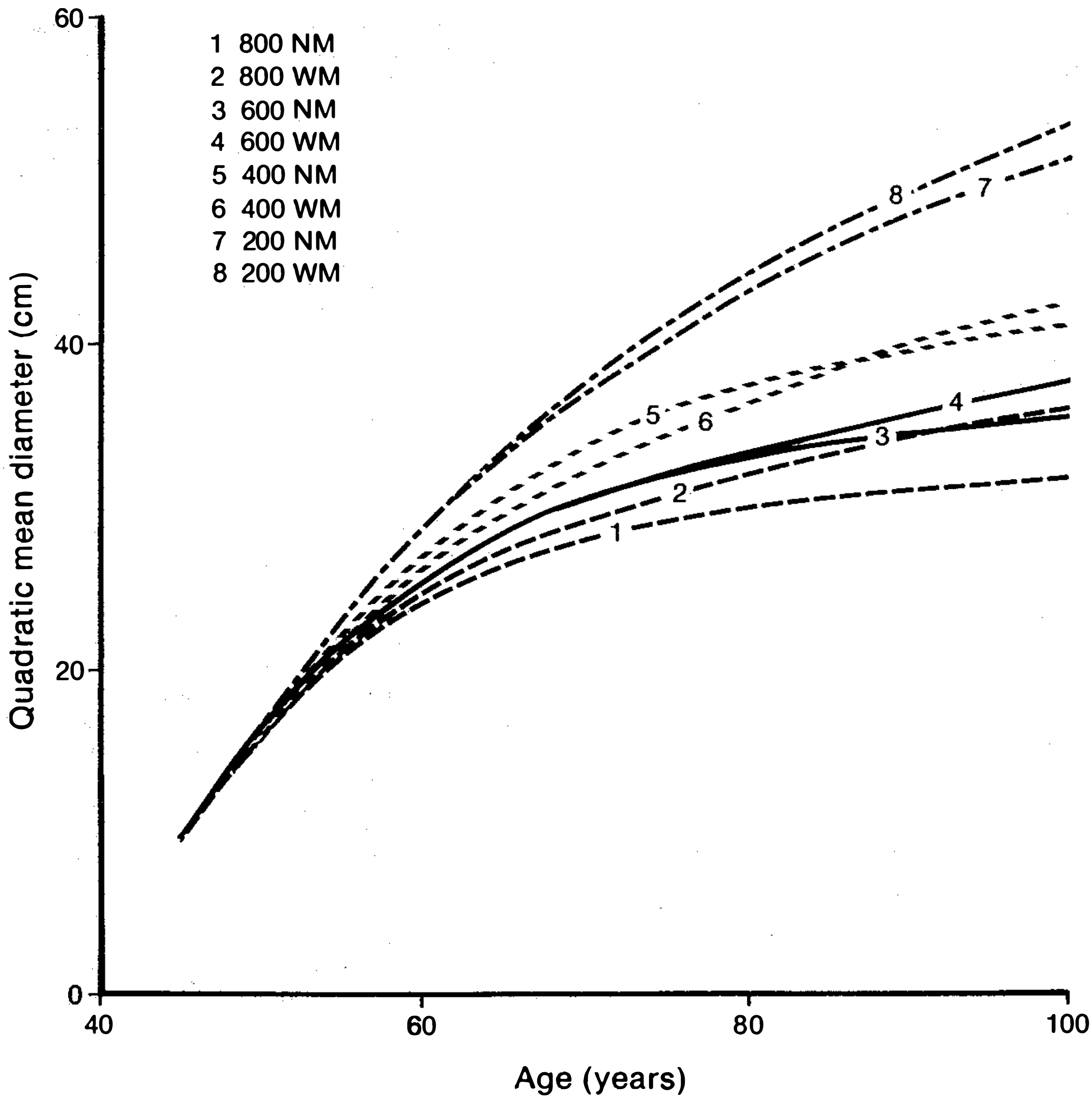

Figure 5. Quadratic mean diameter at breast height by age and density, with (WM) and without (NM) mortality.

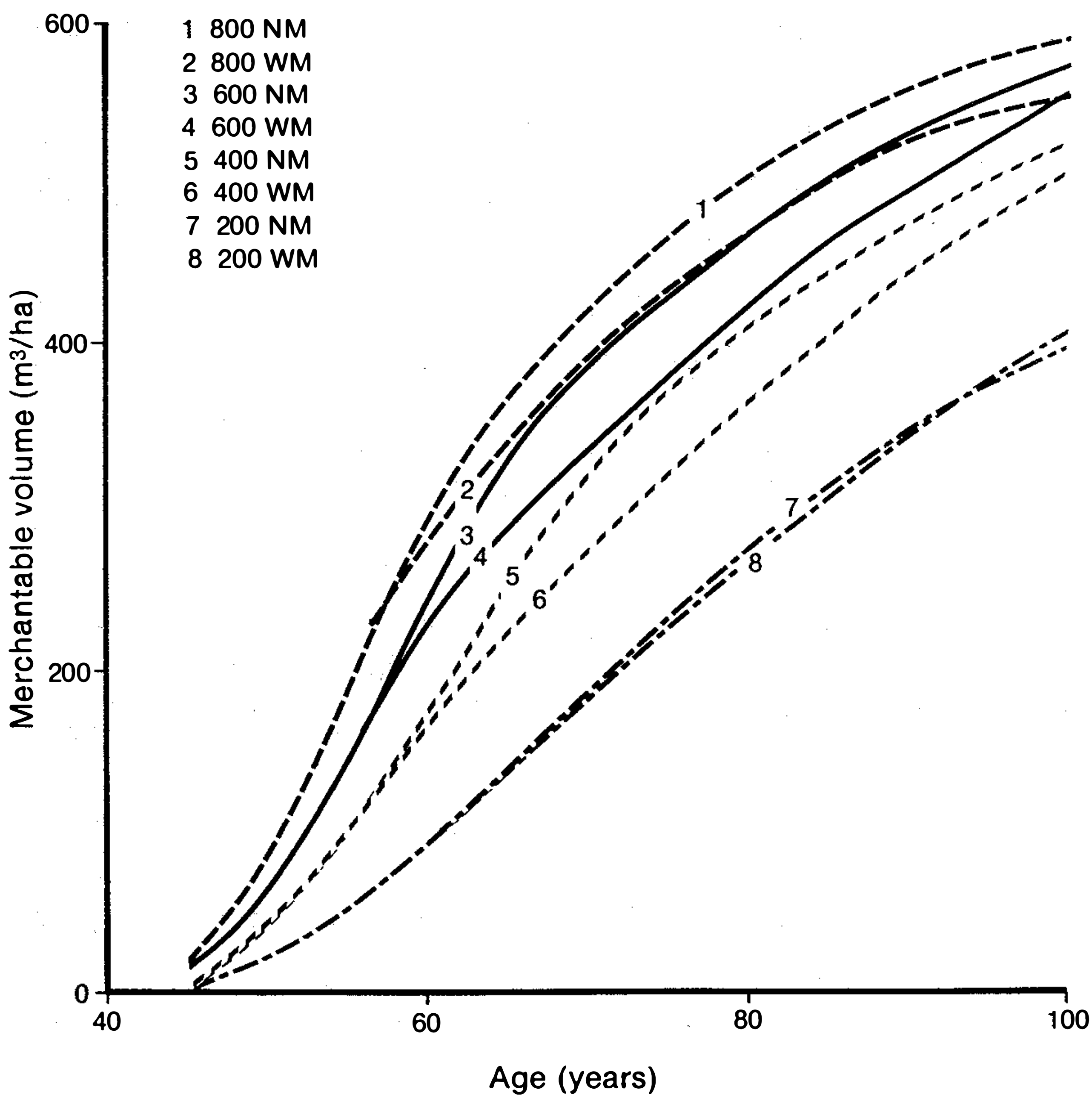

Figure 6. Merchantable volume by age and density, with (WM) and without (NM) mortality.

Table 1. Yield of white spruce (Site Index 24 m at 70 years) at five residual stand densities, with (WM) or without (NM) mortality during prediction period. Release was by harvesting poplar at spruce age 40 years

Age	Number of trees NM[a]	Number of trees WM[b]	Basal area (m²/ha) NM	Basal area (m²/ha) WM	Dbh[c] (cm) NM	Dbh[c] (cm) WM	Height[d] (m) NM	Height[d] (m) WM	Total volume (m³/ha) NM	Total volume (m³/ha) WM	Merchantable volume (m³/ha)[e] NM	Merchantable volume (m³/ha)[e] WM	Mean annual increment (m³/ha) NM	Mean annual increment (m³/ha) WM
45	1000	1000	7.7	7.7	9.9	9.9	7.5	7.5	33	33	24	24	0.5	0.5
50	1000	951	19.1	18.9	15.6	15.9	12.7	12.9	125	123	102	101	2.0	2.0
55	1000	898	32.1	31.0	20.2	20.9	16.7	17.0	255	244	222	212	4.0	3.9
60	1000	859	42.5	41.6	23.3	24.8	19.0	19.7	370	362	325	326	5.4	5.4
65	1000	818	48.5	46.4	24.8	26.9	20.2	20.9	439	419	392	375	6.0	5.8
70	1000	779	53.2	50.4	26.0	28.7	21.0	21.9	494	467	445	422	6.4	6.0
75	1000	741	56.9	53.4	26.9	30.3	21.6	22.6	538	505	488	460	6.5	6.1
80	1000	721	59.8	56.0	27.6	31.4	22.0	23.2	573	538	521	492	6.5	6.2
85	1000	700	62.0	57.9	28.1	32.5	22.3	23.6	599	562	546	516	6.4	6.1
90	1000	676	63.4	59.1	28.4	33.4	22.6	23.9	617	578	563	533	6.3	5.9
95	1000	651	64.2	59.7	28.6	34.2	22.7	24.1	626	588	573	543	6.0	5.7
100	1000	625	64.3	59.9	28.6	34.9	22.7	24.3	627	593	574	548	5.7	5.5
45	800	800	6.2	6.2	9.9	9.9	7.3	7.3	26	26	19	19	0.4	0.4
50	800	774	15.7	15.6	15.8	16.0	12.5	12.6	101	100	83	82	1.7	1.6
55	800	746	27.0	26.4	20.7	21.2	16.5	16.8	212	206	185	180	3.4	3.3
60	800	728	38.0	36.5	24.6	25.3	19.4	19.5	333	317	296	281	4.9	4.7
65	800	709	44.2	41.6	26.5	27.3	20.6	20.8	403	375	366	338	5.6	5.2
70	800	691	49.1	46.1	27.9	29.2	21.5	21.7	460	428	421	389	6.0	5.6
75	800	673	53.0	50.0	29.0	30.8	22.2	22.5	507	474	466	434	6.2	5.8
80	800	654	56.2	53.2	29.9	32.2	22.7	23.2	545	513	503	472	6.3	5.9
85	800	635	58.8	55.7	30.6	33.4	23.1	23.7	577	545	533	504	6.3	5.9
90	800	615	60.9	57.5	31.1	34.5	23.3	24.1	602	568	557	527	6.2	5.9
95	800	593	62.5	58.7	31.5	35.5	23.6	24.4	621	584	576	543	6.1	5.7
100	800	570	63.6	59.3	31.8	36.4	23.7	24.6	634	593	588	552	5.9	5.5
45	600	600	4.6	4.6	9.9	9.9	7.0	7.0	19	19	13	13	0.3	0.3
50	600	590	12.1	12.1	16.0	16.2	12.2	12.3	76	75	62	62	1.2	1.2
55	600	579	21.4	21.2	21.3	21.6	16.3	16.4	165	163	142	140	2.6	2.5
60	600	566	30.9	30.2	25.6	26.1	19.2	19.3	266	259	240	234	4.0	3.9
65	600	551	39.1	34.9	28.8	28.4	21.1	20.6	360	313	330	285	5.1	4.4
70	600	546	44.0	39.3	30.6	30.3	22.0	21.6	416	363	385	334	5.5	4.8

75	600	542	48.0	43.4	31.9	31.9	22.8	22.4	464	410	431	379	5.7	5.1
80	600	537	51.4	47.0	33.0	33.4	23.3	23.1	504	454	469	421	5.9	5.3
85	600	533	54.2	50.6	33.9	34.8	23.7	23.7	538	495	502	462	5.9	5.4
90	600	528	56.6	53.6	34.7	36.0	24.1	24.2	567	532	530	497	5.9	5.5
95	600	523	58.7	56.2	35.3	37.0	24.3	24.6	591	564	553	528	5.8	5.6
100	600	518	60.3	58.4	35.8	37.9	24.6	24.9	611	590	573	553	5.7	5.5
45	400	400	3.1	3.1	9.9	9.9	6.6	6.6	12	12	9	9	0.2	0.2
50	400	398	8.4	8.4	16.3	16.4	11.7	11.7	50	50	41	41	0.8	0.8
55	400	396	15.3	15.2	22.1	22.1	15.8	15.9	114	113	99	99	1.8	1.8
60	400	393	22.6	22.5	26.9	27.0	18.8	18.8	190	189	173	172	2.9	2.9
65	400	390	29.8	27.4	30.8	29.9	20.9	20.3	269	242	249	223	3.8	3.4
70	400	387	36.5	32.0	34.1	32.5	22.4	21.5	345	294	322	273	4.6	3.9
75	400	383	41.3	36.3	36.2	34.7	23.3	22.5	400	343	376	321	5.0	4.3
80	400	380	44.6	40.3	37.7	36.7	23.8	23.3	439	390	413	365	5.2	4.6
85	400	377	47.4	43.9	38.9	38.5	24.3	23.9	473	432	446	407	5.2	4.8
90	400	374	49.9	47.2	39.9	40.1	24.7	24.5	503	472	474	444	5.3	4.9
95	400	371	52.1	50.2	40.8	41.5	25.0	24.9	529	507	500	478	5.3	5.0
100	400	368	54.1	52.8	41.5	42.8	25.2	25.3	553	538	522	509	5.2	5.1
45	200	200	1.5	1.5	9.9	9.9	6.1	6.1	6	6	4	4	0.1	0.1
50	200	199	4.4	4.4	16.7	16.7	10.9	10.9	24	24	19	19	0.4	0.4
55	200	198	8.4	8.4	23.1	23.2	14.9	14.9	59	58	52	52	0.9	0.9
60	200	197	12.9	12.8	28.7	28.8	17.8	17.8	103	102	94	94	1.6	1.6
65	200	196	17.5	17.4	33.4	33.6	19.9	19.9	150	149	140	139	2.2	2.1
70	200	195	22.0	21.7	37.4	37.7	21.4	21.4	199	196	187	184	2.7	2.6
75	200	194	26.3	25.9	40.9	41.2	22.5	22.5	246	241	231	227	3.1	3.0
80	200	192	30.3	29.7	43.9	44.4	23.4	23.4	291	284	274	268	3.4	3.3
85	200	191	34.0	33.3	46.6	47.1	24.1	24.1	333	325	315	307	3.7	3.6
90	200	190	37.5	36.6	48.9	49.5	24.7	24.6	373	362	353	343	3.9	3.8
95	200	188	39.8	39.6	50.4	51.7	25.0	25.1	400	397	379	376	4.0	4.0
100	200	187	41.7	42.3	51.6	53.7	25.3	25.5	422	429	400	407	4.0	4.1

[a] No mortality during the prediction period.
[b] Mortality proportion to stand density during the period.
[c] Quadratic mean dbh (diameter at breast height).
[d] Lorey's height.
[e] 9 cm diameter at breast height outside bark; 7.6 cm top diameter inside bark; 15.2 cm stump.

cover class. Some of these factors may suggest higher densities than would be optimum on the basis of MAI, so these factors would have to be simultaneously considered in crop planning for specific stands.

We also need to note that these forecasts assumed a fairly regular distribution of spruce trees on the area. Clumping of spruce would result in reduced yield for this species in proportion to the degree of clumping. Open patches, however, would be utilized by aspen and poplar and thus would contribute to total yield on the area.

Johnstone (1977) in his mixedwood tables presents total stem volume yield (i.e., spruce and aspen-poplar), of just under 450 m³/ha for stands growing on similar sites. In the 10 scenarios for which we forecasted yield with STEMS, only the low-density scenario (i.e., 200 trees/ha, with and without mortality) produced under 450 m³/ha of spruce at age 100 years. The shortfall was about 40 m³/ha. As we suggested earlier, this shortfall in spruce yield should be made up by aspen and poplar.

Advantages and Disadvantages for Tending and Harvesting Scenario

Successful execution of the tending and harvesting scenario would achieve substantial spruce yields in a shorter time and without the costs and risks associated with establishing and growing new plantations with present technology. It also provides for an aspen harvest.

Disadvantages include problems with adapting current harvesting equipment to protect sufficient understory white spruce adequately enough to produce a crop. There are also potential problems with windthrow on exposed and moist to wet sites, and leader weevilling and loss may prove to be a problem as well. In areas with no demand for aspen and where white spruce has a priority, other scenarios for understory white spruce release not entailing problems of harvest technology and other associated risks to the understory should be considered in order to realize the growth and yield potential of spruce.

Replacement Cost of Spruce Understories

In order to estimate the value of understory stands such as those previously discussed, we assumed a mixedwood site of good productivity (Site Index 21 m at age 70; MacLeod and Blythe 1953) with an aspen-poplar residual density of 50-150 m³/ha after softwood harvest, assigned it to the coniferous land base, and regenerated it to the prescriptions outlined in Table 2.

For each of the options, growth assumptions were made and applied to Figure 7 as follows:

- the guide curve is from MacLeod and Blythe (1953) for Site Index 21 m at 70 years;
- plantations in Prescription 1 (released) were assumed to require 10 years to reach 2 m, after which they grew freely, following the growth trajectory for HS stands with aspen age 60 years (Fig. 6), until reaching a mean height previously determined for each combination of stand type and age. The time required to reach mean height was the reference age to which prescription costs were compounded;
- plantations in Prescription 2 (no release) were assumed to require 10 years to reach 1 m and continued at the same growth rate until they reached 3 m, when they became free-growing and followed the trajectory in Figure 7, with the time derived for compounded cost derivations as discussed for Prescription 1.

The result of the above analysis for each of the six natural stand type and age combinations was a cost per hectare (Table 3). Replacement costs were substantial, as illustrated for HS stands with aspen age 60; at 4% interest, the released stands cost over \$4200/ha and unreleased stands were over \$6600/ha. Even at 3% interest the costs were about \$3000/ha and \$4000/ha for released and unreleased stands, respectively.

Table 4 shows replacement costs in terms of cost per metre of stem and cost per tree. By assigning appropriate survival rates to the 1800 planted original trees and generating a range of understory stocking from 200 to 1000 stems/ha, obtaining aggregate and average heights from number of trees, and then dividing total compounded costs by aggregate height and by number of stems, cost per metre and cost per tree, respectively, were derived (Ball 1980). Results are illustrated further in Figures 8 and 9. Cost per metre and cost per tree rise dramatically as stocking levels decline.

Costs derived here are used to illustrate understory value and consequences of plantation failure, assuming a priority on white spruce regeneration. Actual costs and values for such replacement stands can only be determined from product and market conditions for specific situations and are beyond the scope of this report.

SUMMARY AND CONCLUSIONS

1) Mixedwoods are a large and productive source of forest products in this region. They have historically been primarily a source of softwood, especially white spruce, with little demand for their hardwood components. This situation is now changing, with increasing demand for aspen. This situation poses new

Table 2. Prescription costs for white spruce regeneration with and without aerial release

Year	Option	Cost/ha ($)
Prescription 1		
0	Mechanical site preparation	230.00
1	Planting—1800 bareroot stock at 33.8¢/tree	608.00
4	Regeneration survey	16.45
5	Aerial release of Vision at 5 L/ha	150.00
Total		1004.45
Prescription 2		
As above but not released		854.45

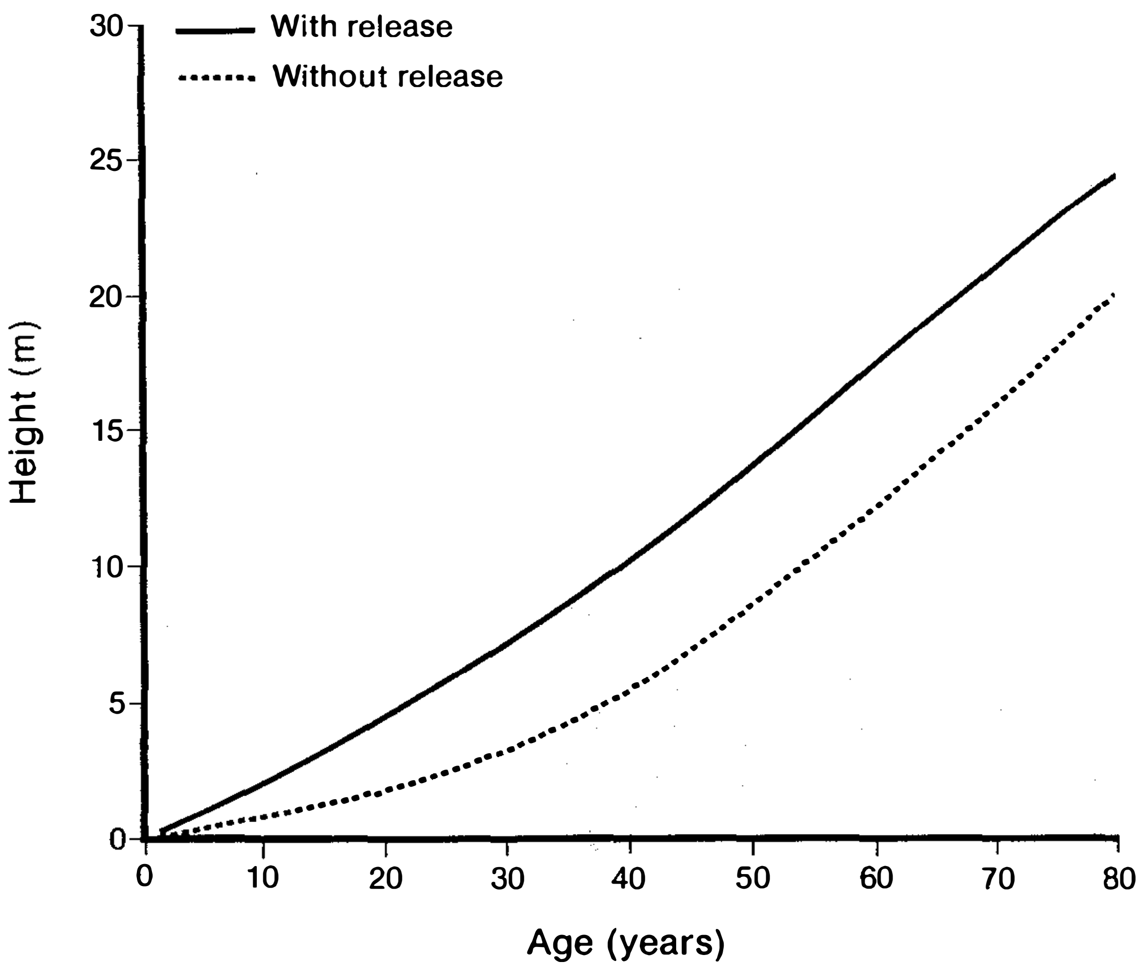

Figure 7. Predicted growth of white spruce regeneration on a good mixedwood site, with and without competition control.

Table 3. Replacement costs at varying interest rates for white spruce stands regenerated with and without release treatment

Stand type[a]	Overstory age (yr)	Mean height (m)[b]	Years to mean height		Replacement value for released stand ($/ha)				Replacement value for unreleased stand ($/ha)			
			Release	No release	3%	4%	5%	6%	3%	4%	5%	6%
HS	60	9.22	37	52	2 965	4 226	6 003	8 502	4 000	6 624	10 920	17 915
HS	70	10.58	42	56	3 437	5 141	7 662	11 377	4 502	7 750	12 273	22 618
HS	80	11.01	43	57	3 540	5 347	8 045	12 060	4 637	8 060	12 937	23 975
SH	60	11.54	45	58	3 756	5 783	8 869	13 550	4 776	8 382	14 633	25 413
SH	70	11.00	43	57	3 540	5 347	8 045	12 060	4 037	8 060	13 937	23 975
SH	80	12.15	47	60	3 985	6 255	9 778	15 225	5 067	9 066	16 133	28 555

[a] HS = 51-75% hardwood; SH = 51-75% softwood.

[b] Mean height of understory white spruce derived from the analysis of HS and SH plots with overstory ages of 60, 70, and 80 years.

Table 4. Cost per metre and cost per tree for stand replacement at 4% interest

	Release					No release				
Average height (m)	9.22					9.22				
Years to average height	37					52				
Replacement value ($/ha)	4226					6624				
Trees per hectare	1000	800	600	400	200	1000	800	600	400	200
Survival (%)[a]	56	44	33	22	11	56	44	33	22	11
Aggregate height (m)[b,c]	9220	7376	5532	3688	1844	9220	7376	5532	3688	1844
Value ($/m)	0.46	0.57	0.76	1.15	2.29	0.72	0.90	1.20	1.80	3.59
Value ($/tree)	4.23	5.28	7.04	10.56	21.13	6.62	8.28	11.04	16.56	33.12

[a] Survival rates applied to original 1800 planted trees to obtain appropriate stocking levels in table.
[b] Number of trees per hectare times average height.
[c] Competition technique from Ball (1980).

management challenges and presents new opportunities, particularly where aspen and spruce are grown and harvested on the same land base.

2) White spruce occur in substantial amounts as understories, particularly in stands currently inventoried H and HS, but current inventories do not document their amount, size, or distribution. As these stands are increasingly being scheduled for aspen harvest, information about the understory component becomes more critical to spruce management planning.

3) White spruce plantations on mixedwood sites in the region have proven expensive, risky, and generally unsuccessful to date, with up to two-thirds reverting to a mixedwood or hardwood status. Unless this situation can be changed, future supplies of white spruce must come mainly from established natural sources, primarily understory stands.

4) This report describes a tending and harvesting scenario that assumes a demand for aspen and has aspen and white spruce grown on the same land base. It is designed to protect existing white spruce understory, leaving a range of viable crop trees during the first cut, then harvesting both hardwoods and spruce in the final cut. If such a procedure proves practical, growth and yield rewards would be substantial and could supplement spruce production losses due to past plantation failures and assist in adjusting for imbalances in middle age classes in white spruce.

5) Harvest technology and crews currently employed may not be capable of providing adequate protection for white spruce understory stands. Under present circumstances, operators are being asked to absorb substantial production penalties and costs now to protect the understory in order to create added stand value 50–60 years in the future. It may be necessary to examine new approaches if future white spruce supplies are a priority issue in understory stands being scheduled for hardwood harvest. This may include specialized equipment and trained crews—possibly silviculture contractors—and may merit financial incentives.

6) Effective understory management planning requires more than improved mixedwood inventory. Because released understory stands may suffer losses due to windthrow on exposed slopes or in moist to wet sites and due to stem weevilling in some areas, a site description technique that incorporates these risk

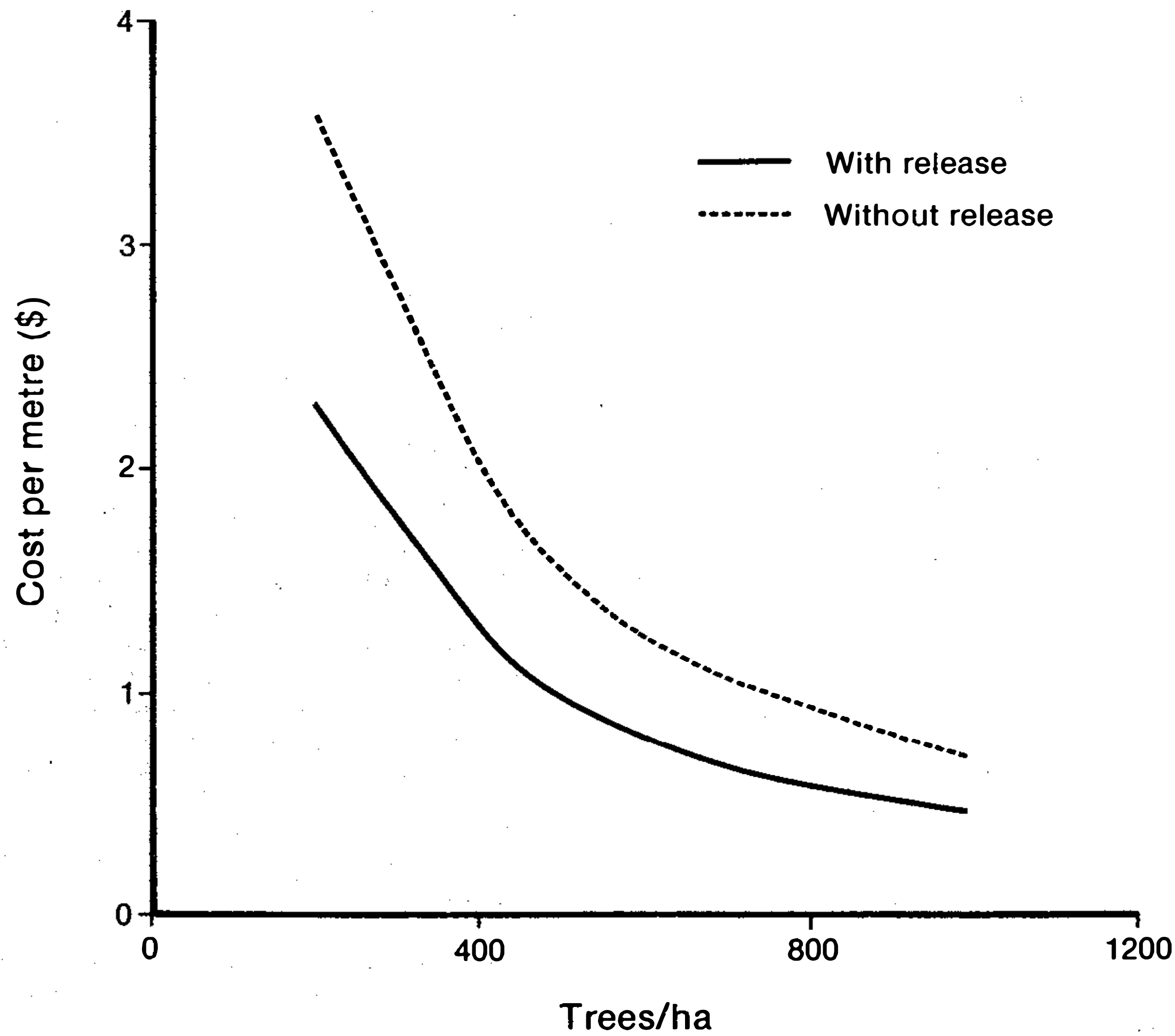

Figure 8. Cost per metre of aggregate height at 4% interest rate for white spruce regeneration for HS stand (51–75% hardwood) of aspen aged 60 years.

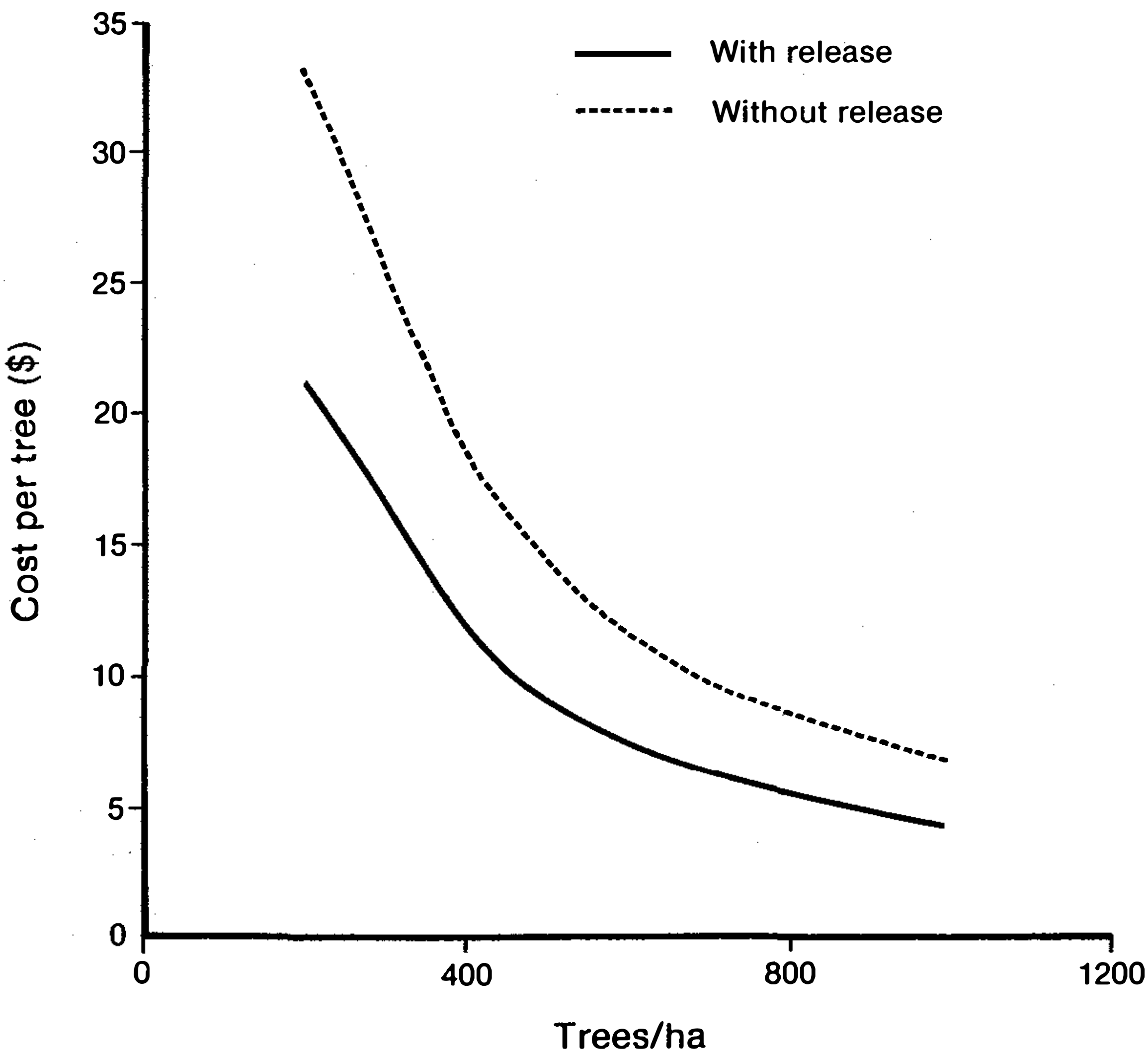

Figure 9. Cost per tree at 4% interest rate for white spruce regeneration for HS stand (51-75% hardwood) of aspen aged 60 years.

factors, along with growth and yield forecasts, is needed as a guide to management prescriptions.

7) In cases where spruce production has a priority, and where understory stands exist, a variety of options for release and protection of these stands should be developed in view of their growth and yield potential.

REFERENCES

Ball, W.J. 1980. Plantation performance in perspective. Environ. Can., Can. For. Serv., North. For. Res. Cent., Edmonton, Alberta. For. Manage. Note. 4.

Belcher, D.M.; Holdaway, M.R.; Brand, G.J. 1982. STEMS—the Stand and Tree Evaluation and Modeling System. U.S. For. Serv., North. Cent. For. Range Exp. Stn., St. Paul, Minnesota. Gen. Tech. Rep. NC-79.

Berry, A.B. 1987. Plantation white spruce variable density volume and biomass yield tables to age 60 at the Petawawa National Forestry Institute. Can. For. Serv., Petawawa Natl. For. Inst., Chalk River, Ontario. Inf. Rep. PI.X.71.

Castrilli, J.F.; Vigod, T. 1987. Pesticides in Canada: an examination of federal law and policy. Law Reform Commission of Canada, Ottawa, Ontario.

Corns, I.G.W.; Annas, R.M. 1986. Field guide to forest ecosystems of west-central Alberta. Can. For. Serv., North. For. Cent., Edmonton, Alberta.

Drew, T.J. 1987. Excellence and results-oriented regeneration in Alberta's spruce forests: the place for cleaning and tending. Psges 176-186 in: Proceedings of IVMAA Seminar, In Pursuit of Excellence, March 18-19, 1987, Calgary, Alberta.

Froning, K. 1980. Logging hardwoods to reduce damage to white spruce understory. Environ. Can., Can. For. Serv., North. For. Res. Cent., Edmonton, Alberta. Inf. Rep. NOR-X-229.

Johnson, H.J.; Gorman, J.R. 1977. Effect of strip width on the regeneration of white spruce in the Mixedwood Forest Section of Alberta. Environ. Can., Can. For. Serv., North. For. Res. Cent., Edmonton, Alberta. Inf. Rep. NOR-X-188.

Johnstone, W.D. 1977. Yield of fully stocked spruce-poplar stands in the mixedwood forest section of Alberta. Environ. Can., Can. For. Serv., North. For. Res. Cent., Edmonton, Alberta. Inf. Rep. NOR-X-175.

Kabzems, A; Kosowan, A.L.; Harris, W.C. 1986. Mixedwood Section in an ecological perspective: Saskatchewan. Can. For. Serv. and Saskatchewan Parks Renewable Resour., For. Div., Prince Albert, Saskatchewan. Tech. Bull. 8. Second edition.

Patosaari, P. 1987. Specific problems of applied ergonomics, safety and health problems in forest operations (chemicals in forestry). Report on chemicals in forestry: health hazards and protection, for the International Labor Organization, Joint Committee on Forest Working Techniques and Training of Forest Workers, the Economic Commission for Europe, Timber Committee, and the Food and Agriculture Organization, European Forestry Commission.

Reynolds, P. 1988. Prognosis for future forestry herbicide use in Canada. Paper presented at the 68th Annual Meeting of the Canadian Pulp and Paper Association, Woodlands Section, March 15-18, 1987. Can. For. Ind. 108(2).

Rowe, J.S. 1972. Forest regions of Canada. Environ. Can., Can. For. Serv., Ottawa, Ontario. Publ. 1300.

Unpublished reports:

Johnson, H.J. 1986. The release of white spruce from trembling aspen overstoreys: a review of available information and silvicultural guidelines. Prepared for the Manitoba Department of Natural Resources, Forestry Branch, Winnipeg, Manitoba, under the Canada-Manitoba Forest Renewal Agreement.

MacLeod, W.K.; Blythe, A.W. 1953. Yields of spruce-poplar stands in northern Alberta. Can. Dep. North. Aff. Nat. Resour., For. Res. Div., Alberta Dist. Off., Calgary, Alberta. Unpublished report.

Yang, R.C. 1988. Growth of white spruce following release from aspen competition. Can. For. Serv., North. For. Cent., Edmonton, Alberta. Unpublished report.

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