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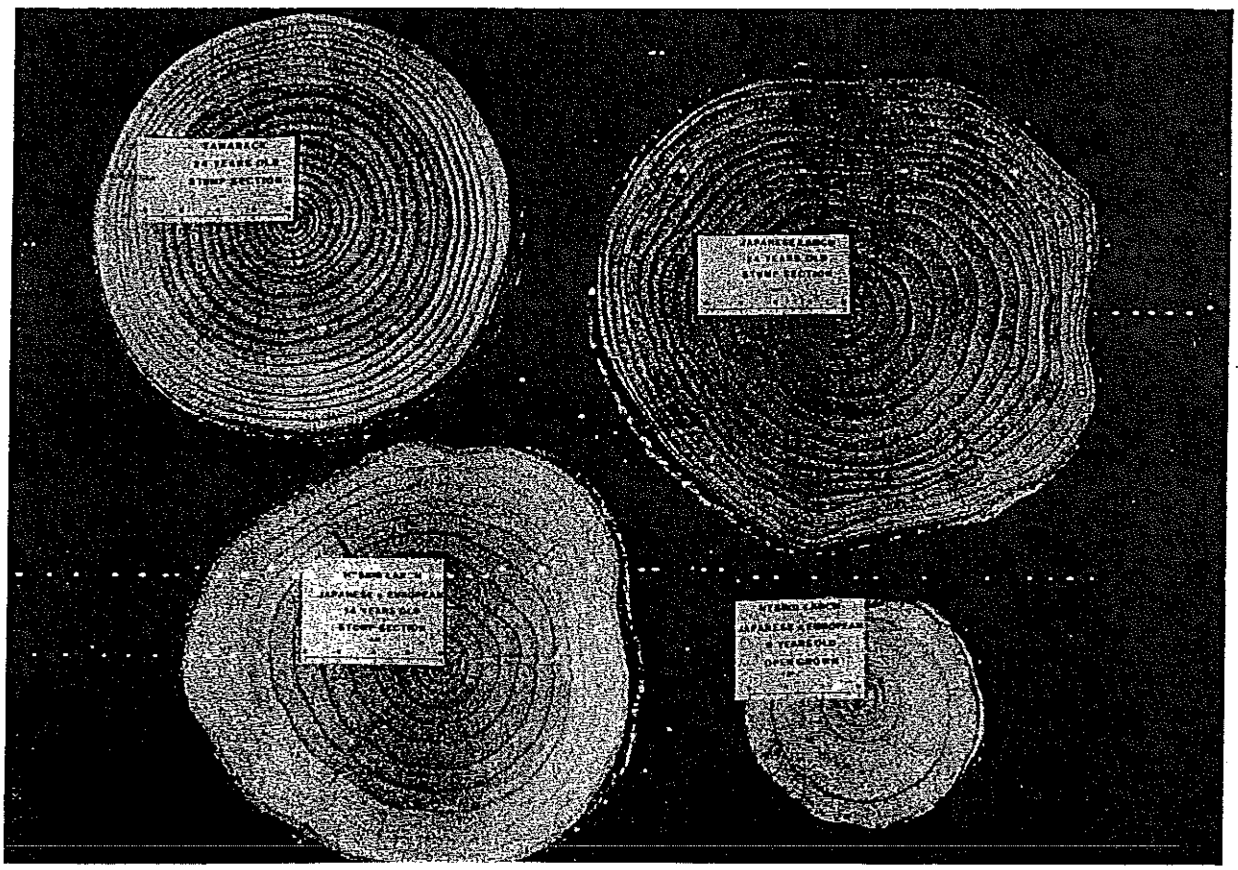

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WOOD SUPPLY IMPLICATIONS OF A LARCH REFORESTATION PROGRAM

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ABSTRACT

Because of its rapid growth rates and resultant early availability for harvest, *Larix* is an attractive species from a wood supply perspective. However, incorporating *Larix* in pulpmill furnish is constrained by the wood properties of the genus. In this paper, we treat these issues jointly in exploring the extent to which *Larix* reforestation can be employed to enhance future wood supplies without degrading ultimate product quality.

To do this, we have selected a 200,000 ha forested area which is generally typical of New Brunswick conditions with respect to age structure, stand composition, and site quality. Using this forest, a number of wood supply analyses have been performed using different proportions of spruce and *Larix* in reforestation strategies under a variety of maximum acceptable *Larix* mixes in the mill furnish. For each scenario of *Larix* utilization, indicators of forest level performance are provided to gauge the impact of including *Larix* in the reforestation strategies. These indicators include (1) maximum sustainable harvest, (2) future harvest expansion, (3) required silvicultural efforts and (4) roadside harvest costs.

INTRODUCTION

Previous papers in this symposium have addressed various facets of larch management, from genetic control and seedling production, to growth and yield, to manufacturing opportunities. In this paper we will link aspects of larch growth with aspects of larch utilization in manufacturing by examining the potential wood supply impact of larch reforestation in a forest management strategy.

The overall contribution to wood supply is an important gauge of any reforestation program's effectiveness and should

1 N.B. Department of Natural Resources and Energy
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strongly influence the nature of the programs which are implemented. The wood supply perspective, together with those set forth in previous papers, should help form a base from which sound decisions can be made regarding the role larch will play in present and future forest management strategies.

OBJECTIVES AND APPROACH

The general objective of this paper is to examine the wood supply impact of operational larch reforestation under conditions in which limited proportions of larch are acceptable in the mill furnish. Specific objectives are twofold: first, to reveal the manner by which larch reforestation can affect wood supply and second, to quantify the magnitude of that affect for a specific forest.

The principles behind the way larch reforestation can affect wood supply are general in nature and are applicable to any forest holding. However, the magnitude of impact on wood supply cannot be generalized. It will be specific to each forest holding, and is largely a function of the characteristics of the forest in which larch reforestation is to occur. Consequently, estimates of impact are only meaningful when determined for, and discussed with respect to, a specific forest holding. For this reason, we have approached examination of larch reforestation effects in wood supply in the following manner.

1. Select forest base and establish wood supply objectives.

   As discussed, use of a specific forest area is necessary to make meaningful estimates of wood supply impact. Further, consideration of impact is most revealing if evaluated against attainment of established supply objectives. Specific supply objectives are also required as targets which the reforestation strategy must be designed to meet.

2. Set constraints on the maximum acceptable larch proportions in the mill furnish.

The extent to which larch reforestation can affect wood supply relates closely to the extent to which larch can be used in the mill. Thus, evaluation of larch reforestation must be performed against specific utilization levels. Here, utilization means the maximum percent larch which can be tolerated in the mill furnish for manufacturing a certain product. Restriction will be made to fibre products in this paper. To cover an array of reasonable alternatives, three larch utilization scenarios will be examined here. The larch utilization levels are 0%, 30% and 50% and will be referred to as scenarios 1,2, and 3, respectively. Scenario 1 represents continuation of the status quo, in which little if any larch is tolerated in the mill mix. Scenario 2 is based on W. Lawford's previous report on CIP research results (in these proceedings) which revealed no product quality degradation with up to 30% larch in the furnish. Scenario 3 represents increased larch utilization which might be realistic with future modifications to manufacturing processes or a reduction in product quality standards.

3. Design larch and spruce reforestation programs which achieve supply objectives and satisfy mill constraints.

Through a series of wood supply analyses, planting and harvest levels were systematically controlled to help define reforestation programs which met supply objectives and utilization constraints for each of the three scenarios. Because it is the most widely planted species in New Brunswick, black spruce has been chosen here as the other species to be considered with larch in reforestation activities.

4. Compare wood supply performance between the three scenarios to evaluate larch impact.

In the wood supply analyses, indicators of performance were tracked and are presented as measures which can be used to evaluate the larch contribution to wood supply. The chosen measures were (1) maximum current sustainable harvest, (2) required silviculture efforts and costs and (3) roadside harvest costs.

FOREST CHARACTERISTICS AND RELATED DATA

The forest chosen for analysis was a 200 000 hectare tract located in New Brunswick. This area is a physically identifiable, contigous tract, but does not have real management significance in that it does not constitute anyone's license or management unit in the Province. The forest is valuable for illustrative purposes, however, because it is generally typical of New Brunswick conditions with respect to stand composition, age class structure, and site quality.

Existing Forest

The 200 000 hectare forest is dominated by and distributed amongst four major stand types; fir softwood, spruce softwood, mixedwood, and spruce plantations. The land base is further divided into high quality sites and average quality sites, generally associated with areas currently supporting mixedwood and softwood stands, respectively. Table 1 presents the distribution of the forest base by stand type and site quality.

Table 1. Distribution of the 200 000 hectare forest by stand types and site quality.

Stand Description	Percent Area: High Quality Sites	Percent Area: Average Quality Sites	Total
Fir Dominated Softwood	-	55	55
Spruce Dominated Softwood	-	15	15
Fir-Spruce/Hardwood mixture	25	-	25
Planted Black Spruce	2.5	2.5	5
TOTAL	27.5	72.5	100

Additional detail about the age structure, softwood yield, and roadside harvest costs for each stand type are presented in figure 1. The age structures and yields have been compiled from the New Brunswick Forest Development Survey. Roadside harvest costs were calculated using an algorithm in which cost is a function of total volume and mean tree size of a stand. The roadside costs are not presented as accurate values for New Brunswick harvesting operations but have been deemed reasonable in relative terms by a number of company personnel.

Planted Forest Stands

Yields and harvest costs for larch and black spruce plantations are presented in figure 2. For all plantations, an initial density of 2000 stems per hectare (2.2m X 2.2m spacing) was used. The larch yields were taken from Bolghari and Bertrand (1984) and pertain to Japanese and European species. Black spruce yields are those compiled by the NBDNR for the forest area in question. Costs were computed using the same algorithm applied to the natural forest

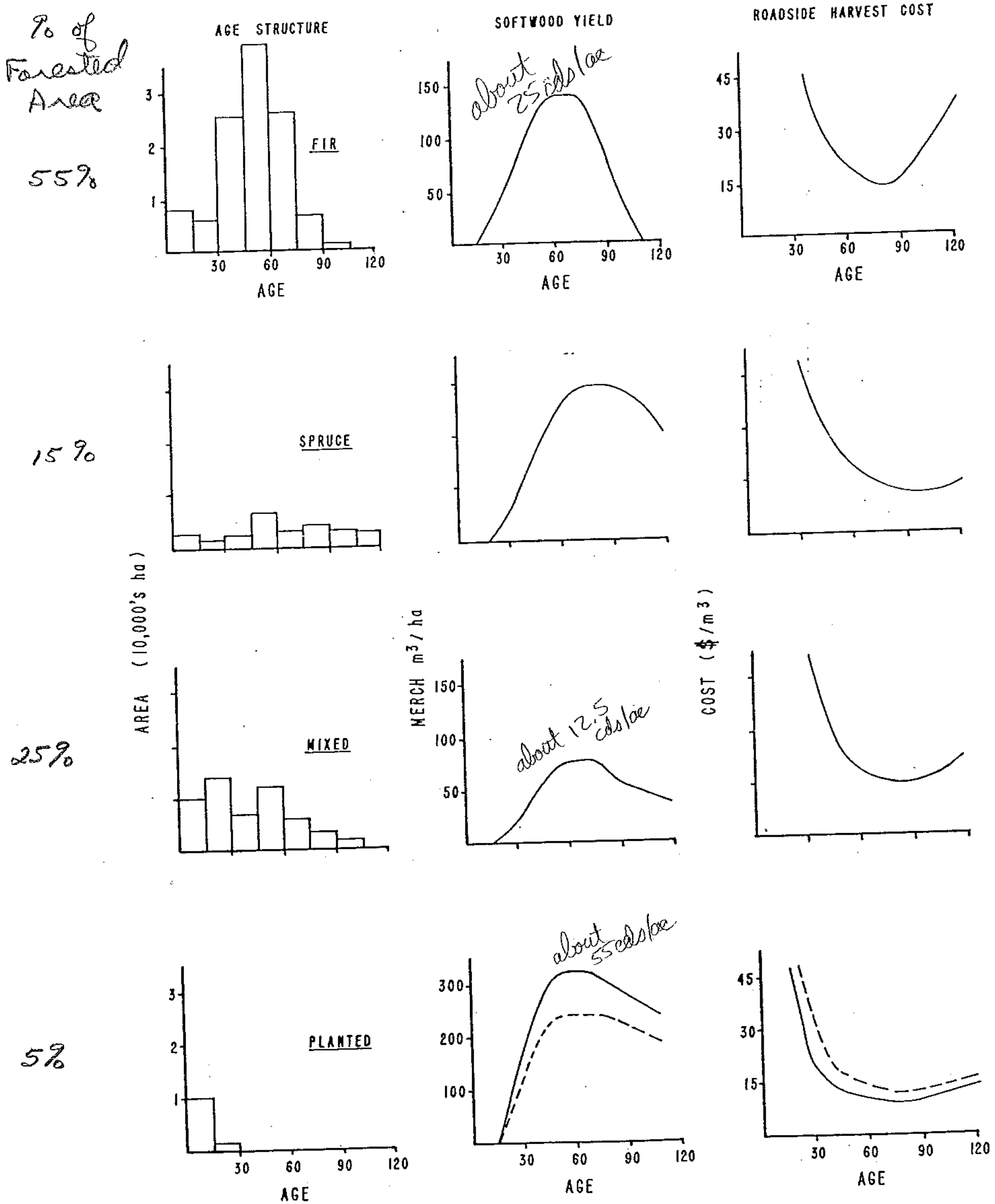

FIGURE 1: Data for existing forest used in wood supply analysis. For plantations, solid and broken lines represent good and average sites respectively.

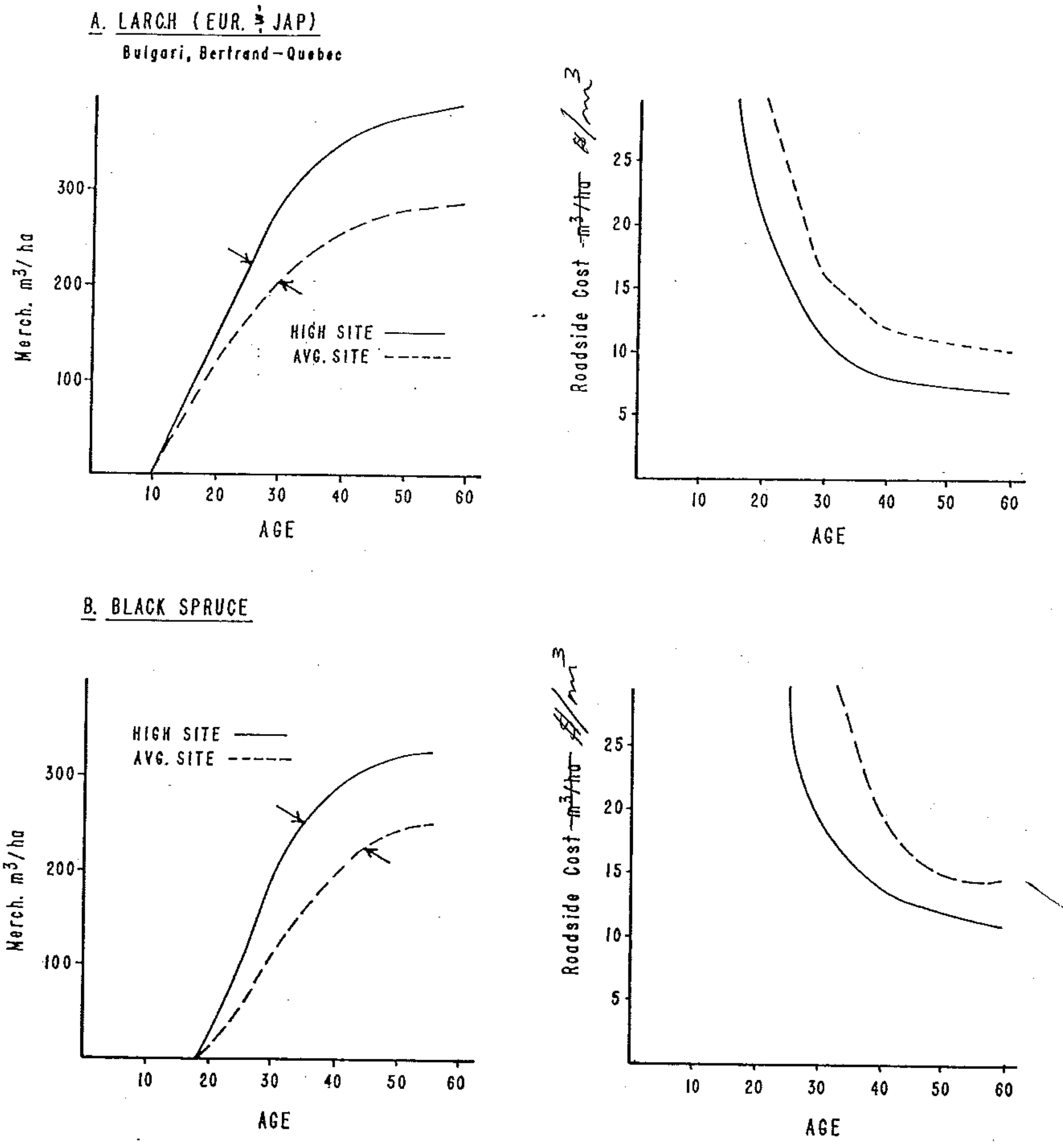

FIGURE 2: Larch and Spruce plantation data used in wood supply analyses. Broken and solid lines represent average and high quality sites respectively.

stands and no attempt was made to account for new and cheaper harvesting systems which may be designed for the uniform conditions which plantations provide.

As will be demonstrated later, the earliest age at which plantations can be economically harvested is an important determinant of wood supply performance. This age of first operability has been set when a mean size of $0.14m^3$ per tree is first attained. The arrows in figure 2 indicate the first operable age using this criterion for larch and black spruce on the two site types. These values should be borne in mind as they are significant in the results presented in subsequent sections.

Silviculture Costs

Wood supply performance is characterized not only by wood volumes, but also by costs incurred in generating that supply. Silviculture operations, as well as harvesting, contribute to the total cost picuture; therefore, silviculture costs of seedling production and stand establishment have been included in the analyses (table 2). Prevailing reimbursement rates for New Brunswick Crown land planting are the basis for the cost values. It has been assumed (1) that higher stand tending costs will be incurred on the higher quality sites which may experience heavier competition and (2) that larch and spruce plantation establishment costs will be similar. Discussion at the larch symposium by P. Etheridge casts some doubt on the validity of this latter assumption and the reader should view the silviculture cost results accordingly.

Table 2. Silviculture costs for plantation establishment and tending (based on New Brunswick Crown land re-imbursement rates).

Species	Good Site ($/ha)	Average Site ($/ha)
Black Spruce	817	692
Larch	817	692

Supply Objectives

Two wood supply objectives were imposed in the forest analysis of larch reforestation. A short-term objective was set to maximize sustainable harvest levels from the forest for the first 45 years. In the long-term the objective was set to increase the harvest by 50% over the maximum short-term rate available under the 0% larch utilization scenario. Year 45 was chosen as the point of harvest expansion because by that time (under the 0% scenario) sufficient mature plantations would be available to sustain such an increase. Figure 3 depicts the harvest strategies graphically.

It is important to note that these objectives were set for illustrative purposes only, and in that sense are somewhat arbitrary. Actual short and long-term objectives for a forest under management would of course be based on the industrial/economic strategy of the managing agency.

The detail of performing the wood supply analyses for each of the three utilization strategies will not be presented here. For specifics of the approach the reader is referred to Wang (1986). In general terms, the analyses were carried out and the harvest reforestation strategies were designed under three guiding considerations. First, the short-term harvest was maximized only to the extent that it did not exhaust the growing stock. Second, in expanding the harvest to the long-term objective, reforestation was performed at rates sufficient to stabilize the growing stock in the long-term. Third, the larch component of each annual harvest was not allowed to exceed the percent specified under each utilization strategy (ie. 0%, 30%, and 50%).

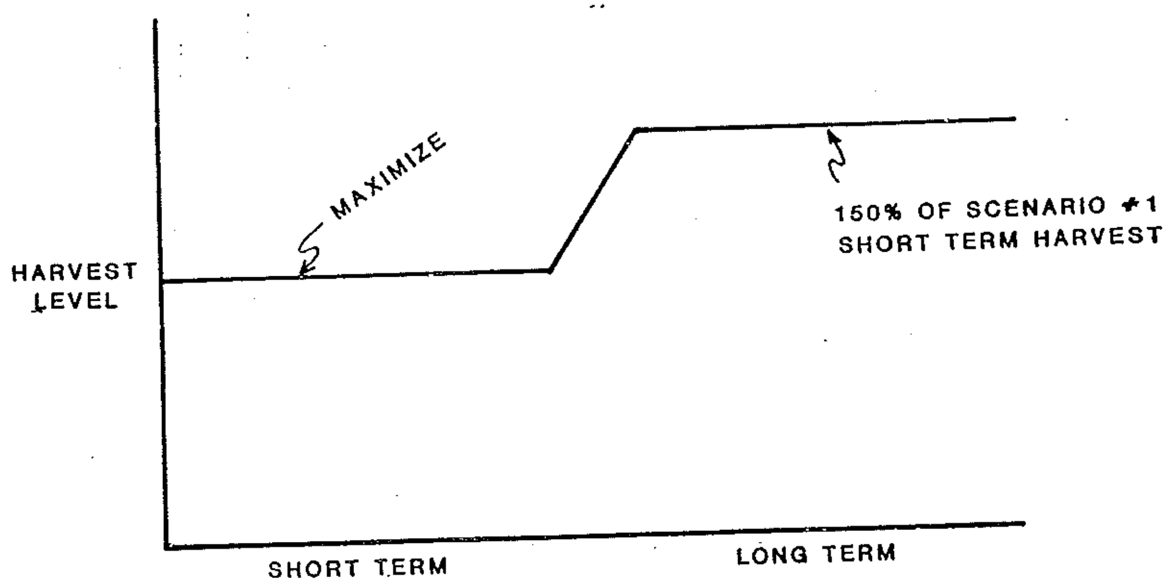

FIGURE 3: WOOD SUPPLY OBJECTIVES APPLIED IN ANALYSES OF LARCH REFORESTATION STRATEGIES.

SHORT TERM: maximize current sustainable harvest.

LONG TERM: at year 45, expand harvest by 50% over maximum short term harvest available in Scenario 1.

RESULTS

The essence of the management problem for this forest is balancing the rate of mature stand liquidation with the recruitment of new plantations and natural stands into the operable inventory. Under the previously set supply objectives this balance must be such that the short-term harvest rate is as high as possible without exhausting the operable inventory. Two major determinants of the rate which strikes this balance are the yield/age structure characteristics of the existing forest and the number of hectares planted and time to operability of those plantations (Baskerville 1983). Since the nature of the existing forest is fixed, attention can be focussed on the control of reforestation rates and time to plantation operability. These are questions of how much to plant and which species to plant on which sites.

Scenario 1 - 0% Larch Utilization

The scenario 1 wood supply analysis excludes larch from the mill furnish and, thus, excludes larch from the reforestation strategy. Black spruce planting is the only alternative in this example and the limitation on wood supply is posed by the time to operability for black spruce plantations (35 and 45 years for good and average sites respectively-figure 2).

The results of the strategy which best meets supply objectives and constraints under scenario 1 are presented in figure 4A. Three key features are depicted: (1) the operable growing stock profile 65 years into the future, (2) the long and short-term harvest rates, and (3) the reforestation program required to sustain those harvest rates. The figure shows that the maximum sustainable harvest to year 45 is 2.75 million m^3 per 5 year period. The long-run harvest rate becomes 4.12 million m^3/period (1.5 X 2.75). This harvest pattern is sustained by a planting program which starts at 4000 ha per year and then drops to, and is maintained at, 3000 ha per year. In combination, harvest and planting levels create a growing stock profile which (1) decreases

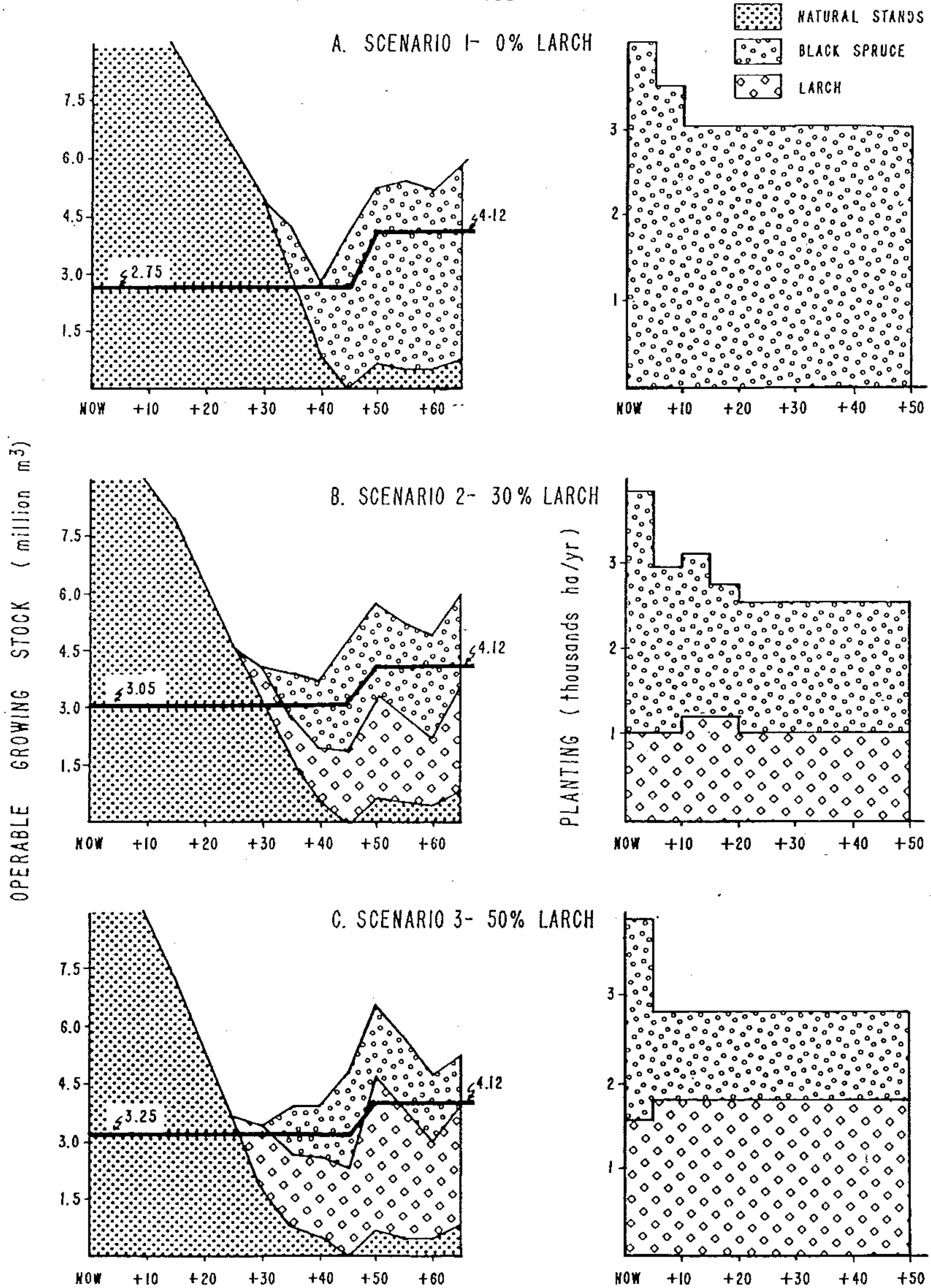

FIGURE 4: Planting efforts and the resulting harvest levels and growing stock profiles for the three Larch utilization scenarios. See text for discussion.

initially as the old forest is depleted, (2) reaches a nadir at time 40 when the old forest is exhausted and plantations are first entering the operable inventory, and (3) increases after time 40 with the recruitment of plantations and some naturally regenerated stands into the operable inventory. The growing stock nadir at time 40 highlights the biological limitation to current wood supply under this scenario. Acceleration of the harvest above the 2.75 million m^3 level is not sustainable because the old forest is exhausted before spruce plantations become operable .

Although the best sites were planted first in this strategy, the paucity of good sites across this forest (27%) severely constraints the plantation volume available before year 40. It is worth noting as an aside that inability to identify and plant the best sites in practise would exacerbate the supply problem considerably.

Comparison of the relative times to operability between black spruce and larch (figure 2), reveals the contribution larch reforestation could make to the supply problem demonstrated for scenario 1. Larch plantations would enter to the operable inventory at 25 and 30 years and, thereby, would help overcome the timing problem which limits wood supply.

Scenario 2 - 30% Larch Utilization

Under scenario 2, the attempt is to capture this potential benefit under the assumption that a 30% larch component is acceptable in the furnish (Lawford 1986). This change in mill utilization from the no larch strategy in scenario 1 adds larch reforestation to the array of effective tools with which the forester must manage that forest.

Figure 4B displays the results of the strategy which best meets the objectives and constraints under scenario 2. Presentation of growing stock profile, harvest levels, and accompanying planting rates are presented the same as for scenario 1. In this case, however, planting rates and operable growing stock contributed by the new forest, are separated into natural, black spruce and larch components.

One obvious effect of accepting larch in the furnish is the immediate increase in sustainable harvest to 3.05 million m^3 per five year period. The early availability of larch relative to spruce plantations shortens the time over which the old forest must sustain the harvest and, therefore, allows a higher harvest rate. Why this increase can occur is evident from comparison of the growing stock in figures 4A and 4B. The slope of the growing stock is sharper for the first 30 years in figure 4B, reflecting the higher harvest rate. Such a harvest rate would have depleted the growing stock in figure 4A by year 30, leaving a 5 to 10 year wood shortage. In scenario 2 entry of larch plantations into the operable inventory between years 25 and 30 bolsters the growing stock during this critical period, thus sustaining the harvest. As set by the supply objectives, at year 45 the harvest is expanded to 4.12 million m^3 per period 150% of the scenario 1 short-term harvest).

The total planting effort required to sustain the scenario 2 harvest rates begins at 4000 ha per year then drops and stabilizes at 2500 ha per year. A considerable proportion of the planting is in larch - in fact the larch component of the program is approximately 40%. This exceeds the 30% larch in the harvest because the balance is supplied by both natural spruce and fir stands, and spruce plantations.

Figure 4B suggests an opportunity to raise the harvest further. By substituting larch for black spruce plantations in the first ten years, the earlier operability of larch would raise the growing stock further at years 25-30, thus enabling a higher harvest rate. The strategy fails in this case however, because of the 30% larch utilization limit. Planting larch in place of spruce creates a corresponding shift in the growing stock composition at years 35 to 40. The operable volume at this time is so dominated by larch that meeting the specified harvest rate can only be accomplished if the larch component is allowed to exceed 30%. This would violate the mill furnish constraints of 30% and would thus be unworkable.

Scenario 3 - 50% Larch Utilization

Scenario 3 demonstrates the additional wood supply impact when larch utilization is increased to 50%. The results are presented in figure 5C. With 50% larch utilization, the short-term harvest can be expanded to 3.25 million m^3 per period. This gain is achievable by increasing the proportion of larch planted which, in turn, supplies more volume to the operable growing stock at an earlier time. This more rapid recruitment of volume to the operable inventory supports faster liquidation of the old forest and therefore sustain a higher harvest.

To support this higher harvest, the area planted in larch is almost 2000 ha per year. Again the larch planting proportion exceeds the larch proportion in the harvest because of the contribution of natural spruce fir stands to the harvest. Some 1000 ha per year of black spruce continue to be planted to supply the furnish requirement of 50% spruce and fir. Although the harvest could be raised further by substituting spruce with larch plantations, the 50% larch constraint would be violated at time 35 to 40. Capture of this higher harvest could only be accompanied by an acceptance of more than 50% larch in the furnish.

PERFORMANCE INDICATORS

Wood supply performance indicators for each of the three larch utilization scenarios are presented in figure 5. To cover the full range of possibilities, results are also presented for analyses under no larch utilization constraints (ie - 100% larch acceptable in furnish). While perhaps unrealistic, this no constraint situation does represent the maximum harvest available and thus provides a good benchmark for evaluation of the other scenarios.

Three key indicators are presented; (1) short-term harvest (ie years 1 to 45), (2) short-term costs, and (3) long-term costs. The intent here is to guage the impact of larch on wood supply, and the base from which impact will be determined is scenario 1; (a continued no larch policy). All results are presented in terms of percent of the scenario 1 value. Figure 5A reveals an immediate positive impact on wood supply as larch is incorporated in the furnish. At 30%, 50%, and 100% larch use levels the supply gains are 11%, 18%, and 27%, respectively. While wood supply continues to increase with increased larch utilization, returns diminish, as evidenced by the decreasing slope in figure 5A. Thus, acceptance of larch in the furnish at low levels is most efficient in increasing supply. Inclusion of 30% larch in the furnish captures 40% of the available gain and a 50% larch mix increases the harvest to 67% of the maximum possible. This may add incentive to larch utilization since modest increases in larch use from the current no larch situation will yield the greatest gains.

The question now becomes; At what cost can these gains be realized? Figure 5B presents the total costs per cubic metre (with harvest and silviculture components) at varying levels of larch utilization. Again the values are expressed as percentages of the scenario 1 values. Costs have been calculated on a per unit basis as the sum of harvest and silvicultural costs divided by the volume of wood harvested.

The total cost curve is essentially flat, indicating that the increased harvest which accompanies higher larch utilization is available at a constant unit price. In essence, more volume can be obtained at the same unit price. While the total cost is constant, it is interesting to note that its composition changes consider-

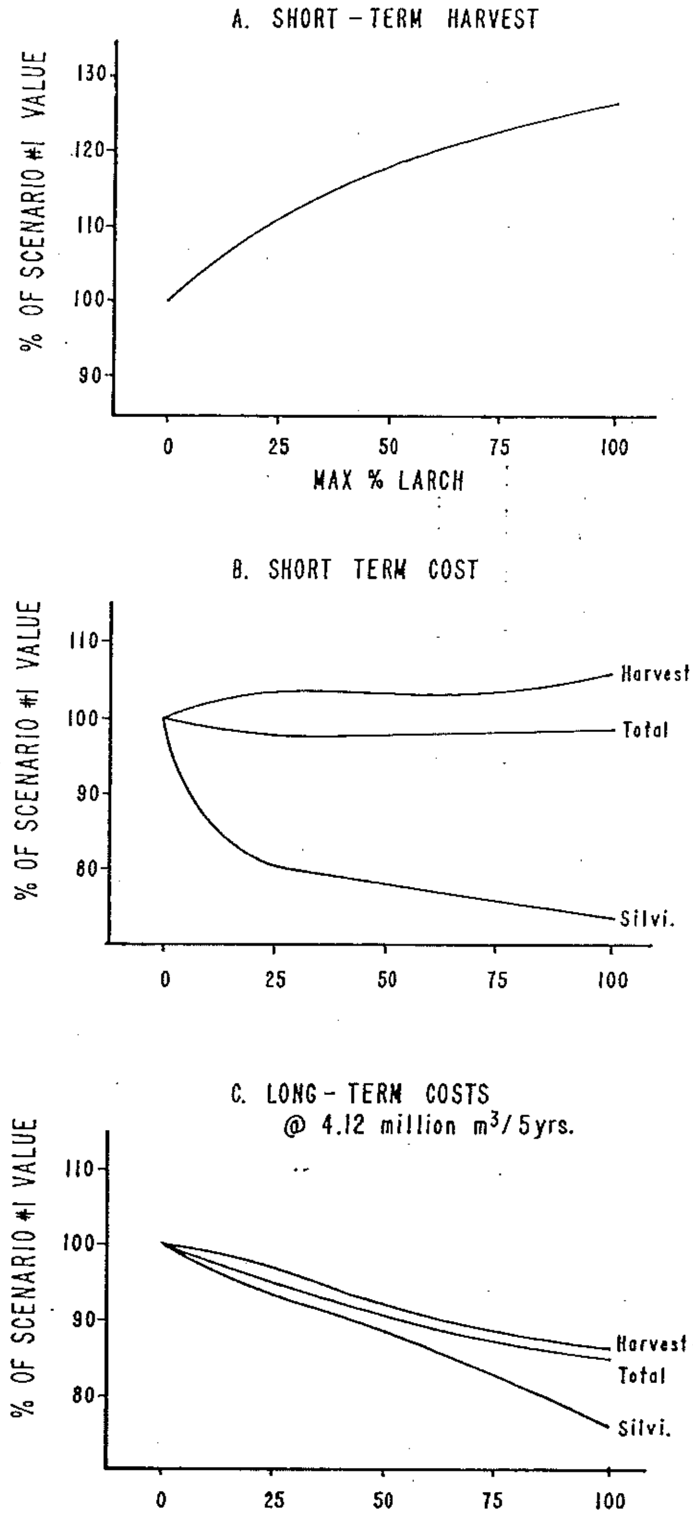

FIGURE 5: Wood supply performance indicators under various levels of maximum acceptable larch percent in mill furnish. See text for discussion.

ably. The harvest component increases as more pressure is placed on the old forest and more stands are harvested up the sides of the cost troughs shown in figure 1. The silviculture component decreases somewhat since increased volumes of wood become available earlier as more larch plantations are established.

In contrast to the short-term, the long term harvest has been fixed at 4.12 million m^3 per period across all larch utilization levels. Here, differential impacts of using larch are reflected solely in the cost of securing that volume. Figure 5C reveals a decreasing unit cost for all increases in larch utilization. The maximum unit savings is 15%, realized under unconstrained larch use (100%). As with the short-term harvest, however, the initial increments in larch use generate the greatest benefit; 30% and 50% larch use captures 35 and 60% of the total available cost reduction. This again demonstrates the relatively high pay off of modest changes from the status quo of no larch utilization.

SUMMARY

Several salient points deserve reiteration in summarizing the implications of the foregoing analyses. First, the general relationship between early stand availability for harvest and wood supply are applicable to any forest. Here larch planting was the means of accelerating stand availability. However, the principles are applicable to <u>any technique</u> by which stand growth can be increased, be it planting some other fast growing species, careful site selection, or effective tending measures.

Second, the magnitude of wood supply response is specific to the forest in question. To quantify this impact, analyses should be performed incorporating the characteristics unique to the forest being managed.

Third, the benefits available from incorporating larch in the mill furnish can be captured in a number of ways. It has been demonstrated that more volume can be available at the same cost (as in the short-term example) or the same volume may be available at a cheaper cost of recovery (as in the long-term example). A third possibility, not discussed here, is an earlier expansion of the harvest rate. Under the three scenarios, all harvest expansion occurred at year 45. The growing stock profiles in figure 4 indicate that under scenarios 2 and 3 the increased harvest could have been initiated five to ten years earlier. It becomes a management issue to select the most advantageous form in which to capture the supply benefits.

Fourth, delay in implementing a larch reforestation strategy will blunt its impact on wood supply. This is not to urge ill-planned, precipitous action, rather it is to emphasize that timely action is most effective in solving forest management problems. The major limitation to wood supply for this example occurs at the transition between harvesting the old and new forests. This problem looms 35 years in the future. A five-year delay in reacting to it, converts the problem to a 30 year one. This, in turn, reduces the remedial measures available, and dampens the effectiveness of those which remain.

Finally, and perhaps most importantly, this analyses has demonstrated that power to manage the forest is in the hands of both the forester and the mill manager. By varying furnish specifications through product research and development, the mill manager exercises tremendous control over the availability of raw materials for manufacturing. Further, he defines the constraints and opportunities within which the forester must design his management actions. By wise management design and quality silviculture decisions and implementation the forester controls the efficiency and effectiveness with which forest management objectives can be attained. The skill with which mill and forest manager exercise their control will determine the degree to which the forest's potential can be realized.

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