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Benefit-cost analysis of forestry investment

G. Alex Fraser

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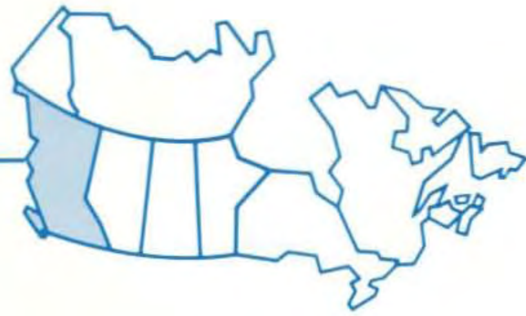

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Abstract

This report reviews the development and application of benefit-cost analysis to forestry investments. By use of examples, it leads the reader through a discussion of measurement of costs and benefits, discounting, and the sensitivity of the method to changes in the underlying assumptions, and clearly states the limitations of benefit-cost analysis.

Résumé

Il s'agit d'une étude de l'élaboration de l'analyse coûts-avantages et de son application aux investissements forestiers. À l'aide d'exemples, l'auteur explique la méthode d'analyse coûts-avantages, les techniques d'actualisation et la degré de sensibilité de la méthode à la variation des hypothèses fondamentales. En outre, il indique clairement les limites de cette méthode d'analyse.

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Introduction

In 1981, the federal cabinet endorsed, in principle, a major push to increase timber supplies through intensive forest renewal and management. The proposed mechanism for program delivery was a new series of federal/provincial forest development agreements. Negotiations with the provinces began in late 1982 and, at this time, all except that with Newfoundland have been signed.

At both the negotiation stage and later when final program approval is requested, there are many elements of choice. Not all projects which can improve the yield of the forests can be carried out within a limited budget, and specific projects or areas of focus for agreements must be selected. Similarly, Cabinet and Treasury Board cannot approve all development programs which will improve the well-being of Canadians within a limited budget. Forest renewal must compete with priorities in other resource sectors as well as with social policy. There is a need to choose between alternatives and to set levels of funding and effort.

In this type of selection process, benefit-cost analysis is a potentially powerful tool. It is a systematic means of identifying and evaluating the relative merits of alternative investment opportunities. In spite of this, little use has been made of benefit-cost analysis in forest investment decision making.

This reluctance to use benefit-cost analysis stems partly from confusion regarding procedure. Benefit-cost analysis is complex and there is considerable debate on a number of important aspects of the analysis. There is uncertainty regarding assumptions, and inconsistency and sometimes errors in practice. Although the Federal Treasury Board recognized these problems and has promoted consistency through published guidelines, confusion remains in areas such as forest renewal and management.

The main intent of this paper is to illustrate proper benefit-cost methodology applied to a forest investment decision. Specifically, two hypothetical forest renewal and management projects are analyzed. Many of the numbers used in this analysis are rough approximations. **Rather than the specific results, the topic of importance here is the deriviation of an appropriate framework for analysis and the illustration of the information requirements.** A heavy emphasis is placed on sensitivity analysis in order to identify the key factors which influence the results and to determine the circumstances under which assumptions can be validly varied. Also, the limitations of the efficiency analysis are considered, and alternative ways of incorporating non-efficiency project impacts are explored.

Description of the projects

The area subject to the two silvicultural treatments is assumed to be one hectare in both cases. Also, the land in both cases is assumed to be located in the Vancouver Forest Region and the grade of land is Site I (the highest classification in the B.C. Ministry of Forests inventory of forest land). In effect, it is the most productive forest land in the province. In the first case, due to a failure to replant after initial harvesting, the site has been invaded and covered by noncommercial brush. In the second case, a dense stand of juvenile Douglas-fir aged 11 years has become established on the site.

The first hypothetical silviculture project is a reforestation project involving several distinct steps. First, the present noncommercial cover must be removed and destroyed without harming the soils. Second, within one year of this site rehabilitation, planting takes place. Finally, four years after planting, brushing and weeding are required to remove the resurgence of undesirable competitive brush growth. Each different step in the project varies in the mix of capital and labor used. For example, site rehabilitation is capital intensive, requiring the use of specialized, expensive equipment, whereas planting is labor intensive. Brushing and weeding can be done either manually or chemically and the labor intensity of the operation depends upon choice.

The second hypothetical silviculture project involves an integrated program of juvenile spacing and fertilization. Spacing involves the selection of superior trees and the removal of the less valuable trees, while fertilization accelerates growth. An integrated program is evaluated because fertilization and spacing are complementary, i.e., their joint impact is greater than the sum of their separate impacts. Like the reforestation project, the mix of capital and labor varies with the project phase. While spacing is largely a labor-intensive operation, fertilization is largely capital-intensive and requires a helicopter delivery system.

National income benefits

The national income benefit of a project is the value of the goods and services produced over and above that which would exist without the project. In the first project, without silviculture, the commercial productivity of the land would be zero. Since the area has been invaded by brush, the establishment of a commercial stand of timber on the site without investment is improbable. Consequently, the benefits amount to the full value of the commercial timber harvest from the site. This, in turn, depends on the age at harvest and the species planted.

It is assumed that Douglas-fir was the species chosen for planting on the basis of the relative productivity of the land, and that age 55 is the selected harvest age. The expected harvest from a planted class 1 site in the Vancouver Forest region is 750 m^3/ha at age 55[1].

The volume benefit from a juvenile spacing and fertilization project is the increment to the expected harvest. Based on studies of the relative impact of these activities, the expected total yield would increase by 195 m^3/ha at age 55. The expected total yield of the site after juvenile spacing and fertilization is 945 m^3/ha[1].

The value of the harvest is affected by the quality of output. As outlined in Table 1, the Vancouver log market differentiates three grades of Douglas-fir with five-year average prices (1981 dollars) ranging from \$38/m^3 for grade #3 to \$100/m^3 for grade #1. The overall average price for all grades was \$50/m^3, indicating that the major proportion of the volume sold on the log market was grade #3. However, silviculture is expected to improve product quality. Both planting and spacing, through control of stand density, can result in larger trees which command premium prices. Fertilization has a similar effect by stimulating tree growth. For these reasons, it is assumed for valuation purposes[2] that the harvest from the two hypothetical projects averages grade #2.

On the basis of these assumptions, the national income benefits of the two forest management projects are outlined in Table 2. The benefit of the reforestation project is simply the total value of the eventual harvest from the reforested land. The benefit of the spacing/fertilization project is somewhat different, incorporating two elements. First, the value of the incremental production is relatively straightforward and is equivalent to the reforestation case, However, a second benefit from spacing and fertilization results from increased value of the entire harvest from the treated land. To calculate this item, it has been assumed that the harvest would have commanded only average prices in the absence of treatment. The \$20 difference between this and the grade #2 average price is the estimated benefit from quality improvement.

National income costs

The costs of silviculture investment represent the value of real resources displaced from other uses. These costs fall into two distinct categories. The primary or direct costs are those goods and services which are used in the silvicultural projects outlined above. Based on reported average per hectare cost of silvicultural treatment in the Vancouver forest region during 1981-1982, project costs by category are estimated in Table 3.

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[1] Since there is no experience with mature planted forests or mature spaced and fertilized stands, the expected harvest volume is not known with precision. There is a wide variety of opinion on the impacts of different silvicultural treatments. The figures used in this analysis are tentative and certainly not subject to unanimous agreement.

[2] Log market prices can be used to value project output only if the market is competitive. If monopsonistic elements are present, market prices may be held below a competitive market equilibrium. In this event, the result would be an underestimate of project benefits. In effect, benefits are missed further down the processing chain which are also attributable to the silviculture investment. Although there is some question regarding the competitiveness of the Vancouver log market, these prices are assumed to be adequate in the absence of alternatives.

The second element of national income cost is the associated cost of harvesting the resource. In valuing the benefits of the projects, the Vancouver log market price was used. This represents the value of output after harvesting and delivery to water. The estimated average cost of harvesting in the Vancouver Forest Region is \$11.00/m^3, while the estimated transport cost is \$0.10/km/m^3. Assuming a distance of 50 km to water, the total associated cost of harvesting and transportation for the reforestation project would be \$12 000 (1981), incurred at year 55 following planting. The associated cost of harvesting and transportation for incremental production from the spacing/fertilization project would be \$3120 (1981) incurred 44 years after treatment.

Present discounted values

The benefits and costs of any silviculture investment are realized over different time periods. While the major direct costs are incurred early in the project, the benefits are realized and the associated costs are incurred many years after the initial investment. Also, there are substantial differences between projects in the time flow of benefits and costs. For example, the direct costs of backlog planting are spread over a five-year period early in the project, while the benefits are realized 55 years after the initial investment. In the case of the spacing/fertilization project, all direct costs are incurred within one year, while the benefits are realized 44 years later. Society is not indifferent to such variations. Delayed benefits are less valuable because they are unavailable for immediate consumption or reinvestment.

In benefit-cost analysis, the discount rate is the means through which benefits and costs which vary widely in timing are compared. In effect, future benefits and future costs are adjusted downwards to reflect their reduced value. There is considerable debate among economists on the appropriate concepts as well as the specific rate to be used in the discounting process. The extensive technical literature on this subject is summarized in Appendix 1.

Federal Treasury Board Guidelines suggest that present values be calculated on the basis of a range of discount rates, including 5, 10 and 15%. In this analysis, calculations are made with a range of rates between 5 and 10% as this is sufficient to illustrate the importance of discounting to project evaluation.

The net benefits of the backlog reforestation projects are positive only with a 5% discount rate (Table 4). The calculations indicate that the internal rate of return on investment (i.e., the discount rate which exactly equates benefits and costs) lies somewhere between 5 and 6% per annum. In contrast, the net benefits of the spacing/fertilization project remain positive at a 7% discount rate. The internal rate of return on the spacing/fertilization investment lies somewhere between 7 and 8% per annum or approximately 2% greater than the return on the reforestation investment. At any discount rate, the benefit-cost ratio for the spacing/fertilization project consistently exceeds that of the reforestation project[3].

Sensitivity analysis

The analysis to this point has been performed in a very elementary framework. There are numerous implicit assumptions which can be changed to reflect current market conditions or possible future industry trends. A number of these possible variations are pursued here in order to test the sensitivity of the results and to explain the conditions under which such variations are valid.

a. Price trends

Timber is becoming increasingly scarce. Both the demand for forest products and the demand for alternative uses of forest land are increasing as world population grows. Some current forest land will be alienated from forest production in the future. Also, as the remaining stands of

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[3] In the example pursued here, the three basic ranking criteria (i.e., Benefit-Cost Ratio, Level of Net Benefits and Internal Rate of Return) result in consistent ranking. The benefit-cost ratio and net benefits from the reforestation project exceed those of the spacing/fertilization project at all discount rates. Also, the internal rate of return of the spacing/fertilization project is higher. For technical reasons, these three criteria need not result in the same ranking of projects. Consistent ranking sometimes requires an adjustment procedure. In general, the level of net benefits is the preferred ranking criterion in the absence of adjustment.

virgin timber are harvested, the future productivity of forest land will be lowered. It is conceivable that future decreases in supply in conjunction with increases in demand will imcrease real prices over the long term. There is undoubtedly some upper limit to such trends beyond which alternative materials are used or substitute materials are developed. However, even minor incremental price increases can have a major cumulative impact over periods in excess of 40 years.

A long-term analysis performed by the U.S. Department of Agriculture Forest Service in 1982 (An Analysis of the Timber Situation in the U.S., 1952-2030) estimated a trend increase in real lumber prices of 0.7% per annum from the year 1950 through to the mid 1970s. Also, in their opinion, this probably reflects a lower limit on future real price trends. Indeed, the trend increase in lumber prices may already reflect a more rapid increase in log prices. If returns to the factors employed in lumber production remained constant over the period, the increased revenue would be passed down the processing chain with a proportionately greater impact.

Table 5 presents the benefits and costs of silviculture investment assuming a 1% per annum trend increase in real prices over the period until the timber is harvested. Given this assumption, gross benefits do increase substantially under all discount rates. Net benefits from the reforestation projects are now positive under a 7% discount rate while net benefits from the juvenile spacing/fertilization project are now positive under an 8% discount rate. The internal rate of return on both investments has increased substantially. It is now approximately 7% for the reforestation project, and between 8 and 9% for the spacing/fertilization project. However, at any given discount rate, the benefit-cost ratio and net benefits for the spacing/fertilization project consistently exceed those of the reforestation project.

b. Technological change

Another factor which can have a major impact over long periods is technological change. Over time, there is a tendency for capital and labor to become more efficient in the production of goods and services. In the context of the two hypothetical projects, the major impact of technological change would be to lower the associated costs of harvesting and transporting the timber. Although technological change will undoubtedly also lower the direct costs of intensive silviculture investment, the major expenditures here take place in the near future. Real cost reductions would not be pronounced in the short term.

Table 6 presents the benefits and costs of silviculture investment, assuming a 1% per annum decrease in the real associated costs of harvesting and transporting timber. In general, assumptions regarding technological change make very little difference to the results. Net benefits of the reforestation project change only marginally, and remain positive only with a 5% discount rate[4].

c. Shadow pricing

In the cost calculations to this stage, the resources used in silviculture investment have been valued at their full market price. This reflects an implicit assumption of full employment in the markets for the inputs required. What if there is a recession with extreme unemployment in the forest industry? Alternatively, what if an individual project is located in an area of high unemployment or, in some other way, generates jobs for unemployed people? Under such conditions, it may be valid to "shadow price" the resources used in the silviculture projects at below their financial costs. However, a number of practical issues should be addressed before proceeding.

The timing of investment activities is an important consideration. Some reforestation activities such as brushing and weeding will not take place for a number of years. Current market conditions should not be projected too far in the future. If the economy is at a cyclical low, present unemployment rates are unlikely to persist. For this reason, shadow pricing, in this illustration, was only applied to the resources used in the first two years of the reforestation project. In effect, it is assumed that the rationale for shadow pricing is a

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[4] The output of the two projects has been valued at Vancouver log market prices, and at the this stage the product is an intermediate input to a sawmill, pulp mill or plywood and veneer operation. Technological change may result in additional cost saving further down the processing chain. In a competitive market situation, these cost savings would be reflected in higher log market prices. This is an additional and potentially significant benefit from technological change which is not dealt with here.

general cyclical downturn in the economy.

Caution should be exercised in estimating the potential of a project to reduce unemployment; it is unlikely that all of the labor hired and capital used will be currently unemployed. A one-to-one relationship between jobs created and reduction in unemployment occurs only where there is very high unemployment and a relative abundance of all required skills and equipment. Even in times of extreme unemployment, shortages can exist for specific skill categories and equipment items. Also, unless hiring is strictly controlled, there is uncertainty that the individuals employed or equipment used will be drawn from the pool of unemployed labor or capital.

Also, what specific shadow value should be attached to a particular input? For example, an assumption that the shadow price of unemployed labor is zero implicitly attaches a zero value to leisure, and this is not strictly true. Similarly, a zero shadow price for capital equipment ignores the deterioration of that equipment through use. Bearing all of this in mind, a shadow value of 50% of financial cost was attached to the capital and labor employed in both projects for illustrative purposes in this analysis,.

Finally, there is the problem of handling intermediate inputs such as fuel and the seedlings planted. For example, if two-year-old seedlings were used in the reforestation project, labor and capital market conditions may have substantially changed. Also, labor and capital are a very small element in the price of fuel. For these reasons, it is best that these intermediate inputs be valued at their full financial costs. For the reforestation project, the fuel cost of the initial site rehabilitation is assumed to be $250, and an additional $250 is the estimated cost of seedlings for planting. For the spacing/fertilization project, the fuel cost for helicopter delivery of fertilizer is assumed to be $150.

Shadow pricing does substantially reduce the direct costs of silviculture investment under all discount rates (Table 7). The effects are particularly pronounced with the spacing/fertilization project where direct costs are reduced to less than 60% of their previous levels. The reason for this is the more immediate nature of the investment. While spacing and fertilization take place within one year, reforestation activities extend over a considerable time period. Shadow pricing, on the basis of current labor and capital market conditions, has more leverage on the costs of the spacing/fertilization project.

Limitations and other considerations

Is the benefit-cost analysis described to this point adequate for decision making?

So far, it has dealt only with the efficiency effects of investment in silviculture. This dollars-and-cents orientation of benefit-cost analysis is often criticized, and it is certainly true that the objectives and responsibilities of government extend far beyond mere economic efficiency. For example, equitable distribution of income and improved quality of life are also fundamental social concerns. In addition, there are technical limitations with the efficiency analysis pursued to this point.

With respect to technical limitations, certain assumptions are implicit within a benefit-cost framework which may not be valid in all circumstances. As a specific example, studies by the British Columbia Ministry of Forests indicate that the present level of timber harvest cannot be maintained with the present level of silvicultural investment. The potential long-term decline in harvests could adversely effect the province as a whole, and particularly those areas which are almost solely dependent on the forest industry. Within the framework of benefit-cost analysis, there is an implicit assumption of a costless and easy adjustment to such changed levels of economic activity. However, this is unlikely to be the case. In general, long-run decisions are being made to invest in plant and equipment and regarding location of residence, etc., on the assumption of future continuity of timber supplies. Given this fact, future timber shortages could impose substantial social and economic costs on future generations of British Columbians. Clearly, avoidance, or at least reduction, of these social and economic costs may be a significant benefit of increased silviculture investment. These potential benefits should be recognized.

With respect to non-efficiency objectives of government, the overall program and individual projects within it may serve these to a greater or lesser extent. For example, in the context of the two hypothetical investment projects analyzed, the reforestation project may generate employment for native Indians or some equally disadvantaged group, while the spacing/fertilization project may have no similar impact. Also, the reforestation project may have more beneficial impacts on the quality of the environment by eliminating an eyesore in a populated area. To the extent that these other objectives of government are served better by the economically less-efficient project, maximizing social rather than economic efficiency may warrant its selection.

There are two general methods of dealing with technical limitations and with non-efficiency objectives in the context of benefit-cost analysis. First, an attempt can be made to integrate these effects within the financial framework. For example, the economic costs associated with falldown could be estimated. In this case, not only the direct but also the indirect (multiplier) impacts are relevant. In addition, the distribution of impacts between private and government sectors is an important consideration. Also, as suggested by Weisbrod (1968), weights can be assigned to the distribution of project benefits. Thus, additional income to a low-income group may be valued more highly than the same income to a high-income group. Finally, attempts can be made to value such nonmarket items as environmental quality. The major problem with this approach is the requirement for an explicit valuation by the analyst, which may require a large amount of information which is unavailable. Beyond this, however, and regardless of the particular methods used to derive such values, this procedure usurps the decision maker's role. In effect, it pushes benefit-cost analysis beyond its limited objective of facilitating rational choice.

A more satisfactory method of handling non-efficiency effects and broader social concerns is simply to document these impacts for parallel presentation with the financial information. In this procedure, the format of benefit-cost analysis is useful for clarifying thinking. Objectives beyond economic efficiency can be verbalized and the extent to which various alternatives contribute to their attainment can be investigated. In effect, it encourages a more tightly argued and quantitative approach to the impacts of a project in social and environmental terms.

A particularly good illustration of this procedure is given in the planning for Canada's west coast salmon enhancement program. Here, several high-priority objectives were identified including income and employment for both Native Indians and for residents in the less developed regions of B.C. Various measures of effectiveness in attaining these objectives were developed. Estimates were then made of the contribution of individual projects, as well as alternative programs, to the achievement of these objectives. All of this information was then provided in the program analysis (Friedlaender and Fraser 1981).

Summary and conclusions

This paper has illustrated benefit-cost methodology applied to two hypothetical silvicultural projects. Table 8 summarizes the net benefits under the initial base case and with the various specified assumptions examined. Under all assumptions, the spacing/fertilization project is the superior investment with net benefits consistently exceeding those of the reforestation project. However, no single assumption investigated here is sufficient to generate positive net benefits from either project at the 10% discount rate recommended by Federal Treasury Board for the evaluation of public sector investments.

It must be remembered that the numbers used in the analysis are rough approximations and the results should be interpreted with care. However, the assumptions regarding both revenues and costs are relatively generous reflecting investments which are undoubtedly superior to the average forest investment in the province. The two hypothetical projects are assumed to be located on the best land, involve the most valuable species and are located relatively near processing facilities. In addition, the outcome of the projects has been treated as certain. Realistically, project benefits should be deflated to reflect the risks of loss due to forest fire, insect or disease attack and plantation failure.

It is resoundingly clear that the discount rate is of overwhelming importance in determining the financial viability of forest investments. For this reason, both the theoretical determination of the appropriate discount rate and the empirical evidence on its specific value are discussed in Appendix I. A second appendix is included which investigates allowable cut effects. This is a controversial method which has often been used in forest investment analysis in order to circumvent the discount rate problem. The validity of using this method is questionable, but it is included for completeness.

The results of the financial analysis underline the importance of other non-efficiency benefits of silvicultural activities. It is likely that these broader social concerns are the primary justification for investment. However, this should not be used as an excuse to ignore the relative efficiency of various alternatives. Complete information on all of the various benefits of the proposed investments should be presented to decision makers, along with the financial information, for their consideration. The choice between various projects and programs remains a basic political decision. However, benefit-cost analysis can facilitate rational choice by ensuring that decision makers know the relative merits of their various options.

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Table 1. Average real price for Douglas-fir on the Vancouver Log Market (1981 dollars per cubic metre)

Year	Grade 1	Grade 2	Grade 3	All Grades
1978	78.44	62.07	35.37	43.72
1979	107.13	82.91	54.77	63.90
1980	107.94	80.99	42.80	53.75
1981	104.52	69.86	33.24	46.06
1982	100.86	58.58	26.28	42.20
Average	99.78	70.88	38.49	50.10

Table 2. The Benefits of Improved Management

	Backlog Reforestation	Juvenile Spacing/ Fertilization
Timber Output **Without** the Project (m^3)	0	750
Timber Output **With** the Project (m^3)	750	945
Incremental Production (m^3)	750	195
Value of Output **Without** the Project (1981 dollars)	0	37 575
Value of Output **With** the Project (1981 dollars)	53 160	66 982
National Income Benefits (1981 dollars)	53 160	29 407

Table 3. Direct Costs and Time Flow of Silvicultural Investment (1981 dollars per hectare)

Year	Description	Cost Element	
		Backlog Reforestation	
0	Site rehabilitation	Labour	254
		Machine rental	1016
		Total	1270
1	Planting	Labor	203
		Seedlings	250
		Total	453
4	Brushing and Weeding[a]	Labor	331
		Total	331
		Spacing/Fertilization	
0	Juvenile Spacing/Fertilization	Labor	969
		Helicopter rental	211
		Total	1180

[a] In some cases, brushing and weeding is unnecessary on planted land, while in other cases it is required a number of times prior to the seedlings reaching a free-to-grow stage. One treatment at year 4 is intended to represent an average requirement.

Table 4. Present Discounted Value of Benefits and Costs of Silviculture Investment (1981 dollars)

Discount Rate	Gross Benefit	Direct Costs	Associated Costs	Net Benefits	Benefit-Cost Ratio
			Backlog Reforestation		
5%	3631	1972	820	839	1.30
6%	2157	1959	487	–289	0.88
7%	1287	1946	290	–949	0.58
10%	281	1906	63	–1688	0.14
			Juvenile Spacing/Fertilization		
5%	3435	1180	364	1891	2.22
6%	2264	1180	240	844	1.59
7%	1498	1180	156	162	1.12
10%	444	1180	47	–783	0.36

Table 5. Present Discounted Value of Benefits and Costs of Silviculture Investment Assuming a 1% Per Annum Increase in Real Prices (1981 dollars)

Discount Rate	Gross Benefit	Direct Costs	Associated Costs	Net Benefits	Benefit-Cost Ratio
			Backlog Reforestation		
5%	6277	1972	820	3485	2.25
6%	3728	1959	487	1282	1.52
7%	2224	1946	290	12	1.01
10%	486	1906	63	−1483	0.25
			Juvenile Spacing/Fertilization		
5%	5323	1180	364	3779	3.45
6%	3508	1180	240	2088	2.47
7%	2321	1180	156	985	1.47
8%	1541	1180	105	256	1.20
10%	688	1180	47	−539	0.56

Table 6. Present Discounted Value of Benefits and Costs of Silviculture Investment Assuming a 1% Per Annum Decrease in Associated Costs (1981 dollars)

Discount Rate	Gross Benefit	Direct Costs	Associated Costs	Net Benefits	Benefit-Cost Ratio
			Backlog Reforestation		
5%	3631	1972	474	1185	1.48
6%	2157	1959	28	−81	0.96
7%	1287	1946	168	−827	0.61
10%	281	1906	37	−1662	0.14
			Juvenile Spacing/Fertilization		
5%	3435	1180	235	2010	2.43
6%	2264	1180	155	929	1.70
7%	1498	1180	103	215	1.17
10%	444	1180	30	−766	0.37

Table 7. Present Discounted Value of Benefits and Costs of Silviculture Investment Incorporating Shadow Pricing[a] (1981 dollars)

Discount Rate	Gross Benefit	Direct Costs	Associated Costs	Net Benefits	Benefit-Cost Ratio
			Backlog Reforestation		
5%	3631	1371	820	1440	1.66
6%	2157	1360	487	310	1.17
7%	1287	1347	290	–350	0.79
10%	281	1312	63	–1094	0.20
			Juvenile Spacing/Fertilization		
5%	3435	666	364	2405	3.33
6%	2264	666	240	1358	2.50
7%	1498	666	156	676	1.82
8%	995	666	105	224	1.29
10%	444	666	47	–269	0.62

[a] Assuming 50% shadow price of labor in year 0 and year 1. Assuming 50% shadow price of capital in year 0. Intermediate inputs are valued at full price.

Table 8. Summary of Net Benefits of Silviculture Investment (1981 dollars)

Discount Rate	Base Case	Price Increase 1% Per Annum	Technological Change 1% Per Annum	Shadow Pricing of Initial Costs
		Backlog Reforestation		
5%	839	3485	1185	1440
6%	–289	1282	–83	310
7%	–949	12	–827	–350
10%	–1688	–1483	–1662	–1094
		Juvenile Spacing/Fertilization		
5%	1891	3779	2010	2405
6%	844	2088	929	1358
7%	162	985	215	676
8%	—	256	—	224
10%	–783	–539	–766	–269

Appendix 1

Discounting and the discount rate

There are few procedures in the evaluation of forest investment as important and as controversial as discounting. The economics of silviculture are significantly affected by the long time horizon until investment payoff. Even with relatively low discount rates, the present values of gross benefits are substantially reduced over periods of 40 and 50 years. For this reason, there is considerable distrust of discounting among foresters. Even when the principle is grudgingly accepted, the rates used in forest investment analysis are often low compared to those used in the evaluation of other government investments as well as the private sector. In the foregoing analysis of two hypothetical forestry projects, we have not chosen this traditional route of least resistance, but have acknowledged Federal Treasury Board guidelines and have used rates in the 5 to 10% range. Consequently, an extensive discussion of the rationale for discounting and for these particular rates is advisable.

Human beings are impatient: individuals have a preference for present versus future consumption. Although individuals differ widely in tastes, income levels and a host of other considerations, it is possible to conceive of a "social time preference" which reflects the weighted average of such individual preferences. This time preference is reflected in a "rate" of compensation in terms of future consumption for the inconvenience of foregoing present consumption. This "social rate of time preference" is a natural starting point for any discussion of discounting.

As society foregoes present consumption (i.e., saves), resources can be invested productively so as to increase future consumption possibilities. Assuming perfect competition in the economy, the rate of return generated by the next investment opportunity, after all savings have been invested, is the "social opportunity cost of capital." Given a number of restrictions the equilibrium rate of time preference will equal the opportunity cost of capital. In this theoretical world, if investment returns were high relative to savings yields, entrepreneurs would offer higher returns to savers, thereby increasing the stock of investable funds and driving up the rate of time preference. Further investments would be made, reducing investment returns and the opportunity cost of capital as the more productive opportunities were exhausted. Finally, in equilibrium, savings yields and the investment returns would be equal, implying equality of the rate of time preference and opportunity cost of capital.

In any real economy, rates of return on investment do not equal savings yields. One obvious cause of divergence is taxation on the corporate sector. Taking an example directly from Mishan (1976, page 127), if 5% per annum is required to attract the necessary volume of savings, and if investment income is taxed at 50% then an investment must generate a 10% gross return. There will be a 5% spread between the rate of time preference and the opportunity cost of capital. Other causes of divergence include imperfect capital markets and imperfect knowledge of savings and investment opportunities. In the real world the opportunity cost of capital tends to exceed the social rate of time preference.

This divergence is important for there is a major debate among economists regarding the appropriate rate for use in the evaluation of public sector projects. The proponents of the opportunity-cost approach argue that this is the marginal rate of return realized in the private sector, and that government investment will be inherently wastefull unless it earns an equivalent yield. On the other hand, the proponents of the time-preference approach argue that the use of opportunity cost will lead to overly myopic decision making; too little investment will occur to the detriment of future generations. The argument proceeds that the social rate of discount expresses society's preferred allocation of resources between present and future and is the valid rate for the evaluation of public investment projects.[1] (Government of Canada 1976, page 25.)

There is some validity in both arguments. The opportunity cost of capital is an efficiency measure of the cost of productive resources in the economy. Its use in public sector evaluations will ensure maximum returns from any given level of investment. On the other hand, this given level of investment may be inadequate for future generations. Use of a second best discount rate which integrates the two concepts has been suggested. For example, one generally accepted approach recognizes that public sector investment funds can be obtained from different sources. Specifically, increased personal taxes will reduce *both* consumption and savings. It is argued that the opportunity-cost approach is appropriate for the portion raised from savings as it displaces private investment, while the rate of time preference is appropriate for reduced consumption. As a result, they suggest that a weighted average rate be used according to the proportion of funds raised from these two sources.

This source-of-funds approach, and its numerous variations, have some opponents. The British Columbia provincial government's guidelines on benefit-cost analysis reject the argument because funds can always be invested in the private sector. Consequently, there is never a rationale to discount at a lesser rate than the opportunity cost of capital (Government of British Columbia 1977, page 71). While Mishan (1976, pages 136-140) generally agrees with this reasoning, he notes the importance of political and institutional constraints. It may be infeasible to invest the funds in the private sector and, under these conditions, the source of funds is important. The appropriate discount rate for funds raised through reduced consumption is indeed the social rate of time preference. Overall, the compromise position is reasonable, and its general use is endorsed in the Federal Treasury Board guidelines.

Setting aside the debate on the appropriate discount rate concept, a second element of debate relates to the specific rate to be used. There are a large number of different rates of return on investments in different sectors of the economy and on different savings vehicles. This is due to unequal risks, differential effects of corporate and personal income taxes and a range of other circumstances. It is not obvious which specific rate should be used as a measure of either opportunity costs or social time preference.

An empirical study by Jenkins (1972) is the most widely cited analysis of the opportunity cost of capital. Jenkins employed the financial statements of numerous Canadian industries over the period 1965-1969 to estimate rates of return on private investment in the Canadian economy. He concluded that rates of return ranged from as high as 15.1% per annum in manufacturing industries to as low as 2.8% per annum in agriculture. However, he estimated the average overall rate of return on private investment at 9.5% per annum. It should be emphasized that even this is no basis for unanimity on the opportunity cost of capital. Some analysts, such as Sumner (1980) and Burgess (1981), have argued that Jenkins average rate of return on private investment is too high. Others, such as Mishan (1976) have argued that the discount rate should reflect only the highest yielding private investments. Suggested rates range between 7 and 15%.

There is considerably more agreement concerning the social rate of time preference. A study by Reuber and Wonnacott (1961) estimated the real rate of return on long-term Government of Canada bonds at 4.75% per annum. Also, a recent empirical study by Kula (1984) estimated the Canadian social rate of time preference at 5.2% per annum on the basis of data over the period from 1954 to 1976. In summary, a discount rate of about 5% appears to have general acceptance as the social rate of time preference.

This review of discounting and the discount rate should emphasize the need for discounting in the proper evaluation of forest investment activities. Disappointment at its impact on the economics of such investments should not lead to a blind dismissal of discounting as an unworthy and unnecessary frill in the analysis. Discounting reflects a rational desire of human beings for rewards to result from their sacrifices. This cannot be dismissed lightly. There is considerable

[1] This debate is often clouded by philosophical preferences. The use of a lower discount rate in the public sector will imply, over time, a larger public sector capital stock and an increased government presence in the economy. This is clearly less acceptable to advocates of free enterprise than to the more liberal and interventionist among the economics profession.

debate among economists on the appropriate concept as well as the specific rate to be used in the discounting process. However, the range of rates between 5 and 10%, used in this analysis, is not excessively high. Even the most generous analyst would not support a rate lower than 5%, while the upper bound of 10% is relatively low. There are a number of analysts who would support a rate of 15% or greater.

Appendix 2

Allowable cut effects

One controversial approach which has been pursued in order to circumvent discount rate problems is the use of allowable cut effects in the evaluation of forest investments. This effect results from the common forest management goal of sustainable yield and the calculations made to attain this target. This often implies that present harvests are perceived to be restricted by the present level of silvicultural investment.

As a specific example, in British Columbia the annual allowable cut is generally determined by the Hanzlik formula. In its simplest form, this can be expressed as:

$$\text{annual allowable cut} = \frac{\text{volume of mature timber}}{\text{no. of years in rotation age}} + \text{mean annual increment of immature stands over the planned rotation age}$$

This type of calculation is also given the general force of law in the Provincial Forest Act.

With this framework for cut calculations, a more immediate impact of silviculture investment is evident. By increasing the mean annual growth of immature stands, investment in forest management can have an impact on the present level of harvesting. In effect, it appears possible to reap the benefits accruing from the investment program gradually over the entire period until the harvest date. For example, the estimated 750 m^3 at year 55 resulting from the backlog reforestation project can be converted to a flow of 13.6 m^3 per annum over the 55-year period until harvest. Similarly, the 195 m^3 resulting from the spacing/fertilization project can be converted to an even flow of 4.4 m^3 per annum over the 44-year period until harvest. This shift of benefits forward in time can have an immense impact on the economics of silviculture. However, the validity of the procedure should be explored.

Is it technically feasible to increase harvests over the period until investment payoff? This depends fundamentally upon the age structure of the forest. The allowable cut effect assumes that sufficient mature forest will be available for harvest until the treated stand matures. This is by no means certain in a forest with age class discontinuities or a general lack of mature forest.

Even if sufficient mature forests are available over the lifetime of the project, there is another more fundamental issue involved. If the timber is available, the failure to harvest this timber is not directly dependent on present forest investment decisions. The decision not to harvest is the result of present forest management policies. The validity of the allowable cut effect therefore depends upon these policies remaining fixed and unchanged.

Is present management policy changeable? From a private company perspective, it appears reasonable to treat allowable cut policy as a fixed feature of management. It is not susceptible to change by independent corporate action. Consequently, the utilization of allowable cut effects in private forest investment decision making is undoubtedly rational. However, from a broader societal perspective, relevant for government investment decision making, it is less obvious that management policies are fixed. The government can change allowable cut policy at any time and thereby realize allowable cut benefits in the absence of forest investment. For this reason, the validity of allowable cut effects in the evaluation of government forest investments is questionable.

If allowable cut effects are considered, the net benefits of both projects increase very substantially under all discount rates (Table 2.1). Also, both projects, for the first time, generate positive net benefits with a 10% discount rate.

However, these results indicate another serious problem with the use of allowable cut effects in forest investment evaluation. Under the basic framework and other specialized variations pursued in this paper, the spacing/fertilization project was consistently rated the superior investment. The level of net benefits generated always exceeded those of the reforestation project. This situation is reversed when allowable cut effects are included. The net benefits of the reforestation project now consistently exceed those of the spacing/fertilization project under all discount rates. A large element of the benefits from spacing and fertilization result from quality improvement, which can only be realized when the treated stand matures and is harvested. In contrast, the major impact of the reforestation project is on the physical quantity of harvest. The allowable cut effect slants investment decisions toward those projects with physical impacts. This is a potentially serious distortion if it results in the rejection of more lucrative alternatives because of lesser impacts on the physical volumes. Other equally perverse results often follow from the use of allowable cut effects in forest investment evaluation.

Table 2.1. Present Discounted Value of Benefits and Costs of Silviculture Investment Incorporating Allowable Cut Effects

Discount Rate	Gross Benefits	Direct Costs	Associated Costs	Net Benefits	Benefit-Cost Ratio
			Backlog Reforestation		
5%	13 792	1972	4077	7743	2.28
6%	11 554	1959	3499	6096	2.12
7%	9898	1946	3050	4902	1.98
10%	6876	1906	2176	2794	1.68
			Juvenile Spacing/Fertilization		
5%	6214	1180	1252	3782	2.56
6%	4926	1180	1090	2656	2.17
7%	4009	1180	961	1868	1.87
10%	2482	1180	698	604	1.32