A Manager's Guide to Forestry Investment Analysis

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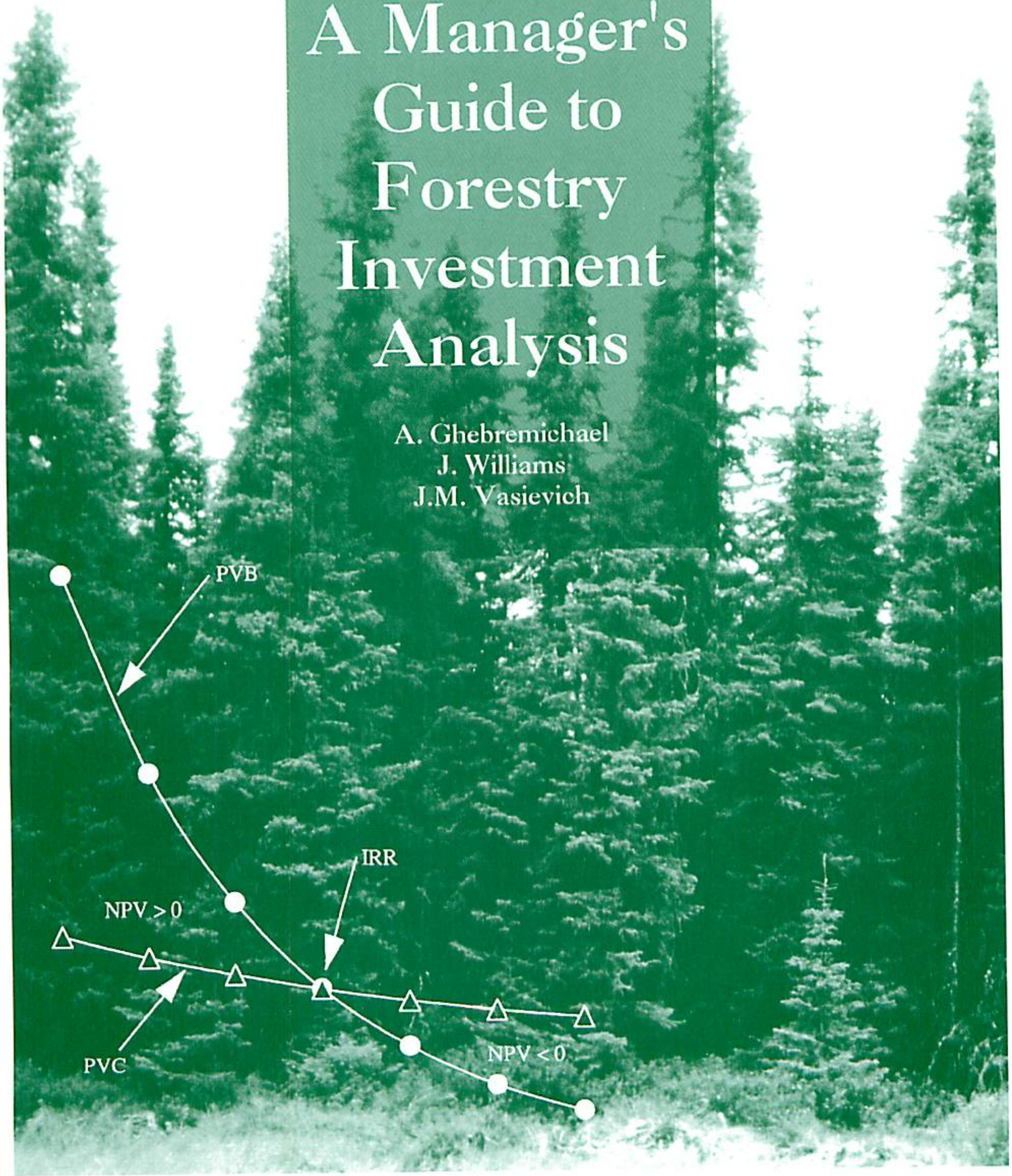

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A MANAGER'S GUIDE TO FORESTRY INVESTMENT ANALYSIS

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PREFACE

Assessing the social, economic, and ecological consequences of forestry operations is a prerequisite for establishing a sustainable code of forestry practices. It is commonly recognized that the task confronting professional foresters, policy makers, and researchers is to develop applicable formulas that will reconcile economic needs with the new and continuously changing environmental and social demands placed upon forest resources.

To allocate scarce resources among alternative courses of action, forest policy makers and managers face difficult choices. The objective of this guide is to help policy makers and practicing foresters to make the best possible decisions under given constraints. The guide presents forestry investment analysis in a ***programmed learning approach***. The user is introduced to a concept, shown an example or examples to illustrate its applications, and then asked to work on exercises that are expected to reinforce an understanding of the concept. Most of the exercises and the two case studies were selected from actual forestry operations in Ontario. They are presented in the "Tell, Show, Do" format that provides an added dimension of realism.

In specific terms, this guide is expected to help the user:

- learn how to apply the various types of forestry investment decision criteria;
- understand the unique characteristics of forestry in economic terms;
- appreciate the determining role of *time* in the process of forestry investment decision making;
- evaluate the impacts of interest, inflation, and tax rates on the final results of an analysis; and
- interpret analysis results that are often generated by computer software.

This guide is expected to be a companion to the Canadian version Quick-Silver release 4 (QS4) and other similar software. QS4 was developed by these authors concurrently with this guide under the socioeconomic research program of the Canadian Forest Service–Sault Ste. Marie with funding from the Northern Ontario Development Agreement (NODA), Northern Forestry Program, and the USDA Forest Service.

The scope of the guide's use is not limited to practicing foresters, managers, and policy makers. Instructors and students of colleges and universities will find it a useful supplement to text books.

The guide is organized into nine chapters and two appendices. Chapter 1 presents an introductory framework on the unique characteristics of timber production. Chapter 2 highlights the time value of money, while the techniques used for calculating present and future values are illustrated in Chapter 3. Applications of the commonly used forestry investment criteria are described in Chapter 4. Chapters 5 and 6 examine the difference between stand and forest level investment analysis procedures, respectively. Selected factors that influence credibility of analysis results are discussed in Chapter 7. *Why* and *how* social and private *perspectives* are always different are reviewed briefly in Chapter 8. Chapter 9 presents a summary. The techniques, the decision criteria, and the steps one has to follow when conducting analyses are summarized. Appendices 1 and 2 present two relatively comprehensive case studies.

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CHAPTER 1. INTRODUCTION

There are many spheres of decision making in forestry. They include investments in wood processing facilities, equipment purchases, road construction, harvest scheduling, silvicultural operations, and activities designed to support the nontimber values of forests. When forest managers deal with all or part of these areas of concern they take into account the unique characteristics of timber production.

1.1 Unique Characteristics of Timber Production

The following five special characteristics of timber production illustrate the complexity of forestry investment analysis and the decision-making difficulties forest managers often face.

Dual Nature of Timber

When a logger marks a tree for harvesting, it is clear that they have made a decision to destroy a production process. A standing tree is both a final product (timber), and a "manufacturing plant" that produced that final product. The output is virtually inseparable from the means of production. That is, the annual wood increment and the existing wood have virtually identical physical and chemical properties. This differs from the common productive processes, such as automobile manufacturing, where the output is easily distinguished from the equipment used to manufacture it.

Long Production Period

Unlike most production processes, timber production takes years to reach a harvestable age. Forest stands in Ontario can take from 50 to over 100 years to reach maturity. In contrast, most other production processes are generally completed within hours or days. This makes the choice of an appropriate discount rate a vital matter. It also requires estimates of future benefits, which are extremely uncertain due to the length of time involved.

Joint Production of Multiple Outputs

The primary objective of a woodlot owner, for example, may be to grow commercial timber, but numerous benefits are associated with the production process. These include wildlife habitat, recreation opportunities, climate regulation function, aesthetic values, soil and water conservation, improvement and preservation of biodiversity, and opportunities to diversify economies of remote communities through the development of a variety of economic activities, such as hunting, fishing, and ecotourism. Thus, joint production of multiple outputs is the most important unique characteristic of forestry operations that one has to bear in mind while designing policy or conducting forestry investment analysis.

Immobility

Although marketable like any other natural resource product, stumpage (i.e., timber on the stump) is fixed in a specific space; it is immobile. Stumpage is sold as it stands in the forest. This characteristic makes stumpage pricing very different from pricing other products, such as fish, oil, autos, sugar, and butter, except where open log markets exist. The stumpage price is highly dependent on the location of the trees.

Derived Demand

Demand for timber is derived from the demand for the various intermediate input products, such as lumber, plywood, and pulp. In turn, demand for these is derived from the demand for end-use products that include housing, furniture, and paper.

1.2 Objectives

This guide has been prepared to assist forest managers and planners in the use of economic analysis techniques. Financial and economic analyses are often given short shrift by forest managers. The goal of this guide is to help redress this situation. There are three key reasons why forest managers have perhaps been reluctant to give economic criteria a high weighting in forest management planning. First, foresters feel that economic analysis is abstract because it has never been fully explained to them. Therefore, they hesitate to use it. Second, some foresters may feel that trees and the activities that go toward maintaining a productive forest are not amenable to being valued in dollar terms. Third, foresters sometimes argue that economists do not understand the forestry context, and hence economic analysis may not be reliable.

Some of these objections can be answered here. The production of this guide is expected to serve as a response to the first and third points listed above, by demonstrating the value of economic analysis and clearly explaining how common analyses are conducted. Moreover, it is expected that this guide will enable foresters to undertake their own economic and financial analyses, or at least fully participate in them, thus ensuring a proper analytical framework is established. The lack of such a framework makes it difficult for forestry projects to compete with other projects for scarce financial or other resources.

Forest managers are responsible for efficiently allocating scarce resources among alternative courses of action. To accomplish this, they should be able to conduct basic economic analysis. In general terms, the social, ecological, and economic consequences of forest management operations should be understood.

Many people, including some foresters, disagree with the notion of placing values on trees, because of the nonmarketable environmental values they possess. Even those who do not object to evaluating all of the marketable and nonmarketable forest products agree that proper evaluation is difficult. Despite these objections, people are nevertheless compelled to evaluate trees and other natural resources. In other aspects of life, such as the insurance industry, values are affixed to human lives. Moreover, the health industry is rapidly approaching the point where economics plays an important role in selecting treatments for various ailments. There is no reason to think that forestry is not answerable to economic analysis.

The long time periods required for timber growth in Canada mean that any economic analysis of silviculture must contain forecasts made far into the future concerning timber prices and interest rates. Many people who are reluctant to make such forecasts are nevertheless willing to predict how forests will grow over time. In addition, it can be difficult to draw up an appropriate framework for analysis. Many forest economics texts focus on stand level financial analysis, but are not especially helpful in extending the analysis to the forest level.

It is technical difficulties such as these that this field guide is intended to address. Through the presentation of simplified analytical techniques, hands-on exercises, and two case studies it provides practising foresters with a working understanding of the principles and techniques of financial and economic analyses.

CHAPTER 2. TIME VALUE OF MONEY AND CASH FLOWS

2.1 Interest and Inflation Rates

People are very familiar with interest rates in their daily lives, although most of the time interest is thought of as being the cost of a loan or income that we receive from savings. Deeper insight can be gained into the nature of interest rates by considering what happens when money is burrowed. If $20,000 is burrowed to buy a new car, someone else's money is being used to pay for the car. The loan agreement is a promise to repay the debt.

However, if $20,000 is borrowed today and simply repaid with a $20,000 cheque 2 years later, the amount borrowed and the amount repaid will not have equivalent value, because the payments occur at different points in time. In other words, from the lender's perspective, the $20,000 borrowed today does not have the same value as the promise of $20,000 being repaid in 2 years time. And this is not just because of inflation.

As a matter of fact, irrespective of inflation and even if the borrower is trustworthy, there is a strong human desire to consume now rather than later. This phenomenon is known as *time preference*. Our impatience to consume now can be attributed to the human tendency to be less concerned with the future than the present, hence the attitude to spend today and let tomorrow look after itself. With the ever-present possibility that they will not be alive to enjoy consuming their savings, people tend to spend rather than save. On the other hand, people's sense of security can be enhanced knowing that there is some money available should an unforeseen expense arise or should their income fall. So, there are counter-balancing inclinations that influence people's rate of saving.

Another reason for the concept of *time preference* is because humans have the capability to use resources to produce manufactured goods. In general, production is the process of creating a product that has a higher value than the total value of the inputs. The manufacturer foregoes some current consumption when resources are devoted to production, but in the end the higher value of the product justifies its creation. Thus, the ability to add value through production means that lending money forecloses opportunities to generate wealth. For this, the lender must be compensated. The same logic also encourages saving and investment at the expense of consumption today.

Saving for future consumption or investment entails a delay in current consumption of goods and services. For instance, if the lender wishes to be compensated for giving up immediate opportunities, compensation will depend on the length of repayment time and the lender's rate of time preference.

Commenting on an earlier draft of this guide, Nautiyal[1] explained two components of *time preference*. On the one hand there is a rate of time preference that is a measure of the "impatience" of consumers. On the other, there is a rate of return from productive investments. This is a measure of the "hope" of increasing future consumption by deferring current consumption as savings or investments. These two are not the same except at the margin, if an equilibrium exits. This gives the marginal private rate of time preference as something equal to the market rate of interest. The former is known only through the latter. The social interest rate is somewhat lower than the private rate for various reasons.

Inflation is defined as a rise in the general price level. If the price of a good increases but there has been no improvement in quality or size (or general economic climate), then inflation has occurred. In effect,

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[1]Nautiyal, J. Faculty of Forestry, University of Toronto, Toronto, Ontario. (Personal communication)

money loses value during inflationary times because a given number of dollars buys less and less over time. Lenders will wish to preserve the value of their capital in the face of inflation, and this is done by increasing the rate of interest charged by some amount that will compensate the lender for inflationary devaluation.

In summary, the commercial rate of interest includes:

- a rate of time preference,
- a premium for risk, and
- a premium to cover the effects of inflation.

2.2 Cash Flows and Present and Future Values (Single Sum)

The previous section indicated that the value of an amount of money (or any object) depends in part on when it is to be received. This implies that when you want to assess the value earned by an investment or the value created by a project, the timing of costs and benefits (revenues)[2] will have to be tracked. Doing so will lay the groundwork for the calculation of the value of an investment project.

A useful device for organizing the costs and benefits of a project by time period is the cash flow diagram. This is simply a *time line*, with the origin representing the present year (i.e., Year 0). The time line can be drawn to a scale such that it extends over an appropriate planning horizon (Fig. 2.1).

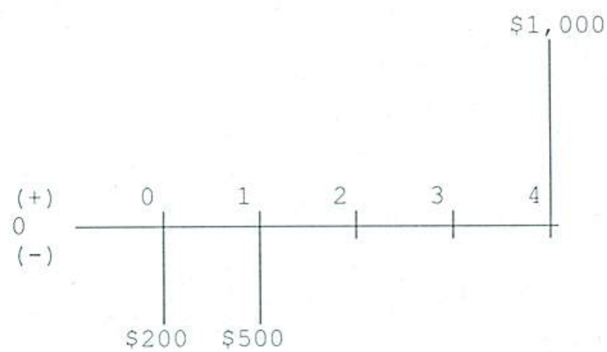

Figure 2.1. Cash flow of a hypothetical ginseng production project.

The costs and benefits associated with the sample project are shown in Table 2.1. Let us say that this project is designed for the production of wild ginseng, and the costs and benefits occur at the end of a given year. To begin the project, $200 must be spent to prepare the planting bed at the end of Year 0. After leaving the land fallow for 1 year, $500 is spent at the end of Year 1 to purchase plants and to plant them. The plants grow for 3 years (Years 2, 3, and 4). At the end of Year 4 the crop is harvested, generating a revenue of $1,000 (Fig. 2.1 and Table 2.1).

What is the value of the project presented in Table 2.1? Since the costs and the revenues occur in different years, the value cannot be ascertained simply by comparing totals of costs and revenues. If this was all that was needed, then a project with an initial cost of $700 in Year 0 and a benefit of $1,000 in Year 100 would have a net benefit of $300, which ignores the time value of money. This is clearly erroneous.

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[2]Benefits and revenues are used interchangeably.

Table 2.1. Cash flow summary of a hypothetical ginseng production project.

Year	Activity	Cost ($/ha)	Revenue ($/ha)
0	Land preparation	200	—
1	Planting	500	—
2	—	—	—
3	—	—	—
4	Harvesting	—	1,000

The standard way to account for time differences is to convert all costs and benefits to their equivalents at a single point in time. The techniques of discounting and compounding are used to calculate present and future values, respectively.

Discounting

Discounting is an analytical technique for taking a financial amount backwards to an initial point in time. Assuming that the impacts of inflation are negligible and the project is risk free, the present value of cost (PVC) of $500 paid at the beginning of Year 2, and the revenues generated at the end of Year 4, are calculated as follows:

Discounting a $500 cost over 1 year at a 10 percent discount rate yields:

$$PVC = 500/(1.10)^1 = 500(0.90909) = 454.55$$

The present value of benefits (PVB) of $1,000 revenue accrued at the end of the fourth year has to be discounted over 4 years. That is, discounting it year after year:

over 1 year gives	1000/(1.10) = 909.09 and
over 2 years gives	1000/[(1.10)(1.10)] = 826.45 and
over 3 years gives	1000/[(1.10)(1.10)(1.10)] = 751.31 and
over 4 years gives	1000/[(1.10)(1.10)(1.10)(1.10)] = 683.01.

This could also be expressed in one line as follows:

$$\begin{aligned} PVB &= 1000/[(1.10)(1.10)(1.10)(1.10)] \\ &= 1000/[(1.10)^4] \\ &= 683.01 \end{aligned}$$

In general, if the amount to be discounted in Year t is A_t and the discount rate expressed in decimal form is i, the present value (PV) is calculated using the formula in (2.1):

$$PV = \frac{A_t}{(1+i)^t} \tag{2.1}$$

Compounding

Compounding is the reverse process of discounting. It is a technique for taking a financial amount forward to a given point in time. That means that A_t is multiplied by a compounding factor to determine its future value (FV) after n number of years as given in (2.2):

$$FV = A_t(1+i)^n \tag{2.2}$$

Note that $\frac{1}{(1+i)^n}$ is a discounting factor (DF) and $(1+i)^n$ is a compounding factor (CF).

In the absence of a computer software package, such as the Canadian version Release 4 of Quick-Silver (QS4), one can follow the steps illustrated in Table 2.2 to calculate PV, FV, and net present value (NPV).

Observe the structure of the data in Table 2.2. Although no costs were incurred nor revenues accrued, Year 3 has to be taken into account to have a complete annual stream of cash flow. The results in Table 2.2 show that the project has an NPV of $28 and an NFV of $157. These two values are equivalent, since they are measures of the value of the project, calculated at different points in time—the present and the future.

Table 2.2. Steps to calculate PV, FV, and NPV using an interest rate of 10 percent.

Year (t)	Amount ($/ha)	DF $\frac{1}{(1+i)^n}$	CF $(1+i)^{n-t} = (1+i)^{4-t}$	PV	FV
(1)	(2)	(3)	(4)	(5)=(2)x(3)	(6)=(2)x(4)
1	(200)	1.0000	1.4641	(200)	(293)
2	(500)	0.9091	1.1000	(455)	(550)
3	—	—	—	—	—
4	1,000	0.6830	1.0000	683	1,000
Sum	—	—	—	NPV=28	NFV=157

In general,

$$NPV = \sum_{t=0}^{n} \frac{B_t}{(1+i)^t} - \sum_{t=0}^{n} \frac{C_t}{(1+i)^t} \tag{2.3}$$

where: B_t = benefits in year t,
C_t = cost in year t, and
n = total number of years in the project.

CHAPTER 3. DIFFERENT SERIES OF CASH FLOWS

Most forest management projects span a very long period of time. To evaluate these projects, one is required to calculate the present and future values of all costs and expected returns. This can be a tedious task when costs and benefits occur at irregular intervals, or are variable in value from period to period.

Fortunately, costs and benefits of large projects are often regular in occurrence. For example, many projects incur regular maintenance costs or involve the payment of annual fees or taxes. In such cases, there are formulae that can be used to facilitate the calculations. These formulae may be categorized into two classes. A distinction is often made between series of annual and periodic payments (e.g., a payment of $A every 4 years). The formulae for calculating the NPV of such series are closely related. A second distinction is made between terminating series and infinite series. As the names imply terminating series have a definite end point, unlike infinite series.

The next two sections describe the procedures for calculating present and future values of different series of cash flows. A summary of the formulae used is presented in Table 3.1 at the end of the chapter.

3.1 Present Values

The concept of present value lies at the core of economic analysis of private as well as public projects and policies involving streams of benefits and costs in future periods (Gillis 1991). This section highlights four types of cash flow series that require different techniques to calculate present value.

Terminating Annual Series

It is perhaps easier to start by deriving the formula for a specific example. Suppose that a payment of an amount $A is to be made at the end of each year for the next 10 years. The diagram in Figure 3.1 illustrates the cash flow:

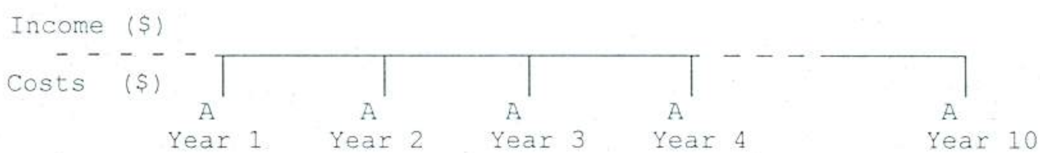

Figure 3.1. Terminating annual expenditure series.

The following summation is the present value of this stream of payments when the annual discount rate is i:

$$PV = \frac{A}{(1+i)} + \frac{A}{(1+i)^2} + \frac{A}{(1+i)^3} + \ldots + \frac{A}{(1+i)^{10}} \tag{3.1}$$

One term represents each year that a payment is made. Since payments are at the end of each year, the present value of the first payment is $A/(1 + i)$. The second payment occurs one year later and has a present value of $A/(1 + i)^2$. The series continues in the manner shown above. Multiplying (3.1) by $(1 + i)$ yields:

$$PV(1+i) = A + \frac{A}{(1+i)} + \frac{A}{(1+i)^2} + \ldots + \frac{A}{(1+i)^9} \tag{3.2}$$

Then, subtracting (3.1) from (3.2) and making simple algebraic arrangements yields:

$$PV = A\frac{[(1+i)^{10}-1]}{i(1+i)^{10}} \tag{3.3}$$

Generally, therefore, the formula for computing the PV of a terminating annual series is:

$$PV = A\ \frac{[(1+i)^{n}-1]}{i(1+i)^{n}} \tag{3.4}$$

where n stands for the number of years in the series.

The formula in (3.4) is useful in many forest management situations, as illustrated by the following example:

Example
The objective is to evaluate the feasibility of using precommercial thinning to offset an anticipated wood supply shortfall. It is estimated that it will be necessary to precommercially thin 500 hectares per year over the next 15 years to provide the required wood. Precommercial thinning costs $200 per ha, and capital can be borrowed at a rate of 8 percent per annum. Another alternative is to set aside $1 million this year to cover expected higher wood purchase costs in the future. Which alternative is financially viable?

Applying (3.4), the present value of the thinning operations is:

$$PV = 200x500\frac{[(1.08)^{15}-1]}{0.08(1.08)^{15}} = \$855,946$$

Thus, paying the precommercial thinning costs out of each year's budget is less costly than the alternative of putting aside $1 million.

Terminating Periodic Series

When the interval between each payment in a series is greater than 1 year, the series is said to be periodic. The formula for calculating the PV of such a series is very similar to the formula used for an annual series. The only differences are in the exponent of the discount term and in the elaboration of the "i" term in the denominator. The equation for such a series can be derived by the approach used above. Here, the interval between payments is t years and there are n periods. The first payment occurs after t years, the second after 2t years, and so on up to the final payment, incurred after n periods, with t years between periodic recurrences of A. Using the approach described from (3.1) to (3.3), the formula for computing the PV of a terminating periodic series can be proved, beginning at the start of Period 1, as follows:

$$PV = A\ \frac{\left[(1+i)^{nt}-1\right]}{\left[(1+i)^{t}-1\right](1+i)^{nt}} \tag{3.5}$$

It must be remembered that n and t stand for the number of periods in the series and for the number of years in each period, respectively.

Infinite Annual Series

In many instances, a tract of land may only be used for forestry purposes. In such cases, timber and other benefits obtained from managed land can be expected to continue indefinitely. That is, the proper planning horizon is infinite. The formula for the present value of an infinite series of annual payments is given in (3.6):

$$PV = \frac{A}{i} \tag{3.6}$$

Example

What is the present value of an infinite series of annual taxes of \$5 per ha when the prevailing discount rate is 5 percent?

Application of (3.6) yields: PV = 5/0.05 = \$100 per ha.

Infinite Periodic Series

The formula for the present value of this type of series is derived by replacing the "i" term in equation (3.6) with the term ($[1 + i]^t$ - 1) for a period of t years. Thus, the formula given in (3.7) is used to calculate the present value of an infinite periodic series.

$$PV = \frac{A}{[(1+i)^t - 1]} \tag{3.7}$$

Starting from bare land, (3.7) is a useful formula when examining the economic returns from stands grown to alternate rotation periods. This is because such a comparison must be done over a consistent time period. It would be misleading to compare the returns from one 80-year rotation to the returns from one 90-year rotation, because of the unequal time periods. One solution might be to extend the analysis of the 80-year rotation for 10 years into the second rotation. However, this would not be a good solution because the analysis period for the 80-year rotation would include two regeneration periods and only one harvest. To make a fair comparison, multiple rotations must be examined over a period of time, such that a final harvest occurs at the end of that period in each alternative.

The analyst would probably resort to comparing returns over a period of 720 years, which encompasses nine 80-year rotations and eight 90-year rotations. If an 85-year rotation was an option, the shortest analysis period would become 12 240 years. The analyst might spend more time selecting the analysis period than actually calculating the present net worth. A simpler approach is to use the infinite series formula, which automatically provides a consistent analysis period of an infinite time length.

Example

With this example the objective is to use (3.7) to determine whether it is more profitable to grow a stand to an 80-year or a 90-year rotation age. Assume that the land is currently bare and that natural regeneration can be obtained at no cost. If the rotation age is 80 years, the yield will be 250 m^3/ha. A 90-year rotation age will yield 275 m^3/ha. Assume that wood is valued at \$20 per m^3 and that the expected discount rate is 6 percent per annum.

If the rotation is set at 80 years, the stand will be worth of \$5,000 per ha at maturity. The PV of the infinite series of harvests is therefore:

$$PV = 5000/[(1.06)^{80} - 1] = \$47.71.$$

If the rotation is 90 years,

$$PV = 5000/[(1.06)^{90} - 1] = \$29.18.$$

3.2 Future Values

There are commonly encountered circumstances when it is necessary to calculate the future value of a series of payments. A common use of future values is in the establishment of a sinking fund, which is a savings fund created when an individual or company wishes their savings to have a given value at a given time in the future. This is often done when a company expects to purchase a large piece of machinery at some time in the future. This section presents the techniques for calculating future values of cash flows that occur in different time frames.

Terminating Annual Series

As above, the annual rate of interest is designated as "i", the amount of the annual cost or benefit as \$A, and the number of years in the series as n. The diagram in Figure 3.2 illustrates the cash flow:

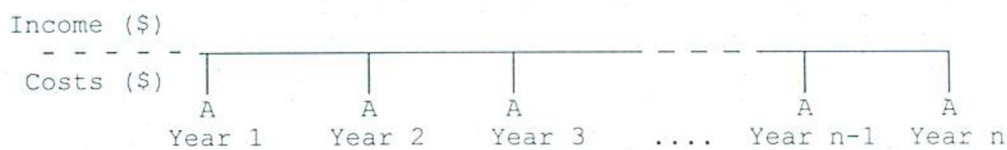

Figure 3.2. Terminating annual expenditure series.

The future value of this stream of payments is:

$$FV = A(1 + i)^{n-1} + A(1 + i)^{n-2} + A(1 + i)^{n-3} + \dots + A(1 + i) + A \qquad (3.8)$$

Multiplying both sides of (3.8) by (1 + i) yields:

$$FV(1 + i) = A(1 + i)^{n} + A(1 + i)^{n-1} + A(1 + i)^{n-2} + \dots + A(1 + i)^{2} + A(1 + i) \qquad (3.9)$$

Then, subtracting (3.8) from (3.9) yields:

$$FV(i) = A(1 + i)^{n} - A$$

That is:

$$FV = \frac{A[(1 + i)^{n} - 1]}{i} \qquad (3.10)$$

Example

Additional wildlife habitat can be produced by managing an uneven-aged forest under the selection system so that there is less growing stock per hectare than is optimal for timber production. The forest manager estimates that this will reduce by \$100 per ha the value of the harvest in the 20-year cutting cycle that has just begun. If the value of the additional habitat is estimated at \$4 per ha per year, and the prevailing rate of interest is 4 percent per annum, is this management decision economically justified?

To answer this question, first calculate the future value of the additional habitat over the cutting cycle and see how it compares to \$100 by applying (3.10).

That is:

$$FV = \frac{4[(1.04)^{20} - 1]}{.04}$$

$$= \$119.11$$

Since this amount exceeds by more than \$19 the expected \$100 reduction in timber value, this management option is financially justified.

Sinking Fund Formula

When a sinking fund is established, the desired future value is known, as is the number of periods for which the fund will be operated and the expected rate of interest. The problem is to determine the appropriate annual payment. The sinking fund formula derived from (3.10) is:

$$A = \frac{i\,(FV)}{\left[(1+i)^{n}-1\right]} \qquad (3.11)$$

Example

The values ascribed to wildlife habitat are often subject to significant uncertainty. If in the previous example the manager wishes to determine the annual value habitat must have for its future value to equal \$100 in 20 years, applying (3.11) yields:

$$A = \frac{.04(100)}{[(1.04)^{20} - 1]}$$

$$= \$3.36$$

Thus, as long as the manager feels that the additional habitat created will be at least equal to \$3.36, the chosen management strategy could be justified.

Terminating Periodic Series

This is similar to the case of the terminating annual series, except that the period between payments is 2 or more years. For example, if the interval is designated as t years, the cash flow diagram would appear as given in Figure 3.3.

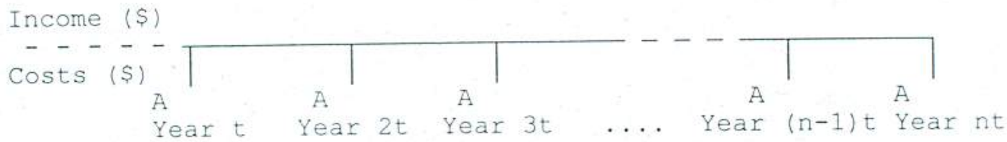

Figure 3.3. Terminating periodic expenditure series.

The future value of this type of payment or income stream can be calculated using the formula given in (3.12):

$$FV = \frac{A[(1+i)^{nt}-1]}{[(1+i)^{t}-1]} \tag{3.12}$$

Example

A 25-year-old plantation is destroyed by fire. The owner wishes to evaluate the damage by calculating the present value of all the expenditures made during the life of the plantation. Suppose that one of the costs involved spraying the plantation every 5 years. The cost of each application was $2,500, starting when the plantation was 5 years old, and the owner had just had the plantation sprayed when it burned. The prevailing rate of interest is 6 percent. What is the PV of this stream of expenditure?

Because the past costs are being brought forward to the present (i.e., compounding previous expenditures), the future value formula should be used. Starting in 1975, there would have been five spray applications during the life of this plantation. Figure 3.4 sets these out:

Figure 3.4. Terminating periodic expenditure series.

This can easily be solved using equation (3.12):

$$PV = \frac{2500[(1.06)^{25} - 1]}{[(1.06)^{5} - 1]}$$

$$= \$24,332$$

Table 3.1. A summary of key formulas.

Frequency of payment	Calculation type	Formula	Equation number
Terminating Series			
Annual	Present Value	$PV = A\frac{\left[(1+i)^{n} - 1\right]}{i(1+i)^{n}}$	(3.4)
Periodic	Present Value	$PV = A\frac{\left[(1+i)^{nt} - 1\right]}{\left[(1+i)^{t} - 1\right](1+i)^{nt}}$	(3.5)
Annual	Future Value	$FV = A\frac{\left[(1+i)^{n} - 1\right]}{i}$	(3.10)
Periodic	Future Value	$FV = A\frac{\left[(1+i)^{nt} - 1\right]}{\left[(1+i)^{t} - 1\right]}$	(3.12)
Infinite Series			
Annual	Present Value	$PV = \frac{A}{i}$	(3.6)
Periodic	Present Value	$PV = \frac{A}{\left[(1+i)^{t} - 1\right]}$	(3.7)

References

Gillis, M. 1991. Economics, ecology, and ethics: Mending the broken circle for tropical forests. *In* F.H. Bormann and S.R. Kellert, eds. Ecology, Economics, and Ethics: The Broken Circle. Yale University Press, New Haven, CN. 233 p.

CHAPTER 4. DECISION CRITERIA

The formulas used for calculating present and future values are used in analyzing investment projects. However, they do not by themselves give any guidance as to how to make decisions. For that, it is necessary to discuss the various decision-making criteria that can be used to assess investment projects.[3]

Generally, the analyst is concerned with selecting the most profitable of several alternative projects. A variation of this involves examining whether a given course of action is profitable, which is really a comparison of two options: to invest or to maintain the status quo. The general approach to answering these types of questions is known as cost-benefit analysis (CBA). As the name implies, the technique compares costs and benefits associated with a project to assess its economic attractiveness.

Not surprisingly, there are a number of measures of a project's economic attractiveness. As these measures are investigated, it is found that each measure (criterion) is more appropriate in some circumstances than in others. It should also be noted that where two or more criteria are applicable, each criterion may provide a unique ranking of projects. In such cases it is necessary to understand what aspect of each project is being assessed by each criterion, because subtle differences may lead to rather different ratings of a particular project.

In this chapter, the commonly used investment decision-making criteria are explained. Their applications are illustrated and the advantages and disadvantages of each criterion are highlighted.

4.1 Payback Period

Payback period (PBP) is the simplest measure of forestry investment attractiveness. It is the length of time required to recover the cash investment in a project. The project with the shortest payback period is the best, according to this criterion. If the annual returns from an investment are equal, the formula for the payback period is:

$$PBP = \frac{I_0}{R_t} \tag{4.1}$$

where: I_0 = initial investment, and
R_t = annual return

If the annual returns are not equal, the mean annual return is used as the denominator. That is, divide I_0 by the mean value of the different annual returns to obtain PBP.

Example

In this example the manager of logging operations, would like to propose to their supervisor that if the company bought a new skidder productivity would increase significantly. Based on market research, a larger machine costs $400,000 and a smaller machine costs $250,000. The annual reduction in harvesting costs is estimated to be $100,000 if the larger machine is bought, while a reduction of $50,000 per year is estimated if the smaller machine is purchased. Which machine should be recommended?

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[3] For an in depth discussion on project evaluation, the interested reader is referred to Chapter 20 of Nautiyal, J.C. 1988. Forest economics, principles and applications. Canadian Scholars' Inc., Toronto, ON. 581 p.

Using PBP can lead to a reasonably good decision:

PBP on the small skidder = 250,000/50,000 = 5 years
PBP on the large skidder = 400,000/100,000 = 4 years

Therefore, purchasing the large skidder would be favorable.

Advantages

Besides its simplicity, PBP is a good indicator of the risk associated with an investment. The shorter the payback period, the less risky the investment. PBP may also be an appropriate indicator to use when investment capital is scarce.

Disadvantages

There are several disadvantages associated with PBP. An obvious one is that it doesn't consider benefits after the payback period. A more subtle drawback is that the interest cost on the invested capital is not considered. This could be significant if interest rates are expected to change over time or if some or all of the extra capital required for the larger skidder is more expensive than the initial $250,000.

In summary, the payback period is useful when used in conjunction with some of the following criteria.

4.2 Net Present Value

Net present value (NPV) is one of the most widely used measures of an investment's viability. It is also interchangeably referred to as present net value (PNV) or present net worth (PNW).

As the name implies, NPV is the difference between the total of discounted benefits (revenues) and the total of discounted costs. The formula described previously in (2.3) is repeated in (4.2) for ease of reference:

$$NPV = \sum_{t=0}^{n} \frac{B_t}{(1+i)^t} - \sum_{t=0}^{n} \frac{C_t}{(1+i)^t} \qquad (4.2)$$

which means: NPV $= \sum$ Discounted Benefits - $\sum$ Discounted Costs

$= \sum PVR_t - \sum PVC_t$

where B_t, C_t, i, and n are as described in Chapter 2 under Equation 2.3.

An important assumption in this calculation is that the intermediate returns will be invested to earn the same rate of interest used in discounting.

The decision rule is to accept projects with the highest NPV. In general terms, any project with a NPV greater than zero is viable.

Example

Table 4.1 summarizes costs and revenues of a Christmas tree project. The plantation establishment cost is in Year 0 and the maintenance costs (overheads) occur in subsequent years. Benefits are recorded in Column 3. Some trees can be cut and sold in Year 6, but most of the trees are harvested in Years 7 and 8. The plantation is replanted at the end of Year 8. What is the NPV of this project at an interest rate of 5 percent? Is it a viable project? The procedure summarized in Table 4.1 is useful to solve problems of this nature.

Table 4.1. Steps to calculate NPV of a Christmas tree plantation.

Year	Costs	Revenues ($/ha)	Discounting factor $\frac{1}{(1.05)^t}$	PVC_t	PVB_t
(1)	(2)	(3)	(4)	(5) = (2)x(4)	(6) = (3)x(4)
0	2,000	n/a	1.0000	2,000	n/a
1	n/a	n/a	0.9524	n/a	n/a
2	400	n/a	0.9070	363	n/a
3	450	n/a	0.8638	389	n/a
4	200	n/a	0.8227	165	n/a
5	400	n/a	0.7835	313	n/a
6	200	750	0.7462	149	560
7	200	2,500	0.7107	142	1,777
8	200	2,500	0.6768	135	1,692
Sum	—	—	—	3,656.00	4,029.00

Note: n/a = not applicable

Therefore: $NPV = \sum PVB_t - \sum PVC_t = 4{,}029 - 3{,}656 = 373$,
PVC_t = present value of costs in year t, and
PVB_t = present value of benefits in year t.

An NPV of $373 per ha indicates that the Christmas tree project is profitable at the given interest rate of 5 percent.

Advantages and Disadvantages

NPV is commonly accepted as a more reliable criterion than the others, provided the following assumptions are acknowledged:

- intermediate returns are reinvested,
- it is possible to forecast estimates of future prices and costs, and
- an estimate of a "correct" discount rate that reflects society's preference can be obtained.

It should also be kept in mind that NPV says nothing about the distribution of costs and benefits among different segments of society.

Note that NPV depends on the rate of discount and the length of time—the higher the discount rate and the longer the time before benefits are received, the lower the NPV. As illustrated in Figure 4.1, NPV declines rapidly as the interest rate increases. This indicates the rising costs of invested capital.

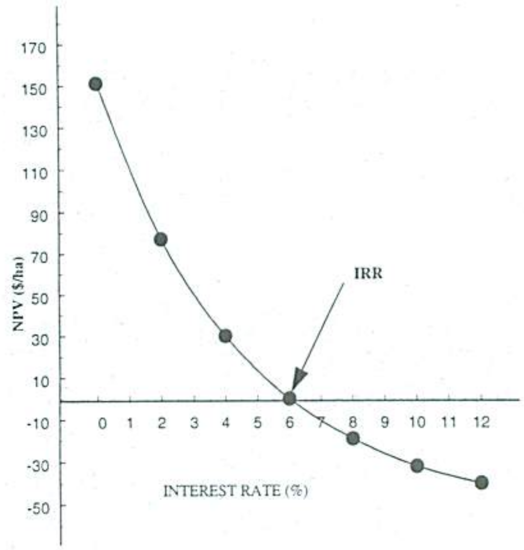

Figure 4.1. Effects of increasing interest rate on the level of NPV.

4.3 Internal Rate of Return

The interest rate that equates NPV to zero is referred to as the internal rate of return (IRR). That is, IRR = i such that:

$$NPV = PVB - PVC = 0 \qquad (4.3)$$

Any project with an NPV of zero earns a return exactly equal to the discount rate. For this to happen, PVB must be equal to PVC.

IRR is viewed by analysts as a measure of the annual growth rate of value generated from an investment. It can also be interpreted as an average appreciation rate of invested capital. To be considered attractive, the IRR of the selected project should be higher than the IRR of the next best investment. If the IRR is less than the rate of interest that prevails in the economy, the project is not attractive.

Project rankings based on the IRR may not agree with rankings based on the NPV, but a project with a positive NPV will always earn an IRR higher than the discount rate.

Advantages

Use of the IRR saves the analyst the difficulties of estimating discount rates. In other words, the IRR is independent of the discount rate. People also like having a measurement of profitability in the form of an interest rate, because it is easy to understand. The IRR of a project should be compared to a minimum acceptable rate of return, which is often known as the hurdle rate. This may be set equal to the interest rate (if capital has to be borrowed) or at the rate of return on the next most profitable investment. Thus, in setting the hurdle rate, the analyst may have to think about appropriate discount rates.

Disadvantages

IRR has two obvious limitations. First, multiple IRRs can be calculated for some investments. This is a drawback, because it is not clear which one to use in evaluating a project. The number of IRRs that can be calculated for a project equals the number of sign changes in the flow of net benefits. The second problem is the assumption that intermediate incomes will be reinvested at the same rate as the IRR. This is not always the case and often not even a possibility. In the final analysis, this criterion is meaningless unless the time horizons of other projects are of the same length.

Example

The Ontario Ministry of Natural Resources is considering an investment in the use of miniplug stock to regenerate black spruce (*Picea mariana* [Mill.] B.S.P.) cutovers in northwestern Ontario. The cost of production of the miniplugs, site preparation, and planting is \$50 per ha. Basic silvicultural operations (e.g., weed control, spacing, and tending) will cost \$50 per ha in 10 years. This relatively intensive silviculture is expected to eliminate the need to thin the stands in 20 years, thereby resulting in a cost saving of \$250 per ha (i.e., benefits of intensive silviculture). What is the IRR of this silvicultural investment?

The analytical procedure and results are summarized in Table 4.2.

The IRR of the hypothetical project described in Table 4.2 is 6 percent. This is illustrated in Figure 4.2. At a point where the PVB and the PVC are equal (i.e., NPV = 0), the IRR is 6 percent.

In summary, the results in Table 4.2 verify three important notions:

1. As the interest rate rises, the NPV decreases due to the higher cost of borrowed money.
2. The IRR of return on the investment is 6 percent, at which the NPV is zero.
3. The interest charge on borrowed money for this purpose should not be greater than 6 percent.

Table 4.2. NPV and IRR of a hypothetical black spruce cutover regenerating project.

Interest	Cost discounting factor (CDF) $\frac{1}{(1+i)^t}$	PVC[1]	Benefit discounting factor (BDF) $\frac{1}{(1+i)^{20}}$	PVB[2]	NPV[3]
0	1.00000	100	1.00000	250	150
2	0.82035	91	0.67297	168	77
4	0.67557	84	0.45639	114	30
6	0.55839	78	0.31180	78	0
8	0.46319	73	0.21455	54	-19
10	0.38554	69	0.14864	37	-32
12	0.32197	66	0.10367	26	-40

[1]PVC = CDFx\$50.00 (the amount after 10 years) + \$50.00 (the initial amount).
[2]PVB = BDFx\$250.00 (benefits of intensive silviculture).
[3]NPV = PVB - PVC.

Notice that as the interest rate increases the PVB of the project declines more rapidly than its PVC (Fig. 4.2). Why? This question is one of the important aspects of forestry investment. Discounted benefits decline faster than discounted costs because, in forestry, benefits generally occur long after project costs, and they are discounted more heavily to yield present values.

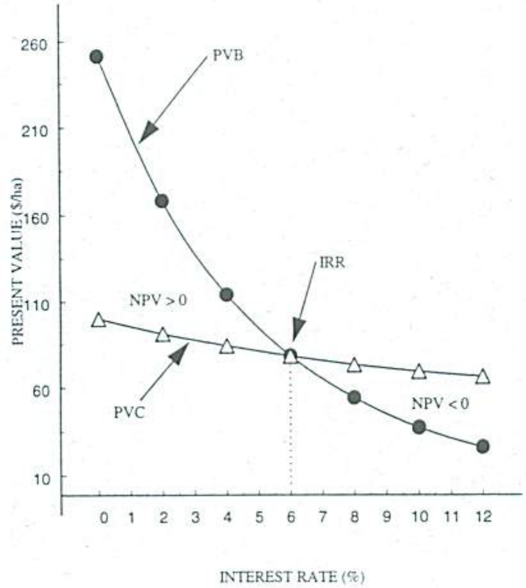

Figure 4.2. Effects of an increasing interest rate on the levels of PVB and PVC.

4.4 Composite Rate of Return

Calculation of the IRR involves an implicit assumption that any income earned is reinvested so that it will earn a rate equal to the IRR. This can lead to situations in which there are multiple IRRs. To illustrate, consider a project that has a net cash flow of -100, 150, and -50 over a 3-year period. If the $150 earned in Year 2 can be invested at a rate of 0 percent (i.e., earns no interest), this will be consistent with a 0 percent IRR. On the other hand, reinvestment at a 100 percent rate of return is also consistent with a 100 percent IRR.

At a 100 percent rate of return, the $150 net revenue will double over the last year of the project and be worth $300. Similarly, the net cost of Year 1 will double twice during the project. Neither of these reinvestment assumptions can be validated as shown in Table 4.3.

Table 4.3. Illustrating the problem associated with the IRR reinvestment assumption.

Year	Net revenue	Compounding factor	Future value of net revenue
1	-50	4	-200
2	150	2	300
3	-100	1	-100
Sum	—	—	0

The composite internal rate of return (CIRR) (Marty 1970) is a measure that corrects this potential flaw in the IRR approach by calculating a rate of return with an explicit assumption of the rate earned through reinvestment. The CIRR can be calculated from the n^{th} root of the ratio of the future value of all benefits (FVB) to the present value of all costs (PVC) minus one.

That is:

$$CIRR = \left[\sqrt[n]{\left(\frac{FVB}{PVC}\right)} - 1\right]100 \qquad (4.4)$$

where n is the time period of the project in years (i.e., at final harvest age).

Advantages

The CIRR has two important advantages over the IRR. First, it provides a unique solution, resolving the multiple IRR problem. Second, it is consistent with NPV in that the CIRR will always exceed the alternate rate of return whenever the investment has a positive NPV, discounted at the alternate rate (Marty 1970).

Disadvantages

Two limitations are obvious. First, the implicit assumption made for the IRR that intermediate incomes will be reinvested is not resolved by CIRR. The second unresolved problem is related to the fact that CIRR is based on a ratio and, as such, its value depends on whether cash flows are treated in net or gross terms.

Example

Suppose in 30 years time the totals of FVB and PVC of a given investment are $10,755 and $2,000, respectively. What is the CIRR?

It can easily be computed by inserting the appropriate values into (4.4).

That is:

$$CIRR = \left[\sqrt[30]{\left(\frac{10755}{2000}\right)} - 1\right]100 = 5.7617\%$$

Note that the roughly 5.8 percent CIRR from this hypothetical investment is unique. That is, there is only one CIRR for this project, resolving one of the limitations associated with the IRR.

The NPV of the project is positive when the CIRR exceeds the reinvestment rate of return, whereas the NPV of a project is negative when the reinvestment rate of return exceeds the CIRR. Investment situations will occur when it will be inappropriate to employ a single reinvestment rate. Different rates can be used without invalidating the approach described above, even though the calculations will be more complicated.

4.5 Equivalent Annual Income

An equivalent annual income (EAI) is the amount of annual payment that will just pay off the NPV of an asset during its lifetime. In other words, the present value of an annual series of payments, each of which is equal to EAI, represents the NPV of the project. EAI is also interchangeably referred to as an equal annual income (EAI) or an equal annual equivalent (EAE). EAI is especially useful for comparing forestry investments with projects that generate annual returns, mainly agricultural investments.

The steps to calculate EAI are simple. First, calculate the NPV of the forestry project. Second, convert the NPV to EAI using the capital recovery multiplier (CRM), the term in the square bracket of the formula given in (4.5).

$$EAI = NPV\left[\frac{i(1+i)^n}{[(1+i)^n - 1]}\right] \tag{4.5}$$

where i is the annual discount rate and n is the length of the time period (rotation) in years.

For comparative purposes, a project with the highest EAI is the best alternative. In general, a positive EAI indicates a profitable investment.

Advantages and Disadvantages

The key advantages of EAI are: a) it is useful for comparing forestry with other land uses, such as agricultural practices, that generate annual benefits; b) it is easier to comprehend than NPV; and c) it has the same drawbacks as the NPV calculation.

Example

The NPV of the Christmas tree plantation described in Example 4.2 was calculated to be \$373. The EAI of this project is:

$$EAI = 373\left[\frac{0.05(1.05)^8}{[(1.05)^8 - 1]}\right] = \$57.71$$

Thus, the Christmas tree plantation earns annual equivalent net benefits of \$57.71 per ha.

4.6 Cost-benefit Ratio

Cost-benefit ratio (CBR) is a measure of the average "bang for your buck" from an investment. It is calculated by dividing the sum of present value of costs by the sum of present value of benefits. That is:

$$CBR = \frac{\sum_{t=0}^{n} C_t(1+i)^{-t}}{\sum_{t=0}^{n} B_t(1+i)^{-t}} \tag{4.6}$$

which means:

$$CBR = \frac{\sum PVC_t}{\sum PVB_t} \tag{4.7}$$

A project that breaks even will have a CBR of one. A profitable project will have a CBR less than one, and a money-losing project will have a CBR of greater than one. CBR is related to NPV in the following manner:

CBR < 1 implies NPV > 0; accept project.
CBR = 1 implies breakeven, NPV = 0; consider nonfinancial issues also.
CBR > 1 implies NPV < 0; reject project.

Note that the actual CBR value depends on the discount rate used for the calculation.

Advantages

The CBR is especially useful when an analyst is considering alternative sets of projects where one or more of the projects may be undertaken a number of times. A common example of this type of situation is when alternative silviculture treatments are being compared. Each treatment is assessed on a per hectare basis but the forester can treat numerous hectares and, in effect, undertake a number of 1-hectare silviculture projects.

Disadvantages

The main drawback of the CBR is that it does not provide information about the size of the net gain or loss. Thus, it is best used in conjunction with another criterion, such as NPV.

Example

The analysis detailed in Table 4.1 for the Christmas tree plantation shows that the totals of PVB and PVC are $4,029 and $3,656, respectively. What is the CBR of this project?

The solution is very straightforward, since the PVB and PVC were already calculated.

Thus:

$$CBR = \frac{PVC}{PVB} = \frac{3656}{4029} = 0.907$$

This implies that the project is financially viable. This is the same conclusion that was reached using NPV.

4.7 Soil Expectation Value and the Annual Rent

Soil expectation value (SEV) is the discounted value of the maximum net revenue that can be earned from a parcel of land. SEV is also referred to as land expectation value and bare land value. It is an indicator of the future stream of net income that a hectare is expected to generate.

Often, the concern of foresters is the value that can be earned by bare land that is expected to be reforested and managed for timber crops in perpetuity. That is, SEV is calculated over a perpetual series of rotations. Although the procedure for calculating SEV is similar to that for calculating NPV, the SEV is a very specific form of NPV calculated under the following assumptions:

- the land is currently bare, but is expected to produce timber in perpetuity;
- the values of all costs and benefits are assumed to be constant over all rotations;
- regeneration costs are always incurred at the beginning of each rotation; and
- the market value of the land does not enter into the calculation: SEV is the land value.

SEV calculation steps are summarized as follows:

First, calculate the net future value (income) per year using the formula in (4.8).

That is:

$$NFV = \sum_{t=0}^{n} B_t (1+i)^{T-t} - \sum_{t=0}^{n} C_t (1+i)^{T-t} \qquad (4.8)$$

where: NFV = net future value of annual income generated at the end of every rotation,
B_t = benefits received in year t,
C_t = costs incurred in year t,
T = rotation age in years,
i = interest rate, and
t = length of time in years, t = 1, 2, 3, ..., T.

Then:

$$SEV = NFV \left[\frac{1}{[(1+i)^T - 1]} \right] \qquad (4.9)$$

Example

An individual is hired by a potential buyer to analyze the financial value of some abandoned farm land in southern Ontario. The buyer plans to reforest this land and manage it for pulpwood on a 30-year rotation in perpetuity. A total cost of $80.00 per ha is estimated for site preparation and regeneration. Annual management costs and property taxes have been estimated to be $1.50 per ha. Intermediate benefits will be generated from commercial thinnings at ages 18 and 25, yielding 15 m^3/ha and 25 m^3/ha, respectively. The final harvest is estimated to be 90 m^3/ha. The stumpage price of pulpwood is estimated to an average $70.00 per m^3. What is the maximum amount that the potential buyer should pay for the bare land? Table 4.4 summarizes the solution.

Table 4.4. A summary of steps required to calculate SEV.

Year	Item	Amount	Compounding factor $(1+i)^{T-t}$	Future value ($/ha)
(1)	(2)	(3)	(4)	(5) = (3) x (4)
Revenues				
18	Thinning	1,050	2.0122	2,113
25	Thinning	1,750	1.3382	2,342
30	Harvest	6,300	1.0000	6,300
TFVR = total future value of revenues				10,755.00
Costs				
0	Site preparation and regeneration	80.00	5.7435	450
1–30	Annual costs (overheads)	1.50	$\left[\frac{(1.06)^{30}-1}{0.06}\right]$ = 79.0582	118.60
TFVC = total future value of costs				568.60

Therefore: NFV = TFVR - TFVC = 10,755 - 568.60 = 10,186.40

Then, the value of the bare forest land is:

$$SEV = 10186.40\left[\frac{1}{(1.06)^{30}-1}\right] = 10186.40(0.2108) = 2,147.30$$

Therefore, $2,147 per ha is the maximum amount that could be paid for the land, such that the property would still earn the required 6 percent rate of return. This means that the client could pay $2,147 per ha for the land and earn at least 6 percent on their investment.

References

Marty, R. 1970. The composite internal rate of return. For. Sci. 16:276–279.

Exercises

1. An owner of a tolerant hardwood stand wishes to harvest the stand this year. Two foresters were asked for a suggested harvest prescription. They were also asked to estimate the harvest revenue that could be obtained at the end of the next two 20-year cutting cycles. Forester A suggested foregoing short-term revenue to build up the stand's growing stock. He/she expected the three cuts to net $800; $1,200; and $2,000 per ha. Forester B suggested a heavy initial cut to remove the low-quality material, earning $1,200 per ha, followed by harvests yielding $700 at the end of the two cutting cycles.

(i) If the interest rate is 6 percent, which regime will yield the highest NPV?

(ii) At what interest rate does the other regime become profitable?

2. What is the internal rate of return of a project that requires investments of $500 in each of the first 2 years and returns $1,200 at the end of Year 3?

3. If jack pine grown on an 80-year rotation yields an NPV of $500/ha when the discount rate is 5 percent, what is the equivalent annual income earned?

4. An individual is planning to purchase a 500-ha tract of land for $100,000. They estimate that they can earn $5,000 each year in perpetuity by selling camping and other recreation rights. If the discount rate is 4 percent, is this investment profitable? (Ignore the resale value of the land.)

   If the next best investment earns 4 percent per annum, should the individual buy the land or make the alternate investment?

5. First, designate two silvicultural intensities as "high" and "low". The low-intensity silviculture costs $200/ha and in 80 years will yield a stand worth $1,500. High-intensity silviculture costs $500 per hectare and yields a stand worth $2,000 in 60 years. Calculate the NPV and CBR of these two treatments, using a 4 percent discount rate. Which level of silviculture is most attractive?

CHAPTER 5. APPLICATIONS OF CRITERIA TO SINGLE STAND LEVEL DECISIONS

In this chapter, uses of the decision criteria to examine single-stand problems will be illustrated. Two common problems in even-aged forest management will be examined: a) selection of an optimal rotation age and b) choosing a viable thinning regime.

5.1 The Economically Optimal Rotation Age

Choosing an economically optimal rotation age is one of the most important issues with which a forest manager has to deal. In this section, cost-benefit analysis will be used to determine an economically "optimal" rotation age for a single forest stand. For example, there are times when a woodlot owner might wish to select the rotation age. The rotation age is usually chosen when a site is being regenerated. Often, the manager simultaneously selects a suitable silvicultural treatment intensity. The owner of a mature even-aged stand will also be interested in calculating the optimal rotation time for the purposes of income planning. The example presented below concerns a reforestation project that is about to commence.

To begin, assume that the level of silvicultural treatment will be independent of the chosen rotation period. The only issue of concern is an appropriate rotation length. Similarly, to keep the analysis focused, only timber values will be considered, although the approach can be used for assessing both timber and nontimber forest values.

An example would be the perspective of a landowner who wishes to establish a red pine (*Pinus resinosa* Ait.) plantation in Ontario. They know that the plantation will probably outlive them, but hope to keep the land in their family. To satisfy themselves that they will not be diminishing their estate by establishing a plantation, they wish to calculate the return on the investment required to establish a plantation. The information required for the calculation includes establishment costs, future wood value, and yields at different ages.

Note that the approach being discussed is useful to manage both Crown and private forests, because in both cases the goal is efficient allocation of input resources (e.g., budgetary funds and labor).

To illustrate the decision process, values of the major criteria discussed in Chapter 4 will be calculated using the yield data given in Table 5.1. The establishment costs are probably easiest to estimate, since they can be judged by seeking quotes from different contractors or using data from recently established plantations.

Assume that the owner determines that the plantation establishment costs will be $1,000 per ha. Because the land is a good site for red pine, no significant management expenditures are anticipated once the plantation is established. The local forester advises that the average value of wood is $20 per m^3, and estimates a real rate of interest of 3 percent per annum. A yield table provided by the forester gives the following merchantable yields in m^3/ha at various ages:

Table 5.1. Red pine yields at six rotation ages.

Rotation age	Merchantable volume (m^3/ha)	MAI (m^3/ha per year)
40	156	3.9
50	209	4.2
60	248	4.1
70	276	3.9
80	299	3.7
90	317	3.5

A fundamental rule for comparing alternative projects, as is in effect being done here, is to compare the projects over the same length of time. Furthermore, since revenues only accrue at the end of each rotation, it is not fair to compare a completed rotation with an uncompleted one. To do otherwise distorts the comparison. When one is selecting a harvest age, the simplest way to address both issues is to evaluate alternate rotations over an infinite period of time. In this way an equal span of time is used and the problem of incompatibility of rotations is resolved.

Following the format presented in (3.7), a simplified formula for the present value of benefits of an infinite series of identical rotations is given in (5.1):

$$PVB = PQ\left[\frac{1}{(1+r)^{T}-1}\right] \tag{5.1}$$

Similarly, the present value of costs can be determined from (5.2):

$$PVC = \frac{C}{\left(1 - \frac{1}{(1+r)^{T}}\right)} \tag{5.2}$$

Then:

$$NPV = PVB - PVC \tag{5.3}$$

where: P = stumpage value ($/$m^3$),
Q = quantity (volume) harvested (m^3/ha),
C = management costs ($/ha),
r = real interest rate (i.e., market interest rate less inflation), and
T = rotation length in years.

Then, CBR can easily be calculated from (5.4):

$$CBR = \frac{PVC}{PVB} \tag{5.4}$$

To determine EAI, divide NPV by the real interest rate.

That is:

$$EAI = \frac{NPV}{r} \tag{5.5}$$

Table 5.2 summarizes the: NPV, CBR, EAI, and IRR of this project. Note that the NPV equals the SEV in this case. Since there are no intermediate revenues in this example, the IRR and the CIRR should be equal. Thus, only the IRR is given in this summary table.

Table 5.2. Values of key criteria for selecting an optimum rotation age at a 3 percent discount rate.

Rotation age	NPV[a] ($/ha)	CBR	EAI ($/ha)	IRR[a] (%)
40	- 63	1.04	- 2	2.89
50	- 60	1.05	- 2	2.90
60	-190	1.19	- 6	2.71
70	-347	1.43	- 10	2.47
80	-483	1.79	- 15	2.26
90	-599	2.27	- 18	2.07

[a] Reexamine Figure 4.2 (Chapter 4) to understand the conditions in which an NPV might be negative while the IRR is positive.

Two characteristics are most evident from the results shown in Table 5.2. First, this investment is not profitable on a purely timber-production basis. Second, the rotation age should be between 40 and 50 years. The NPV and IRR have favorable results at the age of 50, whereas the CBR suggests that age 40 is the best. Because it is not clear whether to make a choice between the values of the criteria, the years of 40 and 50 appear to effectively bracket a range of economically optimal rotation ages.

Here, the economically optimal rotations seem to coincide with the age of the highest mean annual increment (m.a.i.). In fact, it can be proven that when the value per cubic meter is assumed to be constant, with increasing tree size, the economically optimal rotation occurs at an age younger than that of maximum m.a.i., when the discount rate exceeds zero. This can be seen more clearly if the analysis is repeated using a 6 percent discount rate. An increase in the discount rate clearly reduces the present value of the harvest revenue, and this will make the investments more unattractive.

Table 5.3 presents the recalculated values of the key decision-making criteria when the discount rate is set at 6 percent. Note that the IRR is unaffected, but all other values have deteriorated. Also, the 40-year rotation is now relatively more favorable according to the NPV and CBR criteria, although the NPV is still negative.

Table 5.3. Values of key criteria for selecting an optimum rotation age at a 6 percent discount rate.

Rotation age	NPV ($/ha)	CBR	EAI ($/ha)	IRR (%)
40	-805	3.57	-48	2.89
50	-817	4.35	-49	2.90
60	-876	6.67	-53	2.71
70	-898	8.33	-54	2.47
80	-924	12.50	-55	2.26
90	-938	14.29	-56	2.07

Several of the assumptions used in the analysis described above are arbitrary. The price of wood could be quite different than was assumed above. There are two aspects to consider here. The first is the question of how the value per cubic meter changes with increasing timber size. Larger stems are more valuable, because they can be used for higher-value products and because they often contain higher proportions of high-quality clear wood. Larger stems also cost less to harvest and process on a per cubic meter basis. These data can often be estimated by talking to local foresters or contractors.

Assume that the results of such an inquiry are those shown in Table 5.4.

Table 5.4. Yields and values of red pine.

Rotation age	Merchantable volume (m^3/ha)	Timber price ($/$m^3$)	Stand value ($/ha)
40	156	18	2,808
50	209	20	4,180
60	248	20	4,960
70	276	25	6,900
80	299	30	8,970
90	317	40	12,680

A second aspect of the future wood value concerns how the price levels for timber will change over time. These will occur due to inflation, and there may also be changes induced by shifts in the relative value of timber. The impact of inflation has been sidestepped by ignoring its impact on future prices, and using the real discount rate in the calculations shown above.

However, since at least 1800, the real prices of sawlogs and lumber have increased (Sedjo and Lyon 1990). This makes wood one of the few natural resources to demonstrate such a trend, and reflects an increasing degree of economic scarcity.

In 1987, the International Institute for Applied Systems Analysis (IIASA) published a major work examining the present state of the global forest sector and estimating future change. Dykstra and Kallio (1987) describe the model as a "partial market equilibrium model cast in a nonlinear programming framework". The model develops a scenario outcome sequentially, solving for prices, harvest levels, and trade in the current period, then updating the timber supply, population, and industrial capacity of each region before solving for the next period. The world was divided into 18 regions, each with its own module incorporating demand, supply, and trade relationships.

In the base scenario, eastern United States sawlog and coniferous pulpwood prices are expected to rise from approximately \$30 per m^3 in 1980 to between \$90–120 per m^3 by 2010. This corresponds to an average annual real price increase of 3.7 percent to 4.7 percent. In contrast, hardwood pulpwood is expected to show only minor price gains. These levels of price appreciation are higher than those used by many analysts. For example, Sedjo and Lyon (1990) described a base-case scenario in their world model of timber supply and demand where the average world real price of timber rises by 0.2 percent per annum.

Assume that the landowner uses the price data shown in Table 5.4 and an average annual increase of 0.5 percent in real stumpage price. What type of results could be anticipated? Calculation results are presented in Table 5.5.

Table 5.5. Values of key criteria for selecting an optimal rotation age at a 3 percent discount rate, with the stumpage price increasing at a minimum of 0.5 percent per annum.

Rotation age	NPV (\$/ha)	CBR	EAI (\$/ha)	IRR (%)
40	237	0.86	7	3.35
50	434	0.75	13	3.55
60	268	0.82	8	3.32
70	360	0.76	11	3.38
80	357	0.75	11	3.35
90*	484	0.69	15	3.41

* Indicates financially optimum rotation age.

Now, managing a commercial forest has become profitable for all rotation lengths. The difference in economic attractiveness between rotations has narrowed. The NPV of the 90-year rotation is now the highest, mainly due to the large increase (33 percent) in price as the harvest age increases from 80 to 90 years. Now, variations in stumpage price account for much of the changes in NPV. There is no price increase from 50 to 60 years, thereby resulting in a relatively low return at 60 years.

A similar type of analysis can be done to determine when it is best to harvest a plantation that has already been established. Care must be taken to ensure that the analysis periods are equal. This can best be handled by assuming that whenever the current stand is harvested, some given plantation regime will be established and this will continue in perpetuity.

In conclusion, the analysis results have revealed that none of the plantation regimes proved to be financially viable under the baseline assumptions of a 3 percent discount rate and no real timber price increase. This implies that any stand establishment regime that relied on natural regeneration at no cost would prove to be more financially attractive, since the NPV of such an operation would necessarily be positive. This conclusion holds only for small woodlots, and this is not always the case for large industrial timberland holdings.

5.2 Assessing Viability of a Commercial Thinning

As pointed out earlier, the rotation is often chosen simultaneously with the silvicultural regime. The explanation is straightforward—silvicultural inputs affect the species mix, the rate of growth in terms of both volume per hectare and individual tree size, and the cost that must be incurred throughout the rotation.

More complex data are required when selecting both rotation length and silvicultural intensity. The impact of alternate silvicultural regimes on growth and yield must be estimated. More intensive silviculture is generally expected to increase the rate of volume accumulation per hectare, if not the total volume produced on site. When the stock established on a site is derived from plus trees or has other genetic advantages, maximum total yield will also increase. In addition, adding silvicultural inputs usually results in a purer species stand, which generally also has a higher value.

The NPV of an infinite series of regularly occurring silvicultural costs and benefits can be calculated using the formulas in (5.2) and (5.3), respectively. In this case, the variable C is the sum of all silvicultural costs, which were assumed to be incurred when the new stand was established in Year 1. Expenditures incurred later should be discounted back to Year 1 before being summed and included as part of C.

It should be noted that if the optimal time to harvest is being evaluated for a stand that has already been established, past expenses no longer influence the outcome. These previous expenses have the technical name of sunk costs, indicating that present day decisions cannot alter past events. If a juvenile stand was established at a silvicultural intensity that was, in retrospect, too high, then an owner wishing to obtain the maximum economic benefit from timber production should plan the harvest on the basis of current growth rates, prices, and discount rates, while recognizing that the next stand would be established at a more appropriate silvicultural intensity. In other words, past expenditures have no bearing on the harvest decision for the current stand.

To evaluate the economic feasibility of undertaking commercial thinning, the "with/without" approach is used. Any similar analysis can easily be handled using the various cost-benefit measures discussed earlier. However, if a manager is seeking to find the economically optimal thinning regime, the problem is significantly more complicated than the rotation and basic silvicultural intensity problems discussed previously. The complications arise because there are more variables to consider, even if only one thinning operation per rotation is under consideration in a single-species stand. The decision variables include the timing of the thinning operation, the intensity of thinning, the thinning technique, and the post thinning harvest age. The manager should also be able to assess the impact of any improvements in wood quality that result from thinning.

An efficient way to approach the problem is to set up three tables on a spreadsheet, each in the format shown in Table 5.6.

Table 5.6. Analytical scheme for alternate thinning options.

	Harvesting rotations		
Thinning ages	60 years	65 years	70 years
30			
35			
40			

If desired, the tables could be expanded to cover a wider range of thinning and harvest ages than is shown here. Each of the three tables would contain the calculations for a specific thinning intensity, which could be defined in terms of residual basal area, the number of stems, or as a percentage of basal area removed. The thinning and harvest ages in the table used here are simply examples.

The financial attractiveness of thinning can be assessed by comparing the additional value gained through thinning (including both the commercial value of the thinned material and the value of the final harvest) with the cost of the operation. Calculating the cost of thinning and the value of thinned material is relatively easy. It is more complicated to calculate the improved stand value when the thinning changes the time of harvest. The following example shows how this might be done.

Suppose that the thinning is to take place t_0 years from today. If the total of thinning costs is \$C per hectare and the sum of the benefits generated from thinnings is \$B per hectare, then the NPV of the benefits earned during the thinning operation is:

$$NPV = \frac{B - C}{(1+r)^{t_0}} \tag{5.6}$$

Further, suppose that the thinned stand is to be harvested t_1 years from today, with a yield of Q_1 m^3/ha and a price of P_1 \$/m^3. In the absence of thinning the stand would have been harvested at Year t_2 ($t_2 > t_1$), with a yield of Q_2 m^3/ha and a price of P_2 \$/m^3. Then, the improvement in value, due to thinning, equals the NPV of the harvest in the thinned stand less the NPV of the harvest in the unthinned stand. This would be calculated using the formula in (5.7):

$$NPV = \frac{P_1 Q_1}{(1+r)^{t_1}} - \frac{P_2 Q_2}{(1+r)^{t_2}} \tag{5.7}$$

There is one final addition to the equation. Thinning may either increase or decrease the age of harvest, which either delays or hastens the onset of future rotations. If thinning prolongs the growing period, then there is a cost of delaying subsequent rotations that equals:

$$CDR = \frac{SEV_{uth}}{(1+r)^{t_2}} - \frac{SEV_{th}}{(1+r)^{t_1}} \tag{5.8}$$

where: CDR = cost of delaying future rotations,
SEV_{uth} = SEV of all subsequent rotations after the unthinned present stand is cut, and
SEV_{th} = SEV of all subsequent rotations after the thinned present stand is cut.

On the other hand, if thinning shortens the growing period, then a benefit is gained from accelerating the arrival of subsequent rotations, which can be calculated as:

$$BSR = \frac{SEV_{th}}{(1+r)^{t_1}} - \frac{SEV_{uth}}{(1+r)^{t_2}} \tag{5.9}$$

where: BSR = benefits of shortening rotation due to thinning treatments.

One may assume that the decision to thin will not affect the planning of future rotations, in which case SEV_{uth} will equal SEV_{th}. On the other hand, SEV_{uth} may not equal SEV_{th} if the decision to thin or not has implications for subsequent rotations.

If the difference between the harvest ages of the thinned and unthinned stands is negligible, then the future rotation factor just discussed has little bearing on the economic attractiveness of thinning. However, the importance of the effect on subsequent rotations grows as the difference in harvest ages widens.

In summary, the complete formula that can be used to calculate the NPV of thinning, assuming that thinning reduces the final harvest rotation age, is given in (5.10):

$$NPV = \frac{(B - C)}{(1+r)^{t_0}} + \left[\frac{P_1 Q_1}{(1+r)^{t_1}} - \frac{P_2 Q_2}{(1+r)^{t_2}}\right] + \left[\frac{NPV_{th}}{(1+r)^{t_1}} - \frac{NPV_{uth}}{(1+r)^{t_2}}\right] \qquad (5.10)$$

To select the thinning regime that is most economically attractive, results of the above equation would be entered into each cell of the option table shown as Table 5.6. The NPV equation could be modified with little difficulty to determine the CBR and the EAI values. The IRR of each option could also be calculated, but doing so will be tedious unless the spreadsheet has an IRR function, which may require a specific data layout. However, this and similar problems can easily be handled by CQS4.

More complex dynamic programming approaches to finding an optimal thinning regime are discussed in recent forest management texts, such as Davis and Johnson (1987).

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CHAPTER 6. APPLICATIONS OF CRITERIA TO FOREST-WIDE DECISIONS

The stand level analysis described in Chapter 5 is not appropriate on large forest holdings that are managed on a sustained yield basis and where a primary objective of management is to produce an annual flow of timber. The adoption of sustained yield as a guiding principle acts as a constraint on forest harvesting and management. In general, sustained yield management implies that over a reasonable period of time (e.g., 5 to 10 years) one cannot cut more timber than is grown. This interpretation of sustained yield does not apply to a landowner with a small number of stands. When the sustained yield objective is directly linked to the objective of sustained economic timber supply, as it is in most management units in Ontario, management conditions become very different than those experienced by a small-scale landowner. In other words, the manager of a forest management unit cannot administer each stand on an individual basis but must look after the forest as an entity.

6.1 Analyzing Forest-wide Silvicultural Treatments

A simple example will be presented to illustrate the use of cost-benefit analysis on a forest management unit basis. The focus will be on comparing three silvicultural strategies: i) natural regeneration, ii) extensive silviculture, and iii) intensive silviculture.

The specific operations of each strategy are unimportant. The key assumption is that each increase in silvicultural intensity leads to an increase in yield per ha. Cost-benefit analysis compares the value of the increase in wood flow against the additional silviculture treatments required. In short, it is a comparison of marginal benefit (MB) and marginal cost (MC).

In the simplest case, a strictly even-flow harvest is taken and the annual level of silviculture is expected to remain roughly the same over time. Table 6.1 shows, for each of the three options, the annual wood supply volume, the value of the annual harvest, and the annual cost of management. Note that wood has been valued at \$10 per m^3, and nontimber impacts have been excluded.

Table 6.1. Harvest estimates, costs, and revenues by silvicultural treatment type.

Silvicultural intensity	Cost ('000 \$/yr)	Harvest volume ('000 m^3/yr)	Harvest revenue ('000 \$/yr)
Natural regeneration	50	80	800
Extensive management	300	120	1200
Intensive management	600	160	1600

The net gain from management intensification was estimated as the increase in volume and value above the levels achieved using natural regeneration. Since the objective of this analysis is to select the silvicultural intensity, the analysis must determine whether the actual value of the benefit exceeds the incremental silvicultural costs.

Table 6.2 summarizes the net benefits (NBs) and CBRs associated with each silvicultural intensity increment. Note that the term NB is used in place of NPV because only the difference between annual value gain and the annual cost has been measured (i.e., there is no discounting). It is not necessary to calculate the NPV in this situation, because an even annual flow of harvest volume, value, and cost is assumed.

Table 6.2. Cost-benefit analysis of extensive and intensive silvicultural treatments.

Management intensity	MB ('000 $/yr)	MC ('000 $/yr)	NB ('000 $/yr)	CBR
Extensive	400	250	150	1.66
Intensive	800	550	250	2.20

A comparison of the NB levels shows that the greatest amount is associated with intensive management. Therefore, if sufficient funding is available, intensive management would be preferred. However, the CBR increases as silvicultural treatments change from extensive to intensive levels. In other words, gains per dollar spent decline as silvicultural treatment intensity increases.

If there are other investments available with a CBR of less than 1.66, then they should be undertaken. On the other hand, if the alternative investment yields a CBR between 1.66 and 2.2, then the greatest net benefit will be obtained by adopting extensive management and investing the remaining available funds in the other project. In this way the CBR acts to guide investment, so that the greatest overall NPV can be obtained.

In this situation the IRR and CIRR are not useful, because benefits are recovered immediately in the form of higher harvest levels. This situation arises through the allowable cut effect, which has generated considerable controversy.

6.2 The Allowable Cut Effect

Allowable cut effect (ACE) is the decision to increase the present harvest volume, with the belief that present silvicultural treatments will increase the future yield per ha (m^3/ha). In the above example the profitability of management was at least partially justified by the immediate increase in harvest volume made, because of the expected increases in future yield due to intensive silvicultural treatments.

Economists observe that the notion of ACE has often been used to justify inefficient silvicultural investments. Those who argue against the use of an ACE for decision making do so because there are really two separate decisions involved: a) the selection of the harvest level and b) the selection of the appropriate silvicultural treatment. They argue that these decisions should be analyzed separately on their own merits. This would imply that the harvest should only be increased when the increased yields have become available.

On the other hand, forest economists point to sustainable yield requirements as the basis for linking the two decisions (Gregersen and Contreras 1979, Hyde 1980). The sustained yield harvest acts as a limit on the volume (and to a large extent, the value) of wood that can be extracted each year. Any activity that increases future yields might be expected only to result in future increases in harvest levels. However, as the increase in harvest is postponed, the growing stock in the forest will increase to levels above those that are desirable from the perspective of timber production. Thus, to minimize the increase in growing stock, the harvest can be increased immediately in anticipation of higher volumes in the future.

What conclusions can be drawn from this debate? The first is that one should be reluctant to include the ACE when analyzing projects where sustainable yield is not being practised, as is sometimes the case on private land or where the purpose of investing is not solely to grow timber. However, the ACE is a valid factor to include in public forest management. The second point is to heed the economists' warnings and critically examine the merits of the silvicultural projects being considered. Foresters should use careful judgement when planting on medium and poor site classes, and on sites distant from the mill. Due to the additional cost of hauling, the value of distant timber is lower than the value of an equivalent volume of timber grown close to the mill. Foresters should also ensure that if the quality of the second-growth timber differs from the growing stock now on the site, then prices should reflect these differences.

6.3 Establishing a Set of Ground Rules

Typically, the boreal forest manager has to be concerned with four to ten working groups and perhaps three or four major site types in each working group. Also, there are a variety of silvicultural options available for each combination of working group or site type. While it may be relatively easy to pick the best option for each working group and site type, the decisions are difficult and interrelated when the silvicultural plan is being devised for an entire forest. Constraints on budgets, stock, seed, different wood values, and other such factors combine to create a very complex problem.

Short of using a technique such as linear programming, the economically optimal solution can be approximated by judicious use of economic analysis. To keep the discussion tractable, consider a forest with two working groups (spruce [*Picea* spp.] and jack pine [*Pinus banksiana* Lamb.]), three site types in each working group, and three alternative levels of management intensity. Assume that spruce will only be planted on spruce sites and jack pine on jack pine sites.

Table 6.3 shows the silvicultural costs, value of harvested timber, expected harvest age, NPV, and CBR for each silvicultural option, calculated over an infinite time horizon. These numbers are hypothetical in nature. The analysis assumes that the sequence of rotations starts with bare land, and a discount rate of 4 percent per annum is used.

Most of the silvicultural regimes show negative rates of return when evaluated on a per hectare basis, which is not too surprising given the long delay time until harvest. Two other general conclusions can be drawn from these results:

1. The more rapid growth of jack pine outweighs the somewhat lower value of its wood. Therefore, a given level of management on a site of a specific quality yields a higher economic return than does the same expenditure on spruce.

2. The lower management intensity generates higher returns on a given site type. This is because the higher initial cost of management associated with a greater silvicultural intensity is not recovered from the higher volumes, values, and somewhat shorter rotations.

However, these results do not imply that the lowest management intensity should be followed on a management unit. This was tested using the forest level simulation model FORMANCP (Williams 1991). A simple forest with 15 000 hectares in each of the six forest unit/site quality types was used as a test case. The details of the forest are unimportant—instead, it is the financial results which are of significance here.

Table 6.3. Comparative assessment of three silvicultural treatment intensity levels.

Site type	Management level	Silviculture cost ($/ha)	Harvest age (year)	Harvest yield (m^3/ha)	Wood value ($/$m^3$)	NPV ($/ha)	CBR
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Spruce							
Good	High	1000	75	200	50	-498	1.89
	Medium	400	85	165	45	-140	1.52
	Low	50	95	120	40	67	0.43
Medium	High	1000	90	160	48	-798	4.35
	Medium	400	100	120	43	-303	3.85
	Low	50	110	90	38	-4	1.09
Poor	High	1000	120	110	45	-963	25.00
	Medium	400	130	95	40	-379	16.66
	Low	50	140	75	35	-40	5.00
Jack pine							
High	High	1000	60	200	45	-160	1.16
	Medium	400	65	165	41	139	0.75
	Low	50	70	120	37	251	0.17
Medium	High	1000	75	160	41	-690	2.85
	Medium	400	80	120	37	-217	2.08
	Low	50	85	90	35	65	0.44
Poor	High	1000	90	110	37	-907	0.33
	Medium	400	95	95	35	-328	5.00
	Low	50	100	70	33	-4	1.09

Table 6.4 presents the results of selected economic parameters: costs, benefits, marginal costs (MCs), marginal benefits (MBs), NPV, and CBR. The silvicultural treatment specifications are in Column 1. Column 2 presents the maximum even-flow harvest level, while the discounted sums of costs incurred and benefits received during the simulation period are entered in Columns 3 and 4, respectively. Column 5 presents incremental cost (marginal cost) spent over and above the cost incurred in the minimal silviculture scenario. Benefits accrued in terms of the additional wood produced as a result of applying the additional silviculture are recorded in Column 6.

The amounts for each parameter are discounted sums (i.e., totals of present values) over the 150-year simulation period. Seven silvicultural regimes are shown, one per row. The first row shows the costs and values generated when a minimal silvicultural program is followed and the maximum even-flow harvest is taken. The next three rows show results when only medium intensity silvicultural regimes were applied. The row titled "M - 250" contains results from a simulation in which up to 250 hectares per year could be treated with a medium intensity treatment and the maximum even-flow harvest was cut. Treatment priorities were set according to the CBR values in Table 6.3, which indicates that good jack pine sites were given the highest treatment priority, good spruce sites were given the next highest priority, and so forth. Rows 5–7 show simulation results when the high intensity treatment was permitted on the good site types (good jack pine again received priority over good spruce) and medium intensity silviculture was practised on medium grade sites. Again, three different ceilings were placed on a treatment area.

Table 6.4. Forest level analysis (dollar values in thousands).

Silvicultural regime	Maximum harvest volume (m^3/yr)	Costs ($)	Benefits ($)	Marginal costs ($)	Marginal benefits ($)	NPV ($)	CBR
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Minimum silviculture	85,000	951	75,520				
M - 250	95,000	3,266	84,405	2,315	8,885	6,570	0.26
M - 500	110,000	5,648	97,732	4,697	22,212	17,515	0.21
M - 750	115,000	6,780	102,175	5,829	26,655	20,826	0.22
H - 250	115,000	7,279	102,175	6,328	26,655	20,327	0.24
H - 500	130,000	13,433	115,501	12,482	39,981	27,499	0.31
H - 750	140,000	19,158	124,387	18,207	48,867	30,660	0.37

Calculating the NPV and the CBR values in Table 6.4 is straightforward. The NPV of the regime specified as "M - 250", for example, was calculated by subtracting MC from MB; the CBR was obtained by dividing the MB by the MC.

The results in Table 6.4 illustrate that increasing the managed area with increased silvicultural treatment intensity raises the maximum allowable harvest level. It is shown that silvicultural effort now yields positive returns, which might be attributed to ACE. Application of the medium intensity regimes yields the lowest CBRs. However, because the even-flow harvest volume is limited under medium intensity silviculture, the maximum NPVs are obtained by using more intensive management on the best sites.

In conclusion, the analytical approach described in this section can help the forest manager to prescribe treatments that should provide the greatest return per invested dollar. Results of each criterion, such as those values of the CBR, although calculated at the single hectare level, can be used by the manager to make silvicultural treatment decisions for a forest.

References

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CHAPTER 7. SPECIAL TOPICS

This chapter contains a brief discussion of a few relatively advanced forestry economics topics. The primary issue of concern is how the rate of discount changes with respect to: a) risk and uncertainty and b) society's time preference.

7.1 Incorporating Risk and Uncertainty

Up to this point the presence of risk and uncertainty has been acknowledged, but not considered in the analysis. Because an element of risk and uncertainty is present in every project, a brief discussion is warranted on how to handle this problem.

Uncertainty arises for several reasons. These can be grouped into the following three classes:

1. Uncertainty regarding information to define the project's present state,
2. Uncertainty regarding the future state of the project, and
3. Uncertainty regarding the future state of the conditions external to the project.

Examples of Class 1 uncertainty elements include those associated with the output level in terms of volume per hectare, the discount rate used, and output-market prices. Class 2 highlights the possibility that a project may not develop as foreseen. For example, regeneration success rates may differ from those expected, or a plant may operate at a different capacity than was projected. Class 3 addresses those future costs and benefits of a project that are dependent on the broader economic environment—future interest rates, rates of real price change, exchange rates, and other external factors.

When analyzing risk and uncertainty, two strategic approaches are used. The first is to identify important sources of significant risk in a project. This requires thorough analysis, especially the identification of multiple impacts arising from changes in the magnitudes of key variables. The second approach is to accurately capture the riskiness of an investment in the cost-benefit analysis. All of the criteria discussed previously are supposed to be based on average or consensus values of costs and benefits. The suggested approach to highlighting risk is to conduct a sensitivity analysis. If risk is a serious concern in a project, a more detailed risk analysis should be conducted. See, for example, the further reading list given at the end of this chapter.

The standard form of sensitivity analysis is conducted by changing key variables by some fixed percentage (e.g., 10 percent) and calculating the NPV or other relevant decision criterion using the new value of the variable. The degree of change in NPV with respect to the percentage change in the variable used indicates the degree of risk associated with that particular variable.

Risk analysis is a more detailed form of sensitivity analysis. It attempts to take into account the combined effects of changes in several variables and the likelihood of various changes occurring together. Risk and sensitivity analyses are useful for pinpointing sources of risk, but they do not indicate the cost associated with uncertainty. To do this properly would involve a more detailed presentation of potential outcomes, and calculating the expected value of a project, which is its probability-weighted mean outcome. Tables 7.1 and 7.2 show this for two projects.

Table 7.1. Probability distribution of the NPV for Project A.

NPV ($)	Probability	Possible NPV x probability ($)
-50,000	0.1	-5,000
0	0.2	0
100,000	0.5	50,000
200,000	0.2	40,000
		85,000

Table 7.2. Probability distribution of the NPV for Project B.

Possible NPV ($)	Probability	Possible NPV x probability ($)
-150,000	0.4	-60,000
-50,000	0.1	-5,000
200,000	0.2	40,000
500,000	0.3	150,000
		125,000

Projects A and B have very different risk profiles. Project B has a 50 percent chance of leading to a loss, whereas there is only a 1 in 10 chance of this happening with Project A. Someone who is reluctant to accept risk might well select Project A, even though it has a lower expected value. Other people would take the gamble of a very large payoff from Project B. The decision will depend on the general environment as well as the personality traits of the decision maker. Note that the display format used above conveys much more information to the decision maker than would the simple use of the two expected values.

In closing, one shortcut that is often used to account for risk is to raise the discount rate used in an analysis. This is generally a poor approach, however, because it assumes that the degree of risk increases at a compound rate over time. Often this is not so. Finally, the choice of the risk premium to use is rather arbitrary and may be misleading.

7.2 Social Rate of Time Preference

As discussed earlier, the discount rate used in a cost-benefit analysis of an investment project is composed of three components: time preference, inflation, and risk. The time preference component should reflect the perspective of the person or agency undertaking the project. If the investor is an individual, that person's rate of time preference should be used.

Most companies have a preset minimum rate of return that investments must earn. This rate is sometimes known as the hurdle rate. This rate of discount can be used to calculate an indicator such as the NPV, which must be positive for the investment to be considered viable. Alternatively, the IRR or CIRR can be calculated for the candidate project and compared to the hurdle rate.

When a government considers an investment, the time preference part of the discount rate should reflect society's rate of time preference. This rate, the lowest rate at which society is willing to exchange current consumption for future consumption, is called the social rate of time preference (SRTP). The theoretical derivation of the SRTP can be found in Feldstein (1964) and Nautiyal (1988).

The key questions to be addressed here are:

- what value to give to the SRTP, and
- where the SRTP lies in comparison to private rates of time preference.

In 1976, the Canadian government recommended a rate of 10 percent, which two prominent economists felt was too high. One of these felt that it should be set at 7 percent (Burgess 1981) and an analysis published by Kula (1984) estimated a rate of 5.2 percent.

Despite the disagreement, it is widely accepted that SRTP should be lower than private rates of time preference. There are several reasons advanced for this. First, individual and corporate profits are taxed whereas benefits that accrue to society from government projects are not. Thus, individuals and firms need to earn a return great enough to leave an acceptable after-tax return. Second, individuals die whereas society does not. This leads individuals to be less patient than society as a whole and gives rise to higher private rates of time preference. Third, the presence of risk leads individuals and firms to demand a higher rate of return than would otherwise be so. However, society has so many projects underway at any given time that some of these can fail and have only a negligible impact. Thus, the risk associated with a single project is insignificant from society's point of view. For these reasons, analysis of government investments should use the SRTP as the time preference component of the discount rate. This will be lower than that of private and corporate rates. Incidentally, this and similar lines of argument, such as political sensitivity and ecological preservation, appear to justify government decisions to undertake projects that might not be viable for the private sector.

7.3 Recent Developments in Discounting Theory

The standard literature on selecting a discount rate is based on the premise that there is one correct discount rate that should be used for all types of projects and the major problem for an analyst is to identify the "correct" value of that discount rate. If one cannot identify the interest rate with any degree of certainty, then sensitivity analysis is advocated to examine the likelihood of making a poor decision based on an inappropriate rate of discount.

In spite of the general agreement that the major analytical problem was to find the correct discount rate, economists have been embarrassingly unsuccessful in determining what that rate should be. When the federal Treasury Board issued a cost-benefit analysis manual (Treasury Board Secretariat 1976) that advocated using a 10 percent rate for government projects there was immediate controversy, with some authors arguing for rates in the range of 5 percent to 6 percent. The same debate occurred in the United States after the Office of Management and Budget issued guidelines requiring most federal agencies to use a 10 percent real discount rate in project assessment (Scheraga 1990). Recently, empirical findings and theoretical papers have each provided evidence for the following results, which stand in astonishing contrast to the standard perspective:

1. The discount rate used should decrease as the interval between expenditures and resulting benefits increases, or if the benefits are longer term in nature.

2. People simultaneously have different discount rates for different things.

3. It may be appropriate not to discount at all when one considers intergeneration distribution and equity problems.

The bases for each of these findings can be described in general terms.

What is the cost of the capital used in a project? The economic cost depends on what was foregone as a result of the decision to invest in the project. This concept is known as opportunity cost, which is the value of foregone opportunities. Economists generally contend that capital for investment comes either from the stream of consumption or it comes at the expense of investments in other projects. In other words, if $5,000 is spent to plant trees, this represents $5,000 that is not available to spend on a vacation. Alternatively, it represents $5,000 that is not available to invest in mutual funds or an alternative productive activity.

Reducing current consumption to increase future consumption opportunities (i.e., through the investment in tree planting) is thought to reduce the level of social well-being by a lesser amount than when the investment capital is obtained at the expense of other investment projects. Therefore, there is a lower opportunity cost associated with using capital from the consumption stream, and hence it is argued that a lower discount rate should be used. As the source of capital funding includes a greater proportion of funds removed from the investment stream, a higher discount rate should be used to reflect this. Thus, the appropriate discount rate depends upon the source of the investment capital.

Empirical evidence has documented situations where people demonstrate different rates of time preference for different things. Moore and Vicusi (1990) derived implicit discount rates by examining wage rates by industry and the incidence of injury in each industry. Their main hypothesis was that wage rates should reflect the probability of injury in an occupation and, using lifespan data, they estimated that people's wage rates vs risk reflected a 2 percent real rate of discount. They found this to be consistent with the real rates of discount in financial markets during the same period. These authors cited studies in which people demonstrated implicit rates of time preference of 20 percent or more for refrigerator energy efficiency (a follow-up study found rates ranging from 40 percent to 300 percent). Interviews with consumers revealed average financial rates of time preference of 30 percent.

Page (1988) pointed out that issues of intergenerational equity depend greatly on the rules or procedures for assessing whether a particular distribution of benefits over multiple generations is equitable (i.e., fair). Standard discounting can be viewed as one approach that can be used to determine the equity of a distribution. However, Page argued that discounting is not the only rule available for determining fairness and it is not necessarily the most appropriate. In some cases, assessment of fairness may require that no discounting be undertaken.

Unfortunately, it is not clear how the foregoing points affect one's practice of investment analysis. One conclusion appears to be a growing acceptance of the use of lower discount rates for investments in such things as forestry. These investments may have a long time horizon and many people appear to attach relatively low discount rates to forests.

Hultkrantz (1992) surveyed nonindustrial private landowners in Sweden. Results of that survey indicated that many landowners undertook long-term silvicultural investments that would not be expected to generate any pay-off during the owner's lifetime. These forest owners had lower rates of time preference than were found in financial markets at the time. Hultkrantz theorised that these actions could be explained by the owners' desire to leave a healthy productive forest to future generations (i.e., the bequest motive).

The recommendation to set a discount rate based on the sources of capital is not easy to follow in practice. Scheraga (1990) notes that the recommended approach has the virtue of making the social rate of time preference unambiguous in nature, although it does lead to a variety of time preference rates based on funding sources. For the time being, the most reasonable approach is to use sensitivity analysis around the discount rate to guide decision making. The recent discussion also indicates that it would be useful for the Ontario Ministry of Natural Resources to make an effort to determine an appropriate rate of discount.

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CHAPTER 8. ACCOUNTING FOR PERSPECTIVES

8.1 Conceptual Background

It is important to recognize that various economic agents will have different perspectives on the value of forestry investments in Ontario. The two main sets of economic agents—the firms in the forest industry and the provincial government—share management responsibilities, the costs of management, and the benefits from the forest. However, all costs and benefits are not evenly divided for every project. Hence, firms may lean toward some projects whereas the province may lean toward others.

Generally, firms are profit maximizers. In other words firms wish to minimize the costs of production, including wood procurement, while assuring themselves of a sufficient timber supply. Some firms may take a short-term view while others take a long-term view. This will influence how a firm assesses the economic attractiveness of a project.

Due to budgetary constraints, the provincial government may also be keen to reduce its expenses and increase revenues. Government actions can influence the type and intensity of management through the setting of budgets, through the management plan process, and by setting management policy. From this perspective, the provincial government will wish to reduce costs by cutting back on some expenditures and passing others on to industry. The province will also attempt to extract more revenues from forest users.

It is primarily as a result of differing views of costs and benefits that the public and private sectors may disagree over how to rank alternative projects. The second reason for the conflicting perspectives is due to the difference in the size of the discount rate used for analysis. The final perspective is the one that a benevolent God may take, which is to improve the overall level of social welfare. It is difficult to assess projects from this perspective because value judgements are required concerning the distribution of costs and benefits. The criterion commonly used by economists is known as Pareto criterion. This simply states that one state of the economy is "Pareto-preferred" to another if no individual is worse off and at least one person is better off in the latter state (after an action is taken).

8.2 Private Enterprise

Most licensees manage their forests in such a way so as to minimize the cost of producing the desired amount of wood for their mill. As a result, the value of the timber is not an issue, provided that the cost of wood procurement is reasonable in relation to the value of the products and the value of roundwood elsewhere. In addition, since licensees cannot charge people who benefit from the other outputs produced from the forest (e.g., wildlife, recreation), they have little concern for the production level of these values.[4]

The costs of forest management incurred by a licensee equal to the activity costs less any reimbursement from the provincial government. The provincial government has generally stopped reimbursing companies for any portion of road construction and maintenance costs, but still refunds money up to prescribed limits for silviculture. The costs should also include a portion of the firm's overhead and salaries paid to its staff. Stumpage dues and area charges paid to the crown are generally considered as wood procurement costs.

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[4]The pressure on forest companies to become better corporate citizens is causing some companies to take an interest in providing nontimber forest products.

8.3 Public Sector

When a project is evaluated from the perspective of the impact on public sector finances, it is important to note that all funds paid to the provincial government are placed in a general revenue pool and are not directly tied to Ontario Ministry of Natural Resource outlays. The implication of this is that often there is no reason to distinguish funds payable to OMNR from funds payable to other ministries.

From a government revenue perspective, the value of harvested timber should be set equal to the Crown dues rate plus the area charge averaged over the number of cubic meters cut. The area charge should be handled this way because it is paid on the basis of licence area and represents a cost of procuring wood. The value of future wood to be produced from current planting and silviculture should equal the sum of expected dues and area charges per cubic meter harvested. The cost of silviculture is the amount reimbursed to licensees, plus any reimbursements for careful harvesting done to promote regeneration.

8.4 Society as a Whole

Although often very difficult to properly address, social perspective is a most important factor of concern. Governments are charged with increasing the level of social well-being. However, pressures to remain in elected office and, more recently in Canada, pressures to increase government revenue, have compromised government's approach to properly assessing projects.

The social perspective is especially difficult to address in the evaluation of forest management projects, where benefits such as water regulation, aesthetics, wildlife, and recreational opportunities have social value, but are difficult to appraise. Most practitioners suggest that these benefits should be noted in the analysis, even if they cannot be identified. Others suggest that simple rules of thumb may be useful to identify the relative importance of these benefits. For example, when better data are not available, Nautiyal (1988) cautiously suggested that nontimber products be accorded at least equal value with timber.

To complicate matters further, market prices may not reflect social prices. The price of timber probably does not reflect its social value, because the timber market is highly influenced by government and by the oligopolistic nature of the industry. The presence of labor unions and the general lack of mobility in the northern Ontario labor force means that market wage rates are also not reflective of social perspectives. The means by which economists adjust market prices so that they are reflective of social benefits cannot be addressed in detail here, but an overview will be provided. The interested reader is encouraged to consult the literature listed below, and other sources.

When a market price is adjusted to reflect its social importance, the new value is known as a shadow price. The shadow price represents the opportunity cost of the resource. In the case of labor, for example, the opportunity cost is the value of the marginal product of labor foregone elsewhere because labor is used on the current project. Thus, if a project simply results in labor moving from one job site to the project site, the shadow cost equals the value of the marginal output being produced at the former job site. When there is unemployment and the project generates new employment, the shadow cost is zero because hiring the new workers results in no loss of production elsewhere.

From the social perspective, the appropriate discount rate is the social rate of time preference. This rate should reflect policy goals for society. For example, if the government wishes to promote saving at the expense of present consumption, an increase in current saving is valued more highly than an increase in current consumption. However, future savings are of less value than present savings and they should be discounted accordingly. As one can see, cost-benefit analysis can become very complex when the social perspective is being adopted. However imperfect, cost-benefit analysis is still superior to other forms of project assessment. The practitioner should bear in mind that one of the main reasons for undertaking cost-benefit analysis is simply to ensure a complete identification of project impacts.

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CHAPTER 9. SUMMARY OF TECHNIQUES[5]

The previous chapters showed that forestry investment analysis involves several techniques, steps, and tools. This chapter summarizes the general procedure of forestry investment analysis.

9.1 Calculation Steps

The basic method for computing financial returns has changed very little over the last decades. Recently, however, new information and computerized tools have made it easier to calculate profits. Several steps are needed to conduct forestry investment analysis. Like building a house, financial analysis requires materials, tools, and know-how to produce a finished product; that is, reliable analytical results.

STEP 1. Identify all treatments, including "no treatments."
In this step, the different investment options under consideration should be outlined. When do they start and when do they end?

STEP 2. Determine expected timber yields.
Most forestry investments involve the production of timber. The volume of timber to be produced and when it will be harvested are identified. Also, if other outputs are generated by the forest, the yields of these must be specified.

STEP 3. Estimate costs and benefits.
In this step, a detailed schedule of cash flows for each investment option is developed. When costs are paid and when benefits (revenues) are generated must be specified. Both the timing and amount of costs and benefits are important.

STEP 4. Compute financial returns.
Cash flows are analyzed using criteria for judging profitability. This step requires an appropriate discount rate to adjust cash flows for the time value of money.

STEP 5. Test effects of assumptions.
Costs, revenues, and yields are never known for certain. In this step, one should determine the effect of errors in the estimates of these parameters on financial returns. That is, conduct sensitivity analysis.

STEP 6. Compare investment returns.
Because one cannot usually invest in every possible opportunity, the results of the financial analysis must be compared to learn which options are better than others.

STEP 7. Select the best option.
The final step is to select from among the investment options. Profitability is only one of the considerations; nonfinancial factors may also be important.

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[5]With minor modifications, this chapter is adapted from a paper by J. Michael Vasievich, entitled *Tools and Techniques of Forest Finance* published by the USDA Forest Service, Southeastern Forest Experiment Station, Durham, North Carolina. It was presented at the Society of American Foresters, Southeastern Chapter, Appalachian Society of American Foresters' 64th Annual Meeting, 23–25 January 1985, in Norfolk, Virginia.

Although these steps appear to be straightforward, an analysis can be complicated by many factors. Each investment option is different, and no hard and fast rules apply to all cases. Proper data must be used to build a realistic picture of expected cash flows. Costs and revenues must be discounted or compounded to the same time period. Those results must then be used correctly to make appropriate decisions and to avoid common mistakes.

9.2 Types of Analysis

There are different ways to analyze investments. The goal, however, is always to determine if financial returns from one option are better or worse than those from other available options. It should always be kept in mind that forestry must compete with other investment options for public funds.

Foresters and landowners are typically concerned with two types of investment questions. In each case the investor wants to compare forestry with other investment possibilities. The first type of question asks if growing and managing a particular forest is a profitable venture. The investor is comparing two alternatives: forestry vs some other investment.

Some of the common **Type I** questions are:

- How profitable is growing timber?
- Can I make money by buying land and planting trees?
- Is forestry more or less profitable than bonds?

Questions of a second type assume some commitment has already been made to forest ownership and management. They ask if intensive management of an existing forest is profitable. Marginal or incremental analyses are the financial tools designed to answer these questions. They determine the profitability of investing in additional capital.

Some of the common **Type II** questions are:

- Which is more profitable, precommercial thinning or managing an unthinned stand?
- Should more funds be spent on site preparation?
- Are the benefits of planting genetically improved stock worth the costs?

Taxes

Another item to consider is whether to include income taxes. For many forestry projects taxes represent the largest single cost paid throughout the investment, even in present value terms. Taxes should always be considered if income from the project is subject to tax. Taxes do not affect projects on public lands or investments by charity and other nonprofit organizations.

Inflation

Financial analyses may include or exclude inflation. With inflation, the process is termed a nominal or current-dollar analysis. All costs and revenues are specified as actual dollars in the year they occur. Without inflation, the analysis is termed as a real or constant-dollar analysis. All costs and revenues must be adjusted to remove the effects of inflation. Price indices, such as the consumer or the producer price indices, are often used to adjust values for the effect of inflation.

There are pros and cons to including inflation in financial return estimates. When inflation is included, costs and prices projected for 20 or 30 years, for example, may seem excessively high, and perhaps difficult to believe for some inexperienced investors. At 7 percent inflation, a price of \$50 per m^3 today grows to \$381 per m^3 in 30 years.

If inflation is excluded, financial returns may appear abnormally low when compared with typical market interest rates. Market returns, like bond yields and bank interest rates, must then be adjusted for inflation before being compared with forestry returns. Even this adjustment may mislead or confuse the inexperienced investor. Thus, caution has to be exercised before a final decision is made.

Risks

The future of any forest is uncertain, and profits can be affected by three sources of risk: a) natural events, b) variations in market forces, and c) policy changes. Part or all of the timber can be lost to insects, diseases, fire, storms, and other natural hazards. Trees may grow more slowly or quickly than indicated by yield tables. Demand for timber may also be lower than expected, thereby leading to depressed prices. Moreover, provincial and federal policies on timber taxes may also change before the timber is cut. All of these factors may cause profits to be higher or lower than anticipated.

Risk is common to every investment. Investors are wise to consider the chances that things will not work out as planned. Financial analyses require assumptions about future costs, prices, and timber yields. Unfortunately, even with the very best techniques, one can not predict these values with complete accuracy.

It is often suggested that one way to account for risk is to increase the discount rate by one or more points. Higher discount rates are used if the proposed investment is perceived to be more risky than the alternatives. This common technique is somewhat arbitrary. It acknowledges an uncertain future, but fails to systematically account for potential sources of risk. Using a higher discount rate requires the investment to return more than other options if it is to be acceptable.

Several scenarios can be developed for each investment option if sources of risk can be isolated and probabilities can be assigned. Each scenario can be analyzed independently and assigned a probability. This method, called decision-tree analysis, focuses attention on the chances that certain outcomes will prevail.

In extreme cases, detailed probability distributions of costs, revenues, and yields may be used for the analysis. A distribution of expected financial returns can be computed by analyzing many combinations of possible inputs. The results of this approach show the chances that profits will achieve any specified level.

Another technique, called sensitivity analysis, finds out how much costs, prices, or yields must change before returns drop below some minimum level. Sensitivity analyses find such thresholds as the minimum yields or maximum cost needed to get a certain rate of return or a specific present value. The method is limited, because each input is considered separately and all others are held constant.

9.3 Required Data

To conduct forestry investment analysis, one requires data on costs, benefits, yields, and other economic parameters at a specified time. Reliability of the variables is critical. Obviously, analytical results are sensitive to data errors.

Costs

Many different costs must be paid to manage forests. For most analyses, all costs from the beginning to the end of the investment period must be included. For marginal analyses, only the costs of additional (incremental) treatments should be included. The major cost categories that must be considered include:

Land: land purchase or rent, road construction, drainage, fencing or other improvements.
Stand establishment: site preparation, planting, direct seeding, coppice regeneration, or the opportunity costs of leaving seed trees.
Cultural: precommercial thinning, control of undesirable competition, release, fertilization, pest control, and prescribed burning.
Periodic costs: property taxes (ad valorem), management fees, maintenance of roads, boundary lines, and fences.
Harvesting and sale: timber cruising, sale administration, commission, harvesting, and transportation.
Taxes on: capital gains, income, business, special permits, yield, and other forms.

Two categories of costs are often treated incorrectly in forestry investment analyses. These are known as opportunity costs and sunk costs. Opportunity costs are usually forgotten and omitted from analyses. When some potential revenue is forgone, because an investment is made, the lost revenue should be included as an opportunity cost. Marginal analyses that compare treated and untreated stand management options should include some opportunity costs. *Sunk costs* are outlays paid before the beginning point of any investment. They are not relevant to current decisions or future returns, and should always be excluded from consideration.

Benefits

Forestry incomes may come from several sources. Potential sources of benefits to be considered include the following categories:

Sales of: products, land, stumpage, leases, royalties from minerals, and special forest products, such as aromatics, berries, and wild fruit.
Use fees: hunting permits and leases, recreation fees, and grazing fees.
Other incomes: tax credits, depletion, amortization and expense deductions, and cost-sharing payments.

Yields

Projection of yields is very important and several aspects must be considered. Yield tables or stand projections are usually used to estimate future timber volumes and values. Careful attention should be given to the quantity and quality of different products available for harvest. For example, sawtimber is worth considerably more than pulpwood. Therefore errors in estimates of the product (timber crop harvest) mix can greatly affect expected revenues.

Management Schedule

Financial analysis requires a schedule of management treatments to build a list of cash flows. One must specify when treatments and harvests are to be done in order to determine future costs and revenues.

Length of Investment Period: Time Path

The terms of many forestry investments are very long. For analytical purposes, starting and ending points in time must be established. The beginning point is set at the time the decision is made to invest. This is usually the current year, regardless of when the forest was established.

There are three time choices to end investment analyses. The first option is to end the analysis when the forest is harvested, the second choice is when the land or timber is sold and ceases to generate income, and the third option is to project the investment into perpetuity. Results for each option will differ.

Discount Rate

A discount rate is used to adjust cash flows for the time value of money. The appropriate discount rate may be interpreted as the cost of capital or the rate of return that could be earned on the best alternative investment with a similar time length and risk. This rate is often called the marginally acceptable rate of return, or the hurdle rate. It is the minimum rate of return that the investor would accept for a successful investment project. It is also the interest rate paid on borrowed funds needed to finance the project. In most cases, the discount rate is specified in advance by the investor. If analysis is done on an after-tax basis, the discount rate should be adjusted to reflect the after-tax cost of capital or alternative return.

For forestry investments, a before-tax real (less inflation) discount rate between 4 percent and 6 percent is normally considered to be appropriate.

Inflation

Inflation increases future costs and revenues. If the results of the analysis are to be compared with typical market interest rates or bond yields, then a long-term average inflation rate must be factored into the analysis.

Changes in Real Costs and Prices

Expected future costs and revenues are influenced by relative changes in output prices. Market prices for some timber products, particularly softwood timber, have been increasing more rapidly than inflation in the past and this trend is expected to continue. Changes in real price increases should be factored into any analysis. The appropriate rate of real price change depends greatly on future timber supply and demand. Estimates should be based on actual conditions in each supply region.

Income Taxes

Income taxes are important investment costs, but including taxes in analyses is often confusing. The federal and provincial tax legislations and rates must be understood.

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APPENDIX 1

CASE STUDY 1. ASSESSING THE VIABILITY OF JACK PINE PRECOMMERCIAL THINNING IN ONTARIO

A1.1 Background

Jack pine is the second most important commercial conifer species in northwestern Ontario. Only black spruce has greater value. Jack pine is used to produce lumber, poles, and pulp. Because it is desirable, especially on drier sites where it will outperform other commercially important species, it is regenerated after logging. Normal practice is to clear-cut jack pine and regenerate it by planting, seeding, or natural methods, depending on the site and the postharvest seed supply.

The species is superbly adapted to upland sites in fire-prone ecosystems, most notably in the serotinous nature of its cones, the ease of germination when the litter layer has been removed, and its rapid juvenile growth. The conditions that remain after clear-cuts approximate a postburn site in a number of ways. A couple of obvious differences are that logging does not remove the upper duff layers, although it often disturbs them, and logging slash is generally left on the site. There are also differences relating to nutrient supply, ground temperatures, and the effect on established vegetation (logging does not kill this as effectively as a hot fire does).

Therefore, where natural regeneration or seeding are to be used, some light site preparation is often applied after harvest to remove the upper layers of duff. In addition, slash with a high jack pine component is often distributed over the site to enhance regeneration success.

Seeding and natural regeneration may produce stands that are overstocked, sometimes to the extent that they resemble dense postfire stands. When this happens, the high density retards the diameter and volume growth of individual trees, and this prolongs the rotation period. To have the stand produce timber at a reasonable age, pre-commercial thinning is often advocated.

The objective of this case study is to assess the viability of precommercial thinning of jack pine stands in Ontario. In undertaking this analysis, the relative advantages of natural regeneration, seeding, or planting will not be evaluated. It is assumed that plantations are not likely to be precommercially thinned. Thus, precommercial thinning is only likely to be undertaken in stands originating from seeding or natural means, and, in such cases, the costs of seeding and any site preparation are to be treated as sunk costs.

A1.2 The Jack Pine Working Group

The jack pine working group constitutes about 12.2 percent of the regular productive forest in Ontario on both an area and volume basis (Ontario Ministry of Natural Resources 1993). Because of their relative ease and cost effectiveness, natural and direct seeding are generally considered to be better reforestation methods than planting.

Sawmills can effectively use jack pine once the diameter at breast height (DBH) reaches 12 cm. A tree of this size will produce one sawlog that can be used to produce 2 x 4 S-P-F lumber. However, as trees increase in size their value per cubic meter of wood increases, because logging and handling costs fall on a per unit basis and there is an opportunity to make higher valued products.

A1.3 Identifying Costs and Benefits

Jack pine responds well to thinning between the ages of 8 and 20. However, there have been few thinning trials undertaken for jack pine where measurements are available to the public. Fifth year thinning measurements from precommercially thinned stands in northern Ontario have been published by Goble and Bowling (1993). These stands were thinned at the age of 9 to a spacing of 1.73 m and remeasured 5 years later in 1989.

Bell et al. (1990b) published preliminary yield curves for jack pine plantations at six initial spacings on three site classes. These curves were estimated from Plonski's (1981) normal yield tables for natural stands in Ontario and Bolghari and Bertrand's (1984) variable density tables from southern Quebec and variable density yield tables for red pine (Berry 1984). These are based on assumptions of complete survival and an early attainment of full stocking, and thus may be considered optimistic for operational conditions. Bell et al. (1990b) also considered these tables to be relatively weak due to a lack of suitable local models upon which to build.

The thinned stands reported on by Goble and Bowling were thinned at the age of 9 and measured after thinning and 5 years later (at the age of 14). The mean DBH of the treated stands is recorded for each measurement. The measured stands are on track to connect with the Site Class 2 DBH curve and this level of yield will be used in the present case study. Also, it will be assumed that the stand will be thinned at the age of 10.

An average thinning cost of $400 per ha, based on mechanical strip thinning (Willcocks et al. 1990), has been used. In practice, costs may range from $300 to $500 per ha, depending on the technology and technique used, operator's experience, stand density, and site conditions. The costs of seeding and any site preparation that might have been done are not considered in this analysis. These are known as sunk costs—outlays that have been made in the past but which now have no bearing on the decision at hand. In other words, the current condition of the stand is now taken as a given and the question is whether to thin the stand. While past activities, such as site preparation and seeding, certainly affect a stand's growth rate, they represent activities that have been undertaken and cannot be changed. That is, today's decision does not have anything to do with past activities. Accordingly, analysis in this case study gives no indication of whether the past investments were worthwhile or not.

The principal benefit of precommercial thinning is to shorten the time required by the stand to reach operability, which in this case requires an acceptable average DBH of the stand. Goble and Bowling's (1993) results demonstrate this point clearly: 5 years after thinning, the control stands averaged 3.9-cm DBH compared to 6.8-cm DBH in the thinned stands. In this case study, precommercial thinning on Site Class 2 stands is expected to reduce the harvest age to 45 years, as opposed to 65 years in unthinned stands. Bell et al. (1990b) report that technical rotation ages of 40–45 years and 45–50 years can be expected for jack pine stands on Site Classes 1 (SI 20) and 2 (SI 17), respectively, based on a minimum DBH of 15 cm and a density of 1 853 trees per hectare at the age of 30.

A technical rotation is the length of time required to produce a given product. For example, technical rotations for pulpwood occur at the earliest age when there is both a minimum merchantable volume present per hectare and when the average piece size has reached the minimum usable size. Other things being equal, technical rotation length depends on the desired product. Obviously, technical rotations for sawlogs are generally longer than those for pulpwood.

A technical rotation is not necessarily the economically optimal one. An optimal rotation is the length of time at which the greatest soil expectation value is received. Operational precommercial thinning is a relatively recent development in Ontario, and the development of thinned stands can only be estimated.

Specific assumptions must be made regarding the value of timber produced under competing management regimes. In northern Ontario, mills purchase jack pine roundwood at the mill gate for prices ranging from \$30 to \$50 per m^3. While residual value calculations show that the value of wood going to sawmills is greatly influenced by the distance to the mill and the market price of lumber (SSK Management 1993), it is reasonable to assume that the mill gate price represents an average long-run price, and that 75 percent of the price covers harvest and transport costs. If a millgate price of \$40 per m^3 is used, then the value of standing timber works out to be \$10 per m^3. The size and uniformity of timber from a thinned stand may favorably influence its price; however, some fear that timber from plantations will have lower quality than extensively grown timber.

In particular, there is concern that precommercial thinning will produce trees with lower specific gravity and larger and more persistent branches, leading to more and larger knots. Specific gravity is inversely related to wood strength and pulp yield. However, Bell et al. (1990a) cite evidence that jack pine wood from productive sites tends to have a lower specific gravity, but there is more total wood (by weight) produced per hectare, as compared to stands on poorer sites. On balance, it does not appear as though wood quality, and therefore value, will be significantly reduced by precommercial thinning.

Precommercial thinning might also increase the degree of damage inflicted by western gall rust (*Endocronartium harknessii* [J.P. Moore] Y. Hirasts), which damages but rarely kills the thriftiest trees in a stand. Little is known, however, about the relationship between incidence of attack, damage, and precommercial thinning. Therefore, impacts will be assumed to be negligible.

Real interest rates in Canada have generally ranged between 3 percent and 5 percent over the last 20 years—a real interest rate of 4 percent will be used in this case study.

A1.4 Comparing Costs and Benefits Per Hectare

This analysis is being conducted as a marginal analysis, which means that the evaluation is concerned with the economic feasibility of adding one activity (i.e., precommercial thinning) to an existing regime of management activities. The economic attractiveness of growing jack pine by seeding followed by precommercial thinning is not being evaluated. A marginal analysis is appropriate when one is considering either increasing or decreasing the level of activity, or when one is considering whether to change the management intensity (e.g., by increasing the number of trees planted per ha). Note too that had this analysis assessed the feasibility of growing jack pine, then the seeding and site preparation costs would not have been considered as sunk costs. Instead, they would have been included in the analysis.

Table A1.1 compares the present values of the harvest volume at the rotation ages anticipated in thinned and unthinned stands. As shown in Column 2, revenues from both thinned and unthinned stands are equal because thinning is assumed not to have impacts on either the harvest volume or value. The \$634 per ha PV in Column 4, for the harvest revenues from the precommercially thinned stand that is expected to be harvested at the age of 45, is obtained by discounting over 35 years. This is because the stand is 10 years old at present. By comparison, the \$289 per ha PV for revenues from the unthinned stand is discounted over 55 years.

Note that it is not valid to judge financial attractiveness of thinning on the basis of a comparison between the two present values, because the two scenarios do not cover the same period of time. Since thinning shortens the rotation by 20 years, the land is freed sooner for the next crop, which is a benefit. On the other hand, the site preparation and seeding activities for the next rotation will take place sooner, raising the present value of regeneration costs.

Table A1.1 . Comparative analysis of thinned and unthinned stands.

Harvest age (years)	Harvest revenue ($/ha)	Discount period	PV of current stand harvest ($/ha)	NPV series of rotations ($/ha)
45	2,500	35	634	205
65	2,500	55	289	282

To put both scenarios on an equal footing, an infinite series of rotations will be assumed. This effectively gives rise to a time frame of equal length for both scenarios. It will be assumed that subsequent rotations will be identical to the current ones, so that thinning will take place in all future rotations in the thinning scenario, whereas there will not be any thinning in future rotations in the "no thin" scenario. The cost of one application of seeding and site preparation is estimated at $250 per ha in both scenarios.

Therefore, the NPV for the thinned stand is calculated as the sum of the PV of the harvest revenue from the current stand, minus the $400 per ha thinning charge incurred this year, plus the NPV earned by the series of future rotations that begin after the current one. The latter result is based on equations (5.1) for the harvest revenues and (5.2) for the seeding, site preparation, and thinning costs. The values of PVB_t and PVC_t are further discounted over 35 years in the thinned case and 55 years in the unthinned case.[6]

In summary, the PVs given in Column 4 are an infinite series of rotations, beginning with the current 10-year-old stand.

The results in Table A1.2 reinforce our previous conclusion that precommercial thinning in this case study is not viable. Note that the difference between the SEV and NPV values is due to the stipulation that the SEV data be based on bare land, as compared with the data for the land on which the 10-year-old stand was already present.

Table A1.2. Results of key criteria.

Decision criterion	Value
NPV ($/ha)	-77
EAI ($/ha per year)	-2.96
CBR	1.18
IRR (%)	3.2
SEV ($/ha)	-52

Sensitivity analysis that was conducted around various discount rates and yields reveals financial losses attributable to precommercial thinning. For example, changing the discount rate to 4 percent and the expected yield to 250 m^3 per ha lead to a net loss of $77 (Table A1.2). Table A1.3 summarizes variations in NPV with respect to the discount rate and yield per ha. The results show that precommercial thinning is favored under conditions of high harvest yields and a discount rate of not more than 4 percent.

[6] The value of $205 shown in Table 1.1 was calculated as:

$$- 400 + 2500/(1.04)^{35} - [250/(1.04)^{35}]/[1-1/(1.04)^{45}]$$
$$- \{[400/(1.04)^{35}]/[1-(1.04)^{45}]\}/(1.04)^{10}$$
$$+ [2500/(1.04)^{35}]/[(1.04)^{45}-1]$$

Table A1.3. Changes in the level of NPV with respect to yield and discount rate.

Discount rate (%)	Yield (m^3/ha)				
	200	250	300	350	400
	NPV ($/ha)				
1	189	559	930	1300	1671
2	-8	183	375	566	758
3	-102	25	151	277	404
4	-167	-77	13	103	194
5	-218	-152	-85	-19	47
6	-258	-209	-160	-110	-61
7	-291	-259	-217	-180	-143

Further sensitivity analysis was done to find the values of selected parameters that would make thinning a break-even proposition. If the cost of thinning fell from $400 to $335 per hectare, thinning would break even. If the thinned stand was eligible for harvest in 42 years or less, or if the value of wood was higher than $11.75 per m^3, thinning would become profitable.

A1.5 Comparing Costs and Benefits on a Management Unit Basis

Most jack pine in northern Ontario is grown and harvested on management units that are managed on a sustainable yield basis. This implies that over the long term the harvest volume must approximately equal the volume of growth on the unit. Ontario has some very large management units and it is not unusual to encounter situations where the area of jack pine reaches 50 000 ha or more.

The allowable cut constraint only permits a forest manager to increase harvest levels when the growth rate can be increased. The precommercial thinning operation described above is an example of a management treatment that effectively raises the growth rate of jack pine.

Therefore, it is worthwhile investigating the economics of applying precommercial thinning across an entire management unit. In reality, there will be a mixture of site classes found on a management unit. In this simple example, the entire 50 000 ha will be assumed to be of uniform site quality. Since regulating the forest may not be an important management goal, and since there are many ways of regulating a forest, the primary objective of this analysis is to provide a set of benchmarks that indicate potential returns from precommercial thinning.

The economics of precommercial thinning on a hypothetical 50 000-ha forest unit will be assessed under the following assumptions:

1. All of the costs and values used in the previous analysis on a single ha basis apply here.

2. It is assumed that the current forest will yield 150 m^3 per ha at harvest, which is the yield of a fully stocked 55-year-old Site Class 2 stand of jack pine (Plonski 1981). As above, the wood will be valued at $10 per m^3.

3. The forest unit will be regulated on a strict area basis in each scenario. Thus, where the pine is to be thinned, 1 111.11 ha (= 50 000/45) will be cut and regenerated every year at a cost of $250 per ha. Precommercial thinning will be undertaken on 1 111.11 ha annually, starting 10 years in the future, and the first harvest of the thinned material will be available in 45 years.

Where no thinning is to be undertaken, 769.23 ha (= 50 000/65) will be cut and regenerated annually and harvesting will commence 65 years in the future.

Table A1.4 presents a comparative summary of results from thinned and unthinned stands. The results are consistent with those of the single hectare analysis.

Table A1.4. Forest level comparison of thinned and unthinned stands.

Yield (m^3/ha)	PVB from harvests of thinned stands ($ million)	PVB from harvests of unthinned stands ($ million)	Net gain[a] from thinning ($/ha)
200	-5.1	-1.9	-64
250	-2.7	-1.1	-32
300	-0.2	-0.3	2
350	2.3	0.5	36
400	4.8	1.3	70

[a] The per hectare net gain is the difference between the PVBs from thinned and unthinned stands divided by the forest area (50 000 ha).

By excluding the harvest value of the harvest of the existing forest, the allowable cut effect (ACE) is excluded. However, the ACE should be viewed as part of the benefit of thinning. It allows an immediate increase in the current harvest level in anticipation of increased future yields due to improved cultural practices. Because the yields of thinned plantations are not known with certainty, a forest manager may not wish to implement the full ACE immediately. However, as the thinned stands age, the manager could take an increasing proportion of the ACE as it becomes clearer that the yield of the thinned stands will be as originally anticipated. On the other hand, the harvest should be reduced if thinned stand yields fall short of expectations. The value of the ACE was calculated as the difference in the present value of the stream of harvest revenues generated by the existing forest under the two options. The total revenue generated under the thinning program is worth $35.9 million, which is an SEV obtainable when the forest is regulated under the thinning scenario. This amount is $8.2 million more than that of the "no thin" scenario. This increase in value more than compensates for the thinning costs, and thinning is attractive even when the thinned stands yield 200 m^3 per ha.

In conclusion, while this forest level analysis was simplistic, it illustrates the importance of undertaking forest level analyses on large management units.

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APPENDIX 2

CASE STUDY 2. COMPARING THE EFFECTIVENESS OF ALTERNATIVE SILVICULTURAL OPTIONS TO REGENERATE JACK PINE IN ONTARIO

A2.1 Background

The background section of Case Study 1 described the general importance of jack pine in Ontario's forests and for the province's forest industry. That case study was a marginal analysis of the economic attractiveness of precommercial thinning of established jack pine stands.

From a broader planning perspective, it makes sense to ask whether a silvicultural treatment such as seeding, followed by precommercial thinning, is an appropriate management approach to include in the ground rules. An alternative would be for a manager to decide on a case-by-case basis whether or not to precommercially thin stands. This question is relevant in light of Ontario's relatively recent decision to shift to less intensive silvicultural methods. This has caused managers to reconsider the range of less intensive silvicultural options that are available.

The objective of this study is to demonstrate economic analysis techniques of alternative regeneration regimes on a complete project basis, as opposed to the marginal analysis illustrated in Case Study 1. In this assessment, five regimes will be compared:

1. natural regeneration;
2. natural regeneration with precommercial thinning;
3. light site preparation followed by seeding;
4. option (iii) with precommercial thinning; and
5. heavy site preparation and planting.

A2.2 Identifying Costs and Benefits

The five silvicultural options are most likely to be reasonable alternatives on better jack pine sites; intensive silviculture is generally uneconomic on Site Class 2 and lower. Hence, this study will assume that the candidate area for regeneration is Site Class 1 (SI = 20 m at the age of 50).

The success of natural regeneration depends heavily on the postharvest site conditions and the amount of available seed. Clearly, these factors are highly variable from year to year and site to site. However, the decision to seed a cutover site depends on seed availability. So, in a very real sense, the natural regeneration and seeding options are not often realistic alternatives on the same site. In other words, if sufficient seed is available then artificial seeding will not be necessary; if there is insufficient seed then natural regeneration is not feasible if the goal is to produce a new jack pine stand. Accordingly, this case study will examine an intermediate situation, where there is perhaps enough seed to produce a jack pine stand from natural regeneration but where a manager may wish to artificially seed the area to ensure adequate regeneration.

Due in part to the reasons discussed above, no growth and yield curves have been formulated for artificially seeded jack pine stands in Ontario. However, many foresters will be comfortable estimating how stands from various origins will develop. Here it will be assumed that seeding will produce a fully stocked stand that grows according to Plonski's (1981) yield curves. In contrast, the naturally regenerated stand is assumed to be 75 percent stocked and subject to a 5-year regeneration delay. Yields for the planted stand are set at 85 percent of those given by Bell et al. (1990). These yields were reduced by 15 percent because the authors built their tables on the basis of optimal growth and density conditions.

Jack pine responds well to thinning between the ages of 8 to 20. However, there have been few thinning trials undertaken for jack pine for which measurements are publicly available. One exception is the set of fifth-year measurements from thinned stands in northwestern Ontario (Goble and Bowling 1993). Accordingly, it will be assumed that precommercial thinning takes place at the age of 10, and that it shortens the rotation by 20 years but does not affect the yields at harvest. In other words, thinning is assumed to shift the yield curve to the left by 20 years. Thinning also produces larger trees, which are often more valuable. In this example, any benefit of this type will be ignored. (However, the reader will see that if thinned timber was assumed to fetch a higher price, this could easily be incorporated into the calculations.) Table A2.1 shows the per hectare yields under each of the five alternate scenarios, from the age of 25 onward.

Table A2.1. Yields under five alternate silvicultural regimes (m^3/ha).

Age	Natural	Natural regeneration and thinning	Seeding	Seeding and thinning	Planting
25	–	116	48	178	51
30	36	134	89	196	99
35	67	147	125	211	152
40	94	158	155	223	199
45	116	167	178	232	236*
50	134	174	196	238*	262
55	147	179*	211	243	279
60	158	182	223	246	289
65	167	185	232	248	–
70	174	186	238*	250	–
75	179*	–	243	–	–
80	182	–	246	–	–
85	185	–	248	–	–
90	186	–	250	–	–

* An asterisk indicates harvestable (operable) yield under each given treatment at that age.
A stand is assumed to become operable when the average DBH in the stand attains 20 cm.

The significance of the harvest reductions due to thinning are evident in Table A2.1. Table A2.2 shows the schedule and cost of each treatment for each regeneration option. The treatment schedule is based on the assumption that the site is regenerated immediately after it has been harvested. The exception is the natural-origin stands, which experience a 5-year regeneration delay. Thus, the natural stand is thinned at the age of 10, but because of the regeneration lag, this occurs in Year 15.

In northern Ontario, mills pay prices ranging from \$30 to \$50/m^3 of jack pine delivered at the mill gate. While the value of standing timber that is cut and processed in sawmills is greatly influenced by the distance to the mill and the market price of lumber (SSK Management 1993), it is reasonable to assume that the mill-gate price represents a fair long-run average price and that harvest and transport costs account for 75 percent of the price. When the mill-gate price is \$40/m^3, then standing timber has a value of \$10/m^3.

Real interest rates in Canada have usually been between 3 percent and 5 percent over the last 20 years. A real interest rate of 4 percent will be used in this case study.

Table A2.2. Activity costs and schedule for alternative treatment options.

Treatment	Year of treatment	Treatment cost ($)
Natural regeneration - no costs.		
Natural regeneration and thinning		
Precommercial thinning	15	400
Seeding		
Light site preparation and seeding	0	250[1]
Seeding and thinning		
Light site preparation and seeding	0	250
Precommercial thinning	10	400
Plant		
Heavy site preparation and planting	0	1,349[2]
Tending	5	162[3]

[1] Light site preparation is assumed to cost $175 per ha; seed applied at 50 000 seeds per ha is assumed to cost $50 per ha, and the cost of aerial seeding is estimated at $25/ha.

[2] Heavy site preparation is assumed to cost $255 per ha; stock planted at 2.0 x 2.0 meter spacing costs $597/ha, and planting costs $497 per ha (see Table 14 in Part IV of Williams 1991).

[3] Aerial tending is assumed to cost $162/ha (Williams 1991). An average thinning cost of $400/ha has been used, which is based on mechanical strip thinning. In practice, costs may range from $300 to $450 per ha, depending on operator experience and stand and site conditions. As discussed in Case Study 1, any reduction in wood quality due to the rapid growth after thinning is assumed to be negligible.

A2.3 Comparing Costs and Benefits Per Hectare

In order to make the analysis consistent, it is necessary to compare each of the options over the same time period. An infinite time horizon was chosen because of its convenience. Note that the results in Table A2.3 show that NPV is equivalent to SEV. This is because the analysis began with a bare land that has just been harvested.

Table A2.3. Results of selected criteria for five alternate silvicultural treatment options.

Option	NPV ($/ha)	EAI ($/ha per yr)	CBR	IRR (%)
Natural regeneration without thinning	99.47	3.98	undefined	undefined
Natural regeneration with thinning	-17.71	-0.71	1.08	3.9
Seeding without thinning	-130.54	-5.22	1.79	3.1
Seeding with thinning	-244.77	-9.79	1.64	3.0
Planting	-1300.20	-52.01	3.70	1.0

There are several interesting features of the results in Table A2.3. First, CBR and IRR are both undefined in the case of natural regeneration, because there are no "out-of-pocket" costs (although there may be opportunity costs). Essentially, natural regeneration provides an infinite rate of return. Although it is unusual to find projects that have zero cost, and yield a positive benefit, the inability of CBR and IRR to adequately handle this situation is one of the limitations of these two measures. A second interesting point, which is not obvious from the table, is that when the EAI is being calculated over an infinite time horizon the formula for calculating it reduces to:

$$EAI = r\ NPV$$

Note that the NPV and CBR do not provide completely consistent rankings of the five alternative treatments. In particular, the "seed and thin" option is preferred to the "seed only" option according to the CBR measure, but it is inferior according to the NPV and IRR. The explanation is that although the thinning operation does not break even, it is more attractive than the "seed only" option. Therefore, the addition of thinning to seeding improves the average return from the entire regeneration investment, although the addition of thinning increases the economic loss on that hectare.

Overall, Table A2.3 shows that the cost of carrying upfront expenditures reduces the economic attractiveness of forestry investments due to the long wait until the stand can be harvested. The results of the more intensive regimes deteriorate further as the discount rate increases. In contrast, the relative attractiveness of the intensive treatments improves in low interest rate environments, as the sensitivity analysis results shown in Table A2.4 reveal. To make the table easier to interpret, only the impact on NPV is shown.

Table A2.4. Examining the sensitivity of NPV to changes in the discount rate and the price of wood.

Option	Discount rate				Wood price
	1%	2%	3%	4%	$15/m^3
Natural regeneration without thinning	1609.37	522.57	218.24	99.47	149.20
Natural regeneration with thinning	1632.69	457.36	117.63	-17.71	99.01
Seeding without thinning	1815.86	426.77	29.29	-130.54	-48.88
Seeding with thinning	2066.58	447.27	-38.53	-244.77	-49.90
Planting	19.25	-892.56	-1174.44	-1300.20	-1056.00

Table A2.4 shows that the economic attractiveness of the natural regeneration option remains intact until the discount rate approaches 1 percent. However, as the discount rate falls, the relative attractiveness of the "natural and thin", "seed only", and "seed and thin" options improves with respect to the "natural regeneration only" option.

The last column of Table A2.4 presents impacts of a $5/m^3 increase in stumpage price at a 4 percent discount rate. The effect on NPV values is roughly equivalent to a 1 percent reduction in the discount rate. However, the impact is somewhat different from a discount rate reduction in that the regimes with the thinning option show much larger gains in attractiveness compared to the unthinned options. The reason for this is that the shorter rotations of thinned stands allow the wood price increase to have a larger positive impact on NPV.

These sensitivity analysis results have revealed several interesting ideas. The first is that the NPV values are very sensitive to changes in discount rate and the wood value. Thus, if the objective of the analysis is to determine whether a particular regeneration regime is economically feasible, it is important to be as accurate as possible regarding the discount rate and the stumpage price used for the analysis. However, it should be recognized that given the long time spans involved, there will always be a significant degree of forecast uncertainty. But it is also important to note that ranking of investments is not very sensitive to changes in the discount rate. In this case, discount rates greater than one percent all yielded the same ranking of options. Thus, there is much less chance of making a significant error in selecting management regimes and intensities as a result of choosing a discount rate that may be less reliable. The same cannot be said as confidently with respect to wood price. In estimating this variable, many foresters tend to be conservative and ignore the real rates of increase in the stumpage price, especially for high quality timber.

A2.4 Comparing Costs and Benefits on a Management Unit Basis

As described in Case Study 1, most jack pine in northern Ontario is grown and harvested on management units that are managed on a sustainable yield basis. It is worthwhile examining the economic performance of the five options on a management unit basis. However, if it is assumed that the forest manager regulates the forest on a strict area basis, and if the values of the harvests are ignored during the period while the forest is being regulated, then the forest-level analysis will yield the same results as the single-hectare analysis. This is because the forest level analysis simply involves undertaking each activity on a larger area over an infinite time period. Therefore the economic attractiveness is unaffected.

The allowable cut effect comes into play when a forest with an uneven age class distribution is being regulated, and the uniformity of the harvest level over time is constrained. As Willcocks et al. (1990) showed, silvicultural regimes with short rotation periods can be used to fill gaps in the harvest flow. In these circumstances, the benefits of planting may be substantially increased, depending on the desired harvest level and the unevenness of the forest age class structure. The example shown in Willcocks et al. (1990) clearly demonstrates that the results of single-hectare analysis may not adequately indicate which silvicultural regimes will perform best when applied to a management unit.

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