NODA notes
NODA • EDNO
CANADA ONTARIO
Northern Ontario Development Agreement
Entente de développement du nord de l'Ontario
Forestry • Foresterie
NODA Note No. 3

ECONOMIC ANALYSIS OF FORESTRY MANAGEMENT PRACTICES WITH AN APPLICATION TO A WHITE PINE IMPROVEMENT CUT IN ONTARIO

Kimberly Rollins*, Margaret Forsyth**, Samual Bonti-Ankomah**, and Ben Amoah**

INTRODUCTION

Canada's forests are a precious resource. To ensure that they are wisely managed, society must consider and respond to several key questions:

- How much forested land should be dedicated to commercial timber production? At what time and frequency in a forest's lifespan should logging occur?
- How do we take account of both the importance of the forest industry to Canada's economy and the necessity of maintaining forests for recreation and wildlife habitat?
- How much intensive management is desirable to improve future timber yields through silviculture practices such as thinning, pruning, or pesticide application?

These questions can be systematically addressed using the techniques of economic analysis.

This paper outlines the basic elements of forestry economics. The authors apply techniques of economic analysis to an experiment in silviculture undertaken by researchers at the Petawawa National Forestry Institute (PNFI), Chalk River, Ontario, and present a summary of results.

PURPOSE OF AN ECONOMIC ANALYSIS

The purpose of any economic analysis is to show how we can make the most of what we have by using our labor, capital, and natural resources as efficiently as possible. When considering a forest management project, we start with given amounts of basic resources including hectares of forest land, knowledge and technology, labor, money, and time. How should these resources be combined so that they are used in the most beneficial way for society? How much of each should be invested in intensive forest management? Forests, like other natural resources, are given economic value in the context of their usefulness to society. Such usefulness often involves some degree of transformation of the resource by using other productive inputs. This transformation may be as simple as using labor and materials to construct an access road so that cross-country skiers, hikers, nature watchers, or photographers can enter and enjoy the scenic beauty of a standing forest. On the other hand, the transformation may involve harvesting the timber, which requires an investment of labor, money, and materials. Regardless of the magnitude of this transformation, it is obvious that at some level different inputs are combined with the resource to produce something that people value. The economic criterion of efficiency requires that a combination of natural resources and other economic inputs produce the maximum possible value to society, given initial inputs.

A basic rule regarding efficient combinations of resources is that as the proportion of any one input is increased relative to other inputs, the contribution of that input to the overall value of the final product eventually decreases. For example, it may be that an initial investment of one extra hour of labor for thinning a hectare of forest land is very effective in enhancing the value of an output made from sawlogs. Perhaps revenues from harvested timber increase by \$20 per hectare while treatment costs increase by \$15

* Assistant Professor, Department of Agricultural Economics and Business, University of Guelph, Guelph, Ontario.
**Research Assistant and doctoral student, Departments of Economics and Agricultural Economics and Business, University of Guelph, Guelph, Ontario.

Natural Resources Canada / Ressources naturelles Canada
Canadian Forest Service / Service canadien des forêts
Ontario Ministry of Natural Resources / Ministère des Richesses naturelles

per hectare. Therefore, net benefits (revenues minus costs) increase by $5 per hectare. The return on the $15 investment is 33 percent. The next hour invested in thinning may yield an even better return; however, we know that we cannot improve tree growth indefinitely by continuing to add more labor hours of thinning. Eventually, a point is reached where adding another hour of thinning labor will increase costs by more than revenues and the return to this last investment will be negative.

There will always be a limit on how much economic return can be improved by more intensive management. A possible profile of the economic return from forest management is shown in Figure 1. After an initial increase, the return per dollar spent eventually reaches a maximum, then decreases, and finally becomes negative. This general concept, termed "diminishing marginal returns", is true of all inputs to forest management as well as other economic activities. Economic analysis can be used to identify the point at which further spending on management is not justified and when just enough has been invested so that incremental returns on the investment are at a maximum and the benefits to society are at their highest.

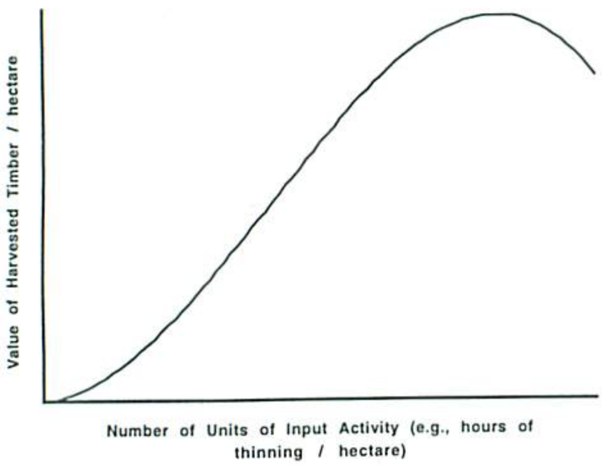

Figure 1. Diminishing marginal returns to management activities.

THE CARTIER LAKE WHITE PINE EXPERIMENT

Economic analysis can be demonstrated by using the Cartier Lake White Pine Experiment, conducted by researchers at the Petawawa National Forestry Institute, near Chalk River, Ontario, as a case study. This experiment, begun in 1971, involved a release cut in a two-story mixedwood forest. The overstory was comprised of 80-year-old (and older) mixed hardwoods. The understory consisted predominantly of 50- to 60-year-old pole-sized white pine intermixed with other softwoods. All tree species of pulpwood size (having a diameter at breast height [DBH] of 9 cm or larger) were cut, leaving the healthy understory of white pine, red pine, and white spruce. The purpose of the treatment was to release the pine and thereby increase the volume of valuable saw timber at a future date. As part of a shelterwood management regime, the objectives of this release cut were to encourage white pine regeneration; improve growth of residual pine trees; offer protection from the white pine weevil through shelterwood regeneration; and maintain amenity benefits associated with recreation, scenic beauty, etc.

For the purpose of this experiment, stands of trees were classified into three levels of pine basal area, averaging 6.9, 11.5, and 16.1 m^2/ha respectively. Each density was sampled by ten permanent plots; five of these were release cut (treated plots) and the remainder were left untouched (control plots). Costs of the release cut were recorded and in 1981 and 1991 the plots were remeasured and growth on them calculated. Results showed that the operation had been highly effective in releasing the white pine and promoting the development of sawlog sizes. Between 1971 and 1991 the merchantable volume of timber on the 11.5 m^2/ha basal area plots grew by 190% for treated areas compared to 106% for untreated sites (Figure 2 and Stiell et al. 1994). The following observation was made at an earlier date:

> the treatments applied have anticipated the natural succession wherein the pine would eventually be released by decadence and breakup of the hardwood overstory. Not only was this process initiated much sooner than might have occurred in untreated stands, but was accomplished abruptly rather than over a number of years. The net effects were to forestall loss of the hardwoods through mortality by harvesting them while still in a merchantable condition, and to accelerate development of the pine, achieving large sizes at a much earlier age and advancing the technical rotation age by some 20 to 30 years (Stiell 1984).

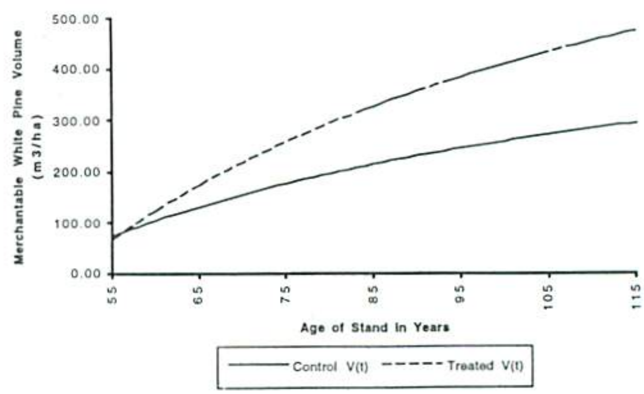

Figure 2. Volume growth of merchantable white pine in treated and control stands.

BASIC ELEMENTS OF ECONOMIC ANALYSIS: AN APPLICATION TO CARTIER LAKE

This example presents a simple economic analysis of the Cartier Lake White Pine Experiment. The bottom-line of any economic analysis is a comparison of the net benefits to society from various proposed forest management schemes including the option of no management at all. To calculate net benefits it is necessary to calculate gross benefits and subtract the costs, taking into account the fact that benefits and costs generally accrue at different times and need to be discounted accordingly. The objective is to choose the course of action which maximizes the dollar value of net benefits to society.

Timber Values and Stumpage Prices

Society derives benefits both from standing timber and from harvested logs. The economic benefits of harvested logs are best measured in terms of what people would be willing to pay for them in a competitive market. Demand for logs reflects demand for products that use logs as raw materials. Therefore, an estimate of both future prices and quantities of timber is required.

Forecasts of the quantity of merchantable timber are obtained using a growth function appropriate for the specific region, site, and species of trees involved. For the Cartier Lake Experiment, actual data exists for tree volumes in 1971, 1981, and 1991 and a volume has been projected for 2001 (Stiell et al. 1994). Mensurational research has indicated general functional forms for white pine volume growth. The form suggested by Nautiyal (1988) was used for this study and growth curves were estimated. Figure 2 illustrates growth curves for both treated and control stands for the $11.5m^2$ density class. Figure 3 shows the mean annual increment for both treated and control stands. Culmination of the mean annual increment occurs at about 112 years for the treated stand compared to 103 years for the control stand. The culmination is when each of the stands would be cut so as to achieve maximum sustainable yield (MSY). This refers to the point where the average annual growth of timber volume is at a maximum. A policy of MSY considers wood volume only, not the value of the wood or management and harvest costs. MSY is not consistent with the goal of economic efficiency. For any kind of economic analysis it is necessary to consider dollar values and input costs rather than just volume of timber.

For this economic analysis the goal is to maximize net benefits from the forest to society as a whole. This will require measuring the economic value of forest outputs to society. Competitive market prices are generally considered the best indicator of the economic value of forest outputs; they are an indication of the demand for all products made from

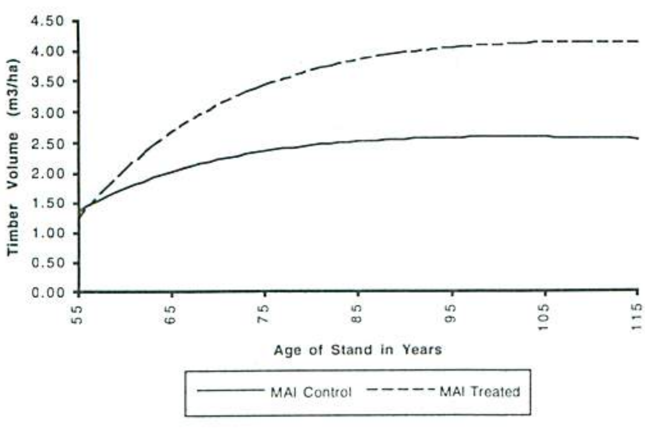

Figure 3. Mean annual increments for treated and control stands.

forest outputs. Stumpage prices set by government do not always reflect how much society values Canada's timber. For example, market stumpage prices for privately owned white pine stands in the Petawawa region of Ontario are four to five times higher than stumpage prices set by the provincial government for crown lands. For this analysis, millgate prices for sawlogs and pulpwood in the Petawawa region, were used. These prices allow for an estimation of the total net benefits to society that will be shared by the government as owner of the land and the operators employed to cut the trees. Just how net benefits are divided up will be determined by the stumpage charged by the government to the operator.

An analysis that used stumpage prices rather than market prices would provide no clues as to the economics of the project from society's point of view. Such an analysis would only reveal whether, given previously set stumpage prices, the government can meet some budgetary objective. Figure 4 shows how the gross value of the white pine (price times quantity) increases as the stands mature.

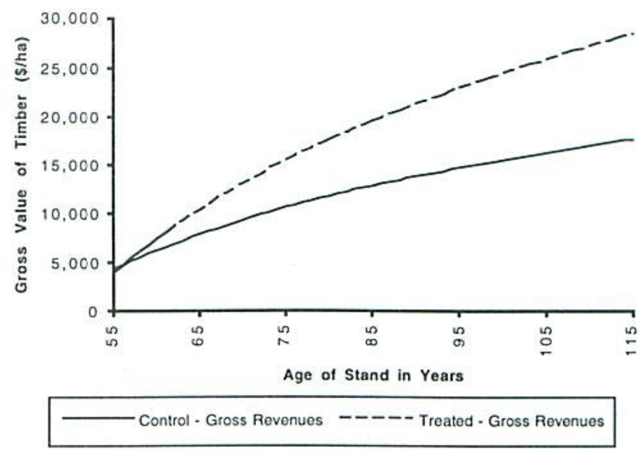

Figure 4. Undiscounted gross value of standing timber.

Amenity Values

Benefits derived from an unharvested forested area are more difficult to measure but can be equally important. People attach significant value to the existence of wild forested areas as places for recreation and as wildlife habitats. To be complete, any economic analysis must make some effort to quantify these less tangible benefits, which are often termed amenity values. Although there is evidence that amenity values are significant at Cartier Lake, to date, there have been no attempts to measure their economic value. Smyth and Methven (1978) indicate that release cuts may have a slight negative effect on amenity values.

Costs and Undiscounted Net Revenues

The measurement of costs of a forest management project are generally less problematic than the measurement of benefits. Clearly we must include the cost of such activities as thinning and pruning, timber harvesting, and replanting the next cycle. These costs will represent time spent on planning and supervision, wages paid to labor, and the cost of equipment and materials.

If revenues from timber sales and the value of amenities are added and then costs are subtracted, what is left is a "naive" measure of net benefits, as shown in Figure 5. It is a naive measure because no account has been taken of the fact that benefits and costs accrue at different times. Ignoring timing differences leaves a very rosy picture of the impact of the release cut. Net benefits of the treated stand are significantly higher than for the control stand. This difference grows with the passage of time and no maximum is reached in the time frame shown. These curves are similar in shape to the volume curves shown in Figure 2. By excluding the impact of time we have left out one of the most important determinants of the economic merits of a project.

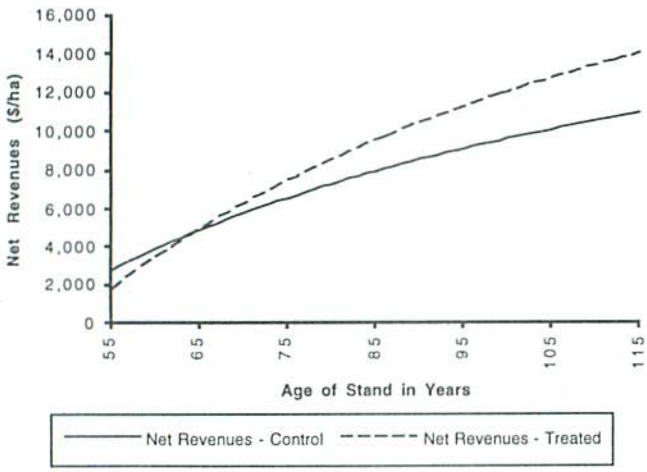

Figure 5. Undiscounted net revenue from timber.

Time, Present Value, and Discounting

Time is the third critical element in any economic analysis. In a forestry project, management costs are often incurred "up-front" at the early stages of a forest's life cycle. The returns from those expenditures are realized only much later when the forest is harvested. But before it is possible to subtract costs from benefits it is necessary to put all dollar values in terms of the same year. We use the term "present value" to indicate that all costs and benefits have been standardized to reflect what they are worth in a given year.

The concept of present value can best be explained with an example. Suppose a colleague asks if they can borrow $1,000 until next Friday. Provided the person is trustworthy and you have the cash, you might be willing to oblige them. You would likely be less agreeable, however, if they say they will pay you back in a year. You can no doubt think of lots of things you could do with that $1,000 in the coming year, including just putting it in the bank and earning interest. If the colleague instead says that they will pay you back $1,050 in a year's time, you would be more likely to agree. If you are indifferent to having $1,000 today and $1,050 in one year's time we say that the present value of $1,050 is $1,000. Your "discount rate" or "rate-of-time preference" is 5%. ($1,000 x 1.05 = $1,050).

Now suppose your colleague wants to pay you back in 3 years. For simplicity, assume the inflation rate is zero. If you demand the same 5% return each year, you would agree to lend the money if you were paid back $1,157.60 at the end of 3 years ($\$1,000 \times [1.05]^3 = \$1,157.60$). The present value of $1,157.60 received in 3 years is $1,000. In other words you are indifferent between receiving $1,000 now or $1,157.60 in 3 years.

Using the same logic, when doing an economic analysis of a forest management project it is necessary to convert all revenues and costs to a present value basis so that they can be compared[1]. A dollar spent in year one of a project is not the same as a dollar spent in year 25 of a project. The present value (PV) formula given below converts a dollar value received in any year to what it is worth if received today.

$$PV = \left(\begin{array}{c} \text{Dollar Value of} \\ \text{Net Benefit Received} \\ \text{During Year t} \end{array} \right) \times \left(\frac{1}{1+r} \right)^t$$

The term $(1/1+r)^t$, referred to as the discount rate, is determined by the real rate of interest, r, and the year, t, in which the cost or benefit is incurred. In this analysis t also represents the age of the stand.

What interest rate should be used to calculate the discount rate? It should be one that represents the rate at which the money invested in forest management would have grown had it been invested elsewhere in the economy. Since there is no general agreement on what the interest rate should be, most analyses will use several different rates to examine the sensitivity of the results to the rate chosen.

Net Benefits

Figure 6 shows the present value of net benefits of timber from treated stands using several discount rates (note: an age of 55 years occurs in 1971). A strikingly different picture from that shown in Figure 5 is presented. Net benefits no longer increase steadily in the time frame shown, but rather peak between the ages of 63 and 75 years, depending on the discount rate used, and then decline steadily. For a 3% rate, net benefits peak at about $1,300/ha in year 75. For 5% and 6% rates, net benefits peak at $325/ha in year 66 and $200/ha in year 63, respectively. These are less by an order of magnitude than are undiscounted net benefits, which reach $20,000 per hectare in year 145.

[1] This procedure is distinct from deflating dollar amounts by an anticipated inflation rate to put everything in terms of real or constant dollars. If inflation has been built into cost and revenue estimates then deflation to constant dollars should be done prior to discounting to present value terms. The discount rate used for present value calculations is a "real interest rate" in that it excludes any return required solely to keep up with inflation.

Clearly, not discounting ignores an important cost that becomes increasingly significant as the interest rate is increased. Intuitively, the higher the interest rate the greater the cost, in terms of foregone interest, of having money and resources (labor, equipment, land) tied up in the project.

Figure 7 shows the results for the untreated stands. Again net benefits are dramatically reduced when compared to the undiscounted case. Furthermore, discounted net benefits peak between 59 and 70 years, depending on the interest rate used. Comparing the treated and control stands, the maximum present value of net benefits for the control stands is slightly less than half of that of the treated stands for all three interest rates. Clearly the investment in the release cut has been worthwhile as discounted net benefits are greatly improved. Although not obvious from these graphs, this improvement becomes less significant as the interest rate is increased from 3 to 6%. As the interest rate increases, the benefits of the release cut become less significant as they become more heavily discounted. This is true, but only to a lesser extent, for the costs of the release cut as costs are discounted over fewer years. Hence the economic return to the release cut is reduced as the interest rate is increased. Indeed, at a high enough interest rate (7% or greater) the economic returns from the release cut would be negligible.

The optimal economic harvest age is that age for which discounted net benefits are maximized. Let's say that the prime rate is 7%, but inflation is at 2%. The "real" interest rate is net of inflation, so it would be 5%. According to Figures 6 and 7, the optimal rotation ages of the treated and control stands would be about 66 years and 61 years, respectively. The discounted net benefits from the treated stands would be approximately \$325/ha while the control stands would net just under \$200/ha.

These optimum rotation ages are significantly less than the MSY that, as noted earlier, was 100 years for control stands and 110 years for treated stands. MSY increases with increasing timber volume, continues to increase even when the current annual increment (the per year growth rate for only the last year) begins to decline, and does not consider costs. The economic optimum, on the other hand, occurs when the productivity (the rate of increase in net value) of the stands is highest. For this reason, the MSY for almost any forestry application will occur at a longer rotation age than that for the economically optimal yield.

SUMMARY

An economic analysis of forest management practices consists of: (1) calculating the present value of benefits, (2) calculating the present value of costs, and (3) subtracting present valued costs from benefits. Omitting the step of putting benefits and costs in present value terms can give a completely false conclusion regarding the economics of a project. This is especially true for the forestry industry because of the long time periods involved. Costs are usually incurred in the early years of a project while the revenues are not seen for 50–100 years. Over that time period the initial expenditures could have been earning a return in another investment. This foregone return can be very significant; yet, it represents a cost that is completely ignored when discounting is not considered. For the project to pass the economic test, this cost must be compensated for by an increase in the value of the forest either through volume growth, price growth, or both. Thus, in an economic analysis where amenity values are disregarded, three key growth rates are of concern: the growth rate of wood volume, the growth rate of price, and the discount rate. Where amenity benefits are of concern, it is also necessary to consider the rate at which these change over the rotation.

The importance of discounting is clear from the Cartier Lake data. When no discounting is carried out, net benefits are an order of magnitude higher than properly discounted net benefits. It is noteworthy, however, that for this particular project the discounting of net benefits did not change the overall conclusion that the release cut was worthwhile. The reason for this is that the cost of the release cut was incurred when the trees were already 55 years old. In calculating present values this cost is discounted over 55 periods

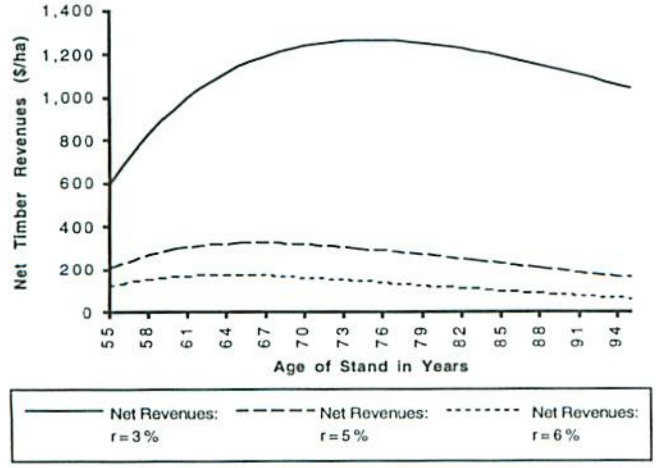

Figure 6. Present valued net benefits at three discount rates – treated stands.

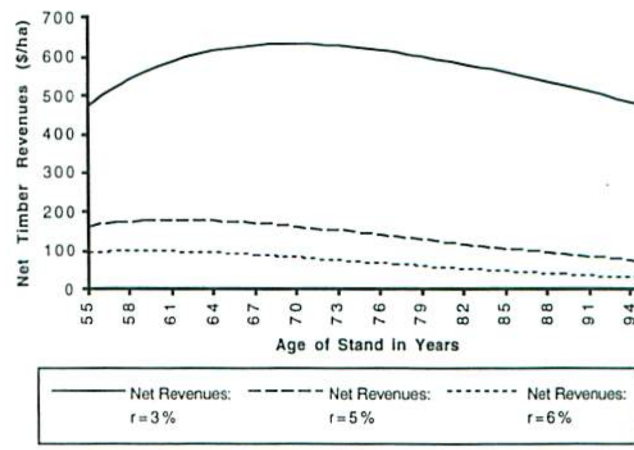

Figure 7. Present valued net benefits at three discount rates – control stands.

and is therefore significantly reduced. At a 5% interest rate the cost of the release cut will be multiplied by .068 ($= 1/1.05^{55}$) to put it in present value terms.

In a forestry project any significant management costs that occur at the beginning of a forest's lifespan can quickly make the project uneconomical because these costs will not be discounted. Management costs incurred at later stages of growth will have a much smaller impact because of discounting.

LITERATURE CITED

Nautiyal, J.C. 1988. Forest economics: principles and applications. Canadian Scholar's Press, Toronto, ON.

Smyth, J.H.; Methven, I.R. 1978. Application of a numerical index to quantify the aesthetic impact of an improvement cut in pine mixedwoods. Dep. Environ., Can. For. Serv., Sault Ste. Marie, ON. Inf. Rep. O–X–270. 12 p. + appendices.

Stiell, W.M. 1984. Improvement cut accelerates white pine sawlog growth. For. Chron. 60(1):3–9.

Stiell, W.M.; Robinson, C.F.; Burgess, D. 1994. 20-year growth of white pine following commercial improvement cut in pine mixedwoods. For. Chron. 70(4):385–394.

Additional copies of this publication are available from:

Natural Resources Canada
Canadian Forest Service – Ontario
Great Lakes Forestry Centre
P.O. Box 490
Sault Ste. Marie, Ontario
P6A 5M7
(705)949-9461
(705)759-5700(FAX)

Catalogue No. Fo 29–41/3–1994E
ISBN 0–662–22536–8
ISSN 1198–2233

This report is printed on recycled paper.

Canada