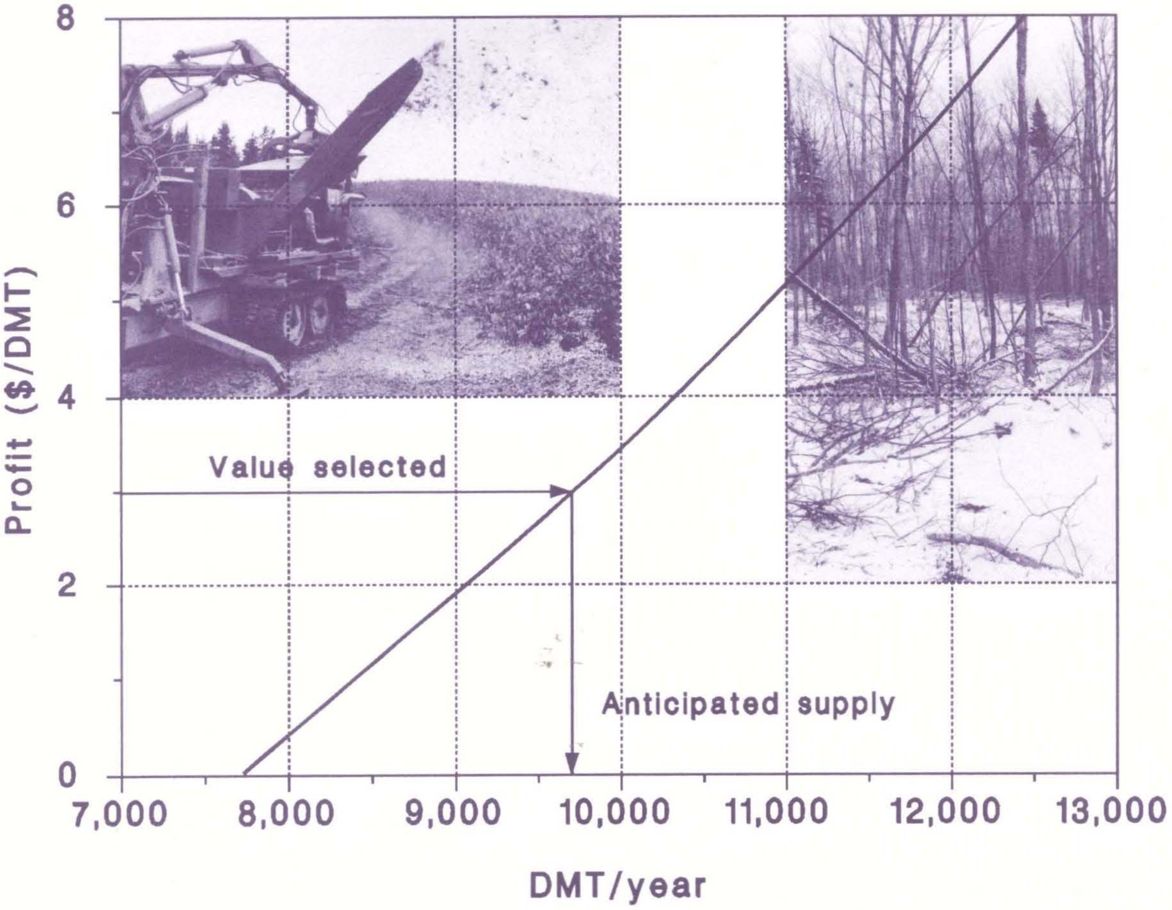
Analysis of integrated production of forest biomass and commercial timber (ENFOR Project P-428)

Louis-Jean Lussier and Robert Boutin
Quebec Region • Information Report LAU-X-112E



Biomass supply function

Natural Resources Canada
Ressources naturelles Canada

Canadian Forest Service
Service canadien des forêts

Energy ENFOR from the Forest

Canada

THE LAURENTIAN FORESTRY CENTRE is one of six regional establishments of the Canadian Forest Service (Natural Resources Canada). The Centre cooperates with other government agencies, educational institutions and the forest industry to promote through research and development the most efficient and rational management and use of Quebec's forests.

In Quebec, the program consists of forest resource and protection research and forest development. Most research is undertaken in response to the needs of the various forest management agencies. The results of this research are distributed in the form of scientific and technical reports, conferences, and other publications.

LE CENTRE DE FORESTERIE DES LAURENTIDES est un des six établissements régionaux du Service canadien des forêts (Ressources naturelles Canada). Le Centre collabore avec divers organismes gouvernementaux, avec les intervenants de l'industrie forestière et avec les établissements d'enseignement dans le but de promouvoir, par des travaux de recherche et de développement, un aménagement et une utilisation plus rationnels des ressources forestières du Québec.

Au Québec, les activités portent sur la recherche dans les domaines des ressources forestières et de la protection des forêts, et sur le développement forestier. La plupart des travaux sont entrepris pour répondre aux besoins de divers organismes intéressés à l'aménagement forestier. Les résultats de ces travaux sont diffusés sous forme de rapports techniques et scientifiques, de conférences et autres publications.

Analysis of integrated production of forest biomass and commercial timber

(ENFOR Project P-428)

Louis-Jean Lussier and Robert Boutin

Information Report LAU-X-112E
1995

Natural Resources Canada
Canadian Forest Service - Quebec Region

CANADIAN CATALOGUING IN PUBLICATION DATA

Lussier, Louis-Jean, 1926-

Analysis of integrated production of forest biomass
and commercial timber (ENFOR Project P-428)

(Information Report ; LAU-X-112E)
Includes an abstract in French.
Issued also in French under title: Analyse de la production
intégrée de biomasse forestière et de bois de commerce.
Issued by the Laurentian Forestry Centre.
Includes bibliographical references.
ISBN 0-662-23157-0
Cat. no. Fo46-18/112E

1. Forest biomass -- Economic aspects -- Quebec (Province).
2. Forest products industry -- Quebec (Province).
I. Boutin, Robert.
II. Laurentian Forestry Centre.
III. Title.
IV. Series : Information Report (Laurentian Forestry Centre) ;
LAU-X-112E.

SD387.B48L87 1995 634.92'09714 C95-980101-4

Catalog No. Fo46-18/112E
ISBN 0-662-23157-0
ISSN 0835-1570

Limited additional copies of this publication are available at no charge from:
Natural Resources Canada
Canadian Forest Service - Quebec Region
Laurentian Forestry Centre
1055 du P.E.P.S.
P.O. Box 3800
Sainte-Foy, Quebec
G1V 4C7

Copies or microfiches of this publication may be purchased from:
Micromedia Ltd.
Place du Portage
165, Hôtel-de-Ville
Hull, Quebec
J8X 3X2

Cette publication est également offerte en français sous le titre «Analyse de la production intégrée de biomasse forestière et de bois de commerce (Projet ENFOR P-428)» (Numéro de catalogue Fo46-18/112F).

PRINTED IN CANADA
IMPRIMÉ AU CANADA

TABLE OF CONTENTS

TABLE OF CONTENTS
(cont'd)

LIST OF TABLES

Page

LIST OF FIGURES

ACKNOWLEDGEMENTS

The authors take this opportunity to thank officials at the Canadian Forest Service - Quebec Region (Natural Resources Canada) for their confidence in making this project possible.

Special thanks go to Gilles Carpentier, Jean-Pierre Dansereau and Sylvain Masse for their constructive comments and the time they spent reviewing this report. Without their invaluable assistance, the quality of this document and of the project as a whole would certainly have been affected.

Louis-Jean Lussier and Robert Boutin

ABSTRACT

This study proposes a method and some computer tools to carry out a coherent, systematic analysis of the financial attractiveness of integrating the production of forest biomass into that of traditional forest products. The proposed general approach was applied to hardwood and mixed stands in Common Area 1202 of the publicly owned Quebec forest in the Lower St. Lawrence River Valley. The study follows the steps of the ECO-4 modular forest management software that was completely revised to accept equations predicting forest biomass. Results from simulations suggest that in the case of Management Unit 12, the existence of a market for hardwood, combined with a reasonable transportation distance and easy trafficability, could make integrating biomass recovery into the harvesting of traditional forest products a highly interesting approach.

RÉSUMÉ

La présente étude propose une méthode et des outils informatisés permettant d'analyser de façon cohérente et systématique l'attrait financier d'une production de biomasse intégrée à celle des produits forestiers traditionnels. L'approche générale suggérée a été appliquée aux peuplements mixtes et feuillus de l'aire commune 1202 de la forêt publique québécoise du Bas-Saint-Laurent. L'étude a été abordée selon la démarche du système modulaire d'aménagement forestier ECO-4 modifié à fond pour qu'il puisse accepter les équations de prédiction de biomasse forestière. Les résultats provenant des simulations suggèrent que dans le cas de l'unité d'aménagement 12, grâce à la présence d'un marché pour les bois francs combinée à une distance de transport raisonnable et à une traficabilité aisée, l'intégration de la récupération de biomasse à la récolte de produits forestiers traditionnels peut s'avérer des plus intéressantes.

FOREST MANAGEMENT:
a four-dimensional world

The primary role of the forest manager is to ***optimize the decisions*** required to develop the forest resources in a given area.

To properly carry out this responsibility, the manager must **necessarily** make decisions based on the four fundamental dimensions of forest management:

- **resources**
- **economics**
- **space**
- **time.**

Each of these dimensions has a significant influence on decision-making; accordingly, none of them can be neglected by the decision-maker. At present, however, only the "resource" dimension is considered, and then only partially, resulting in ***management choices contrary to the best interests*** of the forestry industry and society in general.

This study on biomass recovery is based on an approach that takes into consideration all four dimensions and all pertinent parameters of the resource dimension. It provides an opportunity to assess the methodology currently used in preparing forest management plans (FMP), pointing out the main weaknesses and suggesting required improvements.

In this connection, Appendix 1 presents a document entitled **"Pitfalls of Forest Management"**, which summarizes the current situation with respect to making management choices.

OBJECTIVES OF STUDY AND ORGANIZATION OF REPORT

Millions of tonnes of recoverable forest biomass are generated every year in Quebec through traditional timber felling methods. This fibre is simply abandoned, either at the cutting site or along the roadside. In addition to being unsightly, it hinders the application of silvicultural treatments such as scarification and planting and increases the risk of forest fires. The cost of simply removing and destroying it is high, from $300 to $500 a hectare.

Could this waste of available resources be reduced or eliminated?

A number of studies have been conducted in the past few years on the financial analysis of using this annual accumulation of forest biomass to produce energy, particularly under the ENFOR program. In general, these studies showed that **production** of energy biomass in itself is not particularly viable for the private sector. This potential energy source could only become reasonably viable if oil prices were to rise much higher than present levels.

But what would happen if the production of this biomass were **integrated** into the production of traditional forest products? This approach might well generate sufficient synergy to make it worthwhile to use this available biomass, which is otherwise abandoned at the cutting site for lack of markets.

Integrated production of recoverable but unused biomass could have a number of effects.

It could enable us to:

- Reduce forest management costs through the sale of recovered biomass
- Eliminate trees and waste that prevent efficient re-use of cutting areas
- More economically develop many deteriorated stands in the inhabited forest
- Make more intensive use of available timber, thus increasing net appreciation
- Reduce the risk of forest fires.
- AN OVERALL ADVANTAGE ***would be an increased supply of timber for traditional products and fuel, with all the inherent socioeconomic benefits.***

These benefits are worth examining closely, since a large portion of this unused biomass is found in the mixed and hardwood forests of southern Quebec, close to consumers of power and commercial lumber. Since the rural areas of Quebec are experiencing high unemployment among forest workers, and the supply of wood is generally less than the demand, any attempt to increase forest activity in terms of jobs and the volume of industrial wood products can only benefit the industry and society as a whole.

Objectives and limits of this study

The primary objective of this study is to propose a method and some computer tools to carry out a coherent, systematic analysis of the financial attractiveness of integrating the production of forest biomass into that of traditional forest products. Since they fit quite naturally into the process of preparing an overall forest management plan, the methods and tools proposed here might well be useful in the preparation of such a plan.

The study deals only with the **SUPPLY** of various forest and energy biomass products. The net value of the potentially available biomass, which is the difference between its selling price and the cost of producing it, is assumed to be variable, enabling us to generate a function related to the supply of traditional products and recoverable biomass that expresses the quantities made available at different market values of recoverable biomass.

Determining the net value to be used in a given management unit involves both an analysis of concrete projects for the use of biomass that would enable us to calculate the gross value of this raw material delivered to plants, and a study of transportation and recovery systems in terms of the parameters of strata and the silvicultural treatments to be applied to them, with a view to calculating the ***net additional cost*** of producing recoverable biomass.

These two major components will not, however, be considered in this report, but might and should be carefully analysed as part of a feasibility study on a specific energy biomass project.

The proposed general approach is then applied to hardwood and mixed stands in Common Area 1202 of the publicly owned Quebec forest in the Lower St. Lawrence River Valley. This application provides a concrete illustration of the procedure rather than the results obtained, which are somewhat sketchy.

Why did we choose a common area in Management Unit 12 as an example of application of this proposed method? Common areas from the Lower St. Lawrence River Valley unit area are adjacent to the private forest, near wood and energy-consuming plants, populated by highly qualified forestry workers and has an excellent road network. It thus offers the best conditions for future implementation of an integrated project to produce traditional forest products and biomass for fuel.

The interest and experience of the population in developing regional forest resources ensure particularly favourable conditions for the technology transfer such a project would provide.

It should be noted that, if the results of this study lead to a feasibility study for a concrete energy biomass project, the supply area for such a project should clearly be extended and quite probably include the private forest in this area.

From a forestry point of view, the Lower St. Lawrence public forest presents ideal characteristics for an energy biomass project, since it is made up of a mosaic of highly diversified stands in terms of age, composition and site quality. The forest strata found in Common Area 1202 are fairly representative of those making up the forest of this area in general.

From an industry standpoint, the delicate balance in regional supply/demand for timber would make any contribution to increasing the supply of traditional products through rational use of the forest biomass for fuel most welcome. This would have highly beneficial socioeconomic effects in a region that is severely affected by high unemployment among its forest workers.

Complexity of subject and organization of report

Successfully carrying out this project entailed a number of problems. It is impossible to calculate the supply of forest biomass and its potential synergy with the supply of traditional products without examining thoroughly questions that touch upon many aspects of forest management and economic and financial analysis. The project lies, so to speak, off the beaten track, since as we noted in the first section, economic analysis is generally not included among the concerns of forest managers, and salvaging biomass is usually of little interest to them. We accordingly had to blaze a new trail and develop a management methodology that went well beyond, and often questioned, current practices and decision-making criteria in this field.

The scope and complexity of the subject made the organization of this report somewhat of a problem. If we were to describe all the technical elements it contains, this would amount to writing a textbook on forest management and economics, and that was not the purpose of our study. On the other hand, too succinct an approach would result in a poor understanding of the proposed methodology and would fail to bring out all the efforts expended to successfully complete the project.

We thus adopted the following compromise. The report describes as faithfully and simply as possible the procedure suggested for the preparation of a forest management plan and the conduct of specific projects to study the use of energy biomass combined with traditional forest product production. The actual implementation of this procedure and the results achieved in Common Area 1202 are presented. The software used in the project contains all the technical elements required to carry it out, and readers interested in learning more about this aspect are invited to contact the authors for a detailed presention.

Using this approach, we were able to remove from the main report all the technical descriptions that might have hindered a clear understanding of the study itself.

METHODOLOGY

In general, the study follows the steps of **ECO-4** modular forest management software. This system, which took six years to develop and is now used as a management tool in a few forestry operations, is particularly well suited for this type of project.

Basically, our study of recoverable biomass and its possible effect on the supply of traditional products was carried out within the framework of the actual preparation of a forest management plan, taken in the broadest sense and covering all aspects. To assist in an understanding of this process, the following will give readers a basic explanation of the overall approach used in the ECO-4 system.

ECO-4 system modules

ECO-4 is a forest management system that enables the user to deal with the four basic dimensions of management: forestry, economics, space and time, and to optimize decisions in applied forestry, particularly when preparing a management plan.

As shown in Figure 1, the PC version of ECO-4 contains two independent modules (four modules in the Macintosh version), which correspond to the two levels of study presented in Chapter 1, and two directories of files that supply various data to the modules.

a) Module 1

The first main stage in drawing up a management plan involves an in-depth analysis of the strata of the management unit under study to generate *production data* on forest property and *optimize decision variables* specific to the management strategies chosen for evaluation purposes. Since at this point the strata have not yet been physically located, the transportation distance to timber-consuming plants is varied between the minimum and maximum distances for that unit. This enables us to observe the effect of distance on the values of decision variables for each strategy being evaluated and to take these into consideration later when choosing which strategies to use for the various management parcels.

Module 1 is a management strategy simulator, an optimization tool for decision variables specific to these strategies and a generator of yields of various products, including recoverable biomass. It is basically made up of two parts, a forestry part and a financial part. Input data include stand tables for the forest strata of the management unit under study.

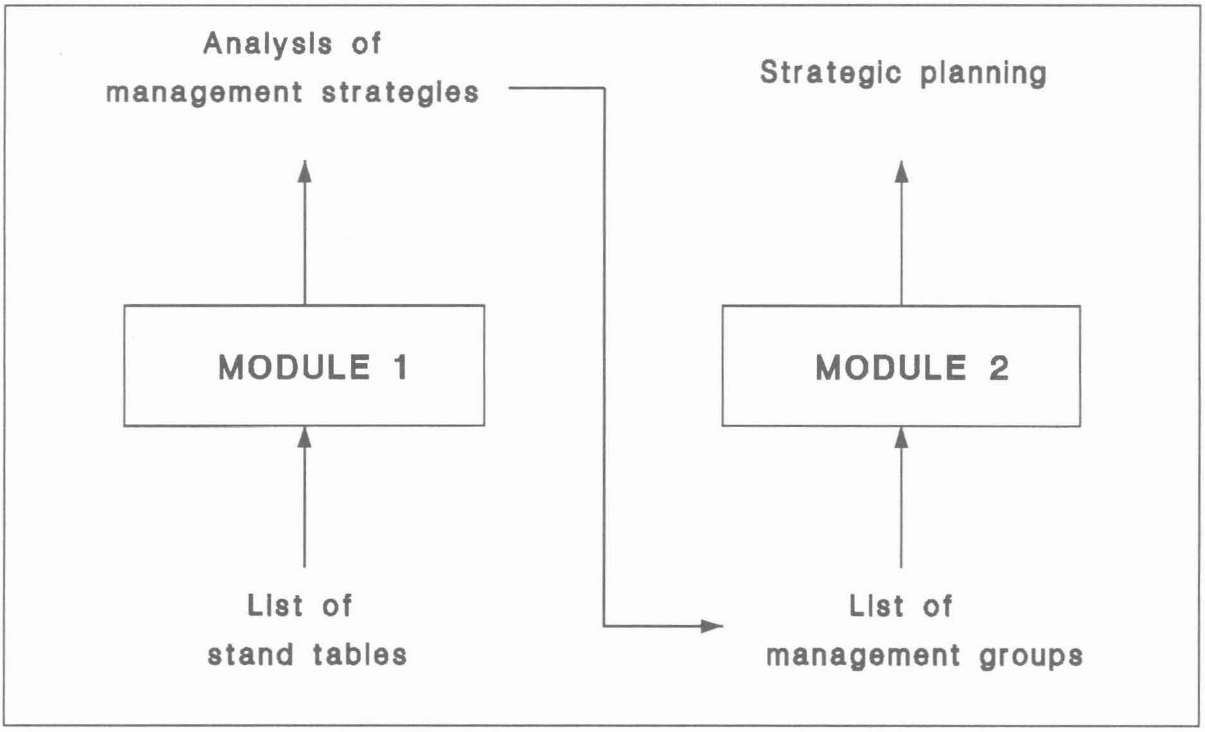


Figure 1. Outline of ECO-4 forest management system.

For this project, we had to completely revise Module 1, which had been based on the increase in the total land area of the stratum and thus could not accept equations predicting forest biomass, which would require use of the stand table for the stratum.

The new Module 1 is designed to satisfy this requirement and can thus increase the table, using simulated scenarios, based on girth increments (cm/year) for each species. Increment data came from the results of analysis of the "ministère des Ressources naturelles du Québec" (MRN) permanent sample plots (**J. Fortin, "La croissance forestière au Québec", 1983**). The effect of treatments, such as commercial thinning, is taken into consideration by applying a girth increment factor. This multiplier effect is normally estimated at 1.5, which is the figure accepted by the MRN.

The best way to gain an understanding of the structure, operation and results of Module 1 would be to see it work on-screen, and we would suggest this to any interested readers.

b) Module 2

The second major stage in preparing a management plan is carried out using Module 2 and involves first constructing a bank of forest management parcels by (1) entering all relevant information on each stratum and management lot, and (2) entering the management strategies to be simulated and the related yield figures generated using Module 1.

The next step in this stage involves: (1) for the planning horizon chosen (e.g. 120 years), estimating the net present value (NPV) that corresponds to the various simulated plans; (2) choosing, based on the maximum NPV, the optimum plan given the constraints involved, in particular that imposed by the available forest management budget; (3) calculating allowable cut and recoverable biomass based on the chosen plan; and (4) preparing the action plan for the next 25 years.

As in the case of Module 1, the best way to understand the structure and operation of Module 2 would be to see it work on a computer, and we strongly suggest this to interested readers.

Stages in analysing biomass production integrated with traditional forest products

Let us now look briefly at the stages involved in analysing the potential interest of producing integrated biomass and traditional forest products in a given area. A simplified outline of all these stages is shown in Figure 2.

a) Data entered into Module 1 and optimization in this specific module

The analysis always begins by using Module 1 to process the data specific to the strata found in the study area.

The following data are entered in the ***forestry part of the module*** for each stratum: stand table, general volume table and height-diameter functions for the survey unit concerned, girth increments for each species in the stratum, breakdown of volume used into peeled and sawn products and pulpwood, management strategies to be considered in the analysis (see Tables 1 and 2 for an example of a strategy description), multiplier effects of proposed silvicultural treatments, rate of use of the merchantable part of trees that will or could be cut and rate of stem rot and mortality. This set of figures is related to the calculation of the yield of traditional products based on various production scenarios.

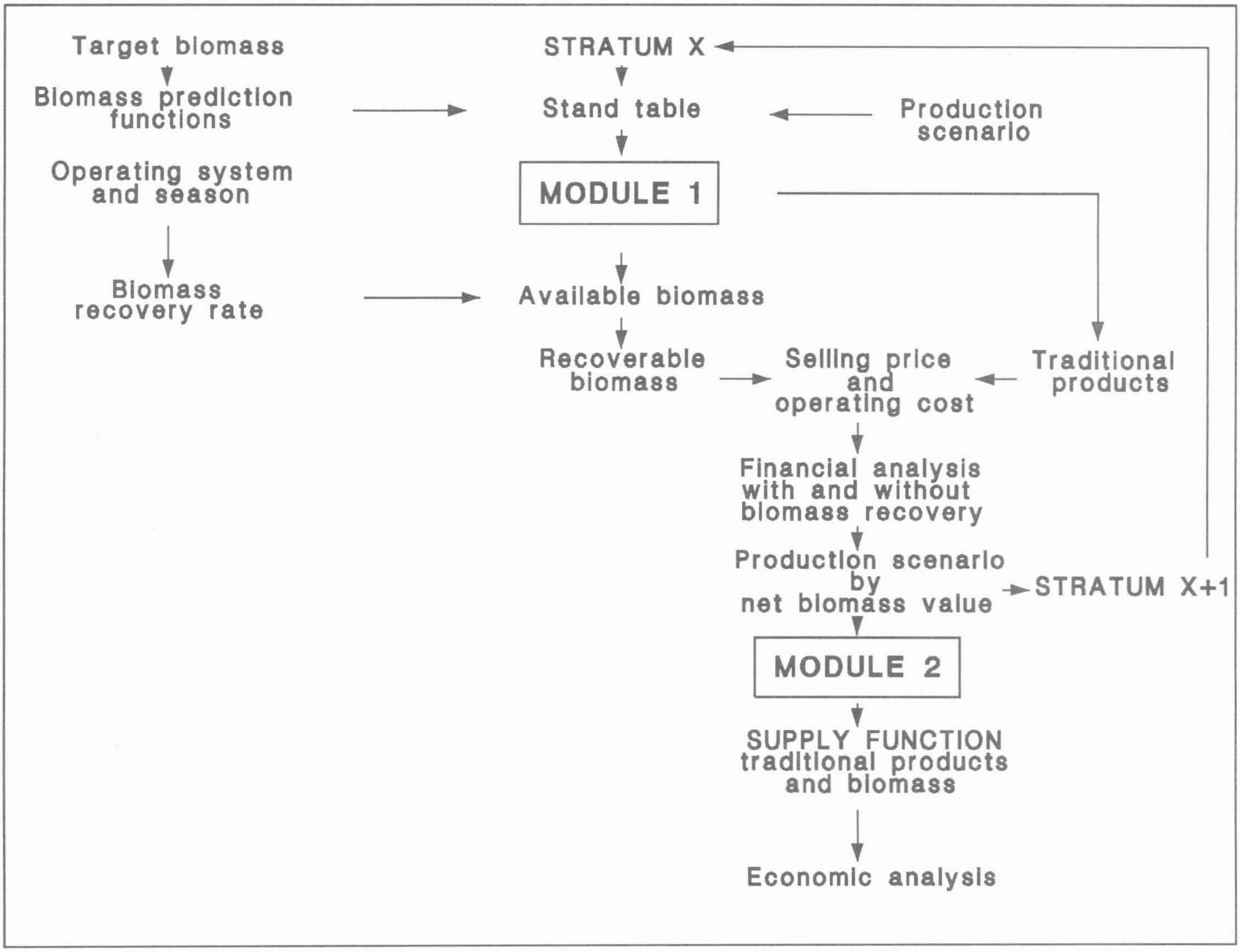


Figure 2. Stages in integrated analysis of production of biomass and traditional forest products.

Table 1. Management strategies for hardwood strata

WB

CT = Commercial Thinning **(Basal area > 18 m^2/ha)**

1- Cut 35% of volume between 40 and 70 years old
2- About 20-30 years later, regeneration cutting of remainder
3- Return stratum will be the same

RG = Regeneration Cutting **(Basal area < 18 m^2/ha)**

1- Clear-cutting around 85 years with regeneration protection
2- No time frame for return
3- Strategy for return stratum will be the same as for commercial thinning above

---

YB-M & M

SCH = Shelterwood Cutting, Hardwoods **(Basal area < 18 m^2/ha)**

1- These are density "C" and "D" stands
2- Stands are cut at maturity
3- Approximately 45% of volume cut the first year, leaving best trees for seed
4- Rotation period is 100 years
5- Strategy for return stratum will be the same as for commercial thinning above

EIC = Extraction and Improvement Cutting **(Basal area between 18 and 21 m^2/ha)**

1- Stems over minimum girth cut. Diameters as follows: YB 26, SM 26, RM 20, WB 20, WS-BS-RS 20. Others 10.
2- Stem quality should remain the same before and after cutting
3- Harvesting percentage between 20 and 30% of volume
4- Return every 30 years

SC = Selection Cutting **(Basal area > 21 m^2/ha)**

1- Stems cut equally for all diameter categories
2- Harvesting percentage between 25 and 35% of volume
3- Return every 20 years

***Note:** For shelterwood cutting, regeneration scalping will be carried out on 20 to 30% of area for poorly regenerated strata.

WB: white birch
YB: yellow birch
M: maple
SM: sugar maple

RM: red maple
WS: white spruce
BS: black spruce
RS: red spruce

Table 2. Strategy analysis

Compt.	Stratum No.	Name	Treatment	Age start	Age update	Age end	Years to mat.	Value $/ dmt
	246	BBSF C4 50	CPF	50	50	55	-5	5

%	PRODUCT	FSJ	YB-M	PO	EWC	OTHER	TOTAL	priority YB-M
		VOLUME - m³/ha						
0.5	peeled	0.0	0.2	0.0	0.0	0.0	0.2	0.2
43.2	sawn	15.9	2.9	0.2	0.0	0.0	19.0	2.9
56.3	pulp	8.1	15.2	1.5	0.0	0.0	24.8	
	unused	0.7	1.3	0.0	0.0	0.0	2.1	
	rot	2.0	0.8	0.1	0.0	0.0	2.9	
	net m³ CC	24.0	18.3	1.8	0.0	0.0	44.0	
	net m³ CT	16.6	12.4	0.6	0.0	0.0	29.6	
		SURPLUS BIOMASS - dmt/ha						
	tma/m³	0.10	0.22	0.12	0.10	0.22	0.17	0.0
	CC, tma/ha	2.4	4.0	0.2	0.0	0.0	6.6	
	CT, tma/ha	2	3	0	0	0	4.5	

	$/ha	$/ha npv
Value CT	22	22
Value cut end	2,112	1,736
Cost CT	0	0
Cost cut end	1,916	1,575
Profit margin CT	1,398	1,398
Profit margin CC	2,079	1,709
Total margin	218	184

stems/ha before update	687
stems/ha simul.	687
stems/ha end simul.	369
CT % stems	45.0
Mai priori.	0.09
Mortality %/year	0.5
distance km	120
int. rate %	4.0
PROJECTION	5

	Price, $/m³
Peeled	55
Sawn	50
Pulp	45

	CT
% softwood	45
% hardwood	45
Cost, $/ha	
Effect	1.50

Note: FSJ: fir, spruce, jack pine
PO: poplar
EWC: eastern white cedar
Other abbreviations: see Table 1

If we want to calculate the recoverable biomass, however, we must add other related information, such as the target biomass (crown, merchantable part of stem, stump, bark, etc.) and the biomass prediction factors specific to these various components. Using Module 1, we would thus obtain an estimate of the ***available target biomass*** on the basis of various management strategies.

What we are seeking to determine, however, is not the available biomass, but the ***recoverable biomass***. To this end, we must introduce into Module 1 the appropriate recovery, or salvage, rates, which will vary depending on the logging season (summer or winter) and the type of harvesting (whole-tree, tree-length, etc.)

Once the forestry part is completed, we go on to the ***financial part of Module 1.*** Here we enter, for the type of operating system, timber cost factors linking this cost to the main stratum parameters such as volume harvested per hectare, diameter of trees cut, difficulty of terrain, density of road system and cost of road construction, and the distribution of mature stands. Also entered are transportation distances and means of transport used, stumpage fees, forestry costs and credits, selling price of various products delivered to plant (unit prices).

After all the forestry and financial data have been entered, Module 1 can then produce projections of timber yields and financial returns for each of the management strategies simulated.

Two important decision variables are then optimized for a given strategy: 1) the ***financial maturity*** of the various strategies, and 2) the ***selected forest products.*** The criterion used for optimization is the maximum net present value (Max. NPV). Calculated at various ages of the stratum under study and for various products, including recoverable biomass, NPV corresponds to the net present value of the current stand and the base value of the stratum.

The yields of selected products to be entered in Module 2 would be those that correspond to the financial maturity of the strategies to be simulated.

b) Financial analysis with and without biomass recovery

Financial analysis of biomass use is done, as for other products, in Module 1. The analysis will be examined in greater detail in the chapter entitled "Financial analysis of biomass recovery".

c) Optimization in Module 2 and calculation of economic potential of various products

The simulations performed in Module 1 enable us to enter into Module 2 the most appropriate management strategies for the various parcels, taking into account the production goals and operating constraints defined in the parcelling plan. The production data generated by the Module 1 simulations, by product, including recoverable biomass, are then entered into Module 2.

Among the constraints defined is the silviculture budget. Intensive management strategies (those that include silvicultural treatments) are then introduced into the forest parcels in descending order (generally determined by the cost/benefit ratio of the best strategy that includes treatments), up to the limit of the silviculture budget, following which the parcels will be extensively developed (without treatment) using the extensive strategy found most attractive.

Forest management parcels for which none of the strategies simulated contains a positive NPV are said to be non-viable and rejected for that production area. By definition, the ***economic potential*** of a management unit corresponds to the sustained annual harvestable volume yield based on parcels that each produce a positive net present value of production for the operator. It should be emphasized that the ***biophysical potential***, as normally calculated, does not take into account this economic constraint and thus, particularly in northern units, overstates the actual potential of the area being managed.

d) Determination of supply function for biomass and other forest products

The purpose of the supply function is to estimate the quantity of traditional products and recoverable biomass that can be harvested annually at different net yearly biomass values.

Determining the supply function is discussed in greater detail in the chapter entitled "Supply of biomass and hardwood saw timber in Common Area 1202".

e) Economic analysis of biomass recovery

This project dealt only with the financial analysis of biomass recovery and thus considers only the possible ***profits to operators***. This type of harvesting would obviously have an impact on the overall economy that would be much greater than these profits alone, which amount to only 10-20% of the total resulting financial contribution.

Forest management is first and foremost an area of interest to the public at large since in Quebec it deals with resources that are mainly public property. It thus appears basically unacceptable for society as a whole to leave management decisions entirely up to private enterprise, with its particular, limited objectives of maximum profits.

If we are to properly assess how public forests are managed, it is important, in our view, to consider the ***added value*** generated by various intensities of development since, it will be recalled, corporate profits represent only a small portion of the value added to the economy. Decisions on biomass recovery, which is an integral part of forest management strategies, must then also be made on the basis of objectives and criteria that correspond to the best interests of society as a whole. We therefore recommend that a full-fledged economic analysis should, at some point, be carried out on this study.

ESTIMATE OF RECOVERABLE BIOMASS

Forest biomass available and recoverable in Quebec

By available biomass, we mean that portion of the total biomass left in various forms at the cutting site or along roadsides after partial or clear-cutting of commercial timber.

This biomass is found in various forms: crowns, unused commercial timber, non-merchantable trunks, stumps and roots. It may or does contain wood, bark, leaves and fruit.

There have been several studies on determining available biomass, among them an excellent study by the Canadian Forest Service, which contains complete, well-documented information on the subject. The biomass prediction equations for the main commercial species in Quebec produced by Denis Ouellet[1] of the Canadian Forest Service are an invaluable tool for calculating the available biomass in a given forest stand. These equations are used in this study and have been incorporated into Module 1 of the ECO-4 system.

It is estimated that some 8 million tonnes of forest biomass are generated annually in Quebec as a result of commercial logging. But what portion of this can actually be recovered at a reasonable cost and be made available at reasonable prices to large energy consumers?

It is not easy to answer this question, since there are few examples of use of forest biomass in Quebec. In any case, the question generates little interest at the present time, given the difficulty of competing with the low cost of oil.

Oil prices, however, may rise rapidly, and it might thus be interesting to determine orders of magnitude for biomass that can be recovered in the medium term by formulating some hypotheses that, based on experience, appear realistic.

We may at the outset consider unrecoverable in the medium term most of the biomass from conifer species, mainly because of the distance of softwood logging areas from potential energy-consuming centres.

Biomass from northern softwood species is estimated at some 3 million tonnes a year.

---

[1] Ouellet, D. 1983. Biomass prediction equations for twelve commercial species in Quebec. ENFOR Project P-236. Environment Canada, Can. For. Serv., Laurentian Forest Research Centre. Inf. Rep. LAU-X-62E.

Obviously, not all of the biomass in the mixed and hardwood forests of southern Quebec, which is estimated at some 5 million tonnes a year, is recoverable. Only the crown and the merchantable but unused part of commercial stems can reasonably be considered recoverable. Depending on the harvesting system used and the season, however, the recovery rate will vary between 45 and 75%.

Based on the most reliable data available, the net recovery rate for available biomass is about 65% of the total, leaving some 3 million tonnes, or 38% of the total biomass generated annually, for southern Quebec forests.

This is of course only an order of magnitude, but even reduced by 62%, the quantity of biomass that could be salvaged is fairly large and is worth examining, particularly since recovering this material could have a considerable beneficial effect on the economic potential of traditional products.

Estimate of recoverable biomass in a given stratum

How can we calculate the recoverable biomass in a given stratum?

We first determine, using the stand table for the stratum in question and the prediction equations developed by Denis Ouellet, the dry weight, in kilograms per tree, of the crown and merchantable part (MPT) of the species forming the stand. It will be recalled that only the crown and merchantable parts of merchantable trees are considered recoverable for our purposes.

To obtain an estimate of the merchantable part of trees left on logging sites, we must apply the appropriate rot and non-utilization rates for each species. Thus a softwood species would have a rot and non-utilization rate of 7%, a hardwood species 11% and an unused species 100%. We may use for this purpose the rates suggested by the MRN in its forest management manual, or we might prefer to use the real rot and non-utilization rates calculated by operators in the area for which the management plan is being prepared. In certain cases, for species like yellow birch, the non-utilization rate might be as much as 20% or even 30%.

The sum of the weight of the crown and the merchantable but unused part of the stem can be used to predict the weight of available biomass by species and by tree. Multiplying these unit weights by the number of trees of each species per hectare yields an estimate of the available biomass per hectare, normally expressed in dry metric tonnes (DMT) per hectare.

It is also possible, if preferred, to deduce the yield of biomass per m³ (DMT/m³) by simply dividing the number of metric tonnes of recoverable biomass per hectare by the volume harvested as shown in stock tables.

To calculate the recoverable biomass, a realistic recovery rate must be applied to the available biomass. The rate will vary depending on the harvesting system used and the logging season. A study by Zundel[1] shows a recovery rate of 77% for softwoods if logging is carried out in summer using the tree-length system, and 43% if it is a winter, whole-tree logging system.

Recoverable biomass may be brought to the roadside in two main ways. In the first method, the biomass left on the site is brought to the haul road after the commercial timber has been hauled. In the second method, the biomass is cut and hauled along with traditional products.

Previous studies seem to indicate that the second method is much more efficient than the first in terms of cost. It does, however, require large haulers or skidders, since the weight to be carried is considerable. If the trees are to be carried rather than skidded, the largest might have to be cut in two to fit on the truck.

When we want to calculate recoverable biomass, we may assume that operations in Quebec are summer operations, since logging normally finishes in December. In the winter, frozen trees break more easily during hauling, which reduces the recovery rate.

The simultaneous harvesting of commercial timber and biomass assumes that the whole-tree system is being used, which according to Zundel and the considerations above, would result in a lower recovery rate. Biomass is lost mainly during hauling, as small trees are lost on the way, others are broken, and branches are torn off when scraped along the ground. Trucking trees rather than skidding them seems preferable in a biomass operation, particularly since it prevents the accumulation of soil on branches, which could damage the blades of the chipper that cuts the biomass into chips.

These general remarks in no way form an analysis of the harvesting system preferred for efficient biomass recovery, but are simply intended to show that recovery depends on a number of variables, and it is only as part of a concrete project study that the recovery rate could be established with any reliability.

---

[1] Zundel, P. 1986. The economics of integrated full-tree harvesting and central growing in jack pine. Special Report No. SR-37. ENFOR Project P-322. For. Eng. Res. Inst. Can.

For the purposes of this report, we have chosen a recovery rate of 65%, which seems to fit the hypothesis of summer harvesting with partial transport of the harvested trees.

Tables 3a and 3b give an example of calculation of the available and recoverable biomass for a given stratum.

Estimating the recoverable biomass may be considerably simplified by calculating the weight of biomass per m³ (DMT/m³) harvested by the main types of stand (S, SH, HS or H) or by product (e.g. FSJ (fir-spruce-jack pine), birch-maple, poplar, cedar). These figures, obtained by simulation in Module 1 using Ouellet's equations and the stock tables for the strata under study, simplify estimates of biomass quantities when calculating allowable cuts, and use of them is recommended. Given the possible margin of error in estimating non-use and recovery rates, these figures appear to be accurate enough for the purposes of this study.

Table 3a. Calculation of recoverable biomass in a given stand

1 Species	2 DMT/m³ crown	3 Volume m³/ha MPT	4 (2 x 3) DMT/ha crown	5 Timber density	6 NU rate** MPT****	7 (3 x 5 x 6) DMT/ha MPT***		8 (4+7) Total DMT/ha
BF	0.17	14.2	2.4	0.34	0.10	0.5		2.9
BS	0.07	1.2	0.1	0.42	0.10	0.1		0.1
RS	0.15	0.9	0.1	0.40	0.10	0.0		0.2
WS	0.16	3.9	0.6	0.38	0.10	0.1		0.8
JP	0.07	0.5	0.0	0.40	0.10	9.9		0.1
LA	0.23		0.0	0.45	0.00	0.0		0.0
WP	0.17	2.6	0.4	0.32	0.10	0.1		0.5
RP	0.17	1.4	0.2	0.35	0.00	0.0		0.2
EWC	0.15		0.0	0.40	0.00	0.0		0.0
TA	0.16	19.7	3.2	0.45	0.10	0.9		4.0
BPO	0.17	3.4	0.6	0.45	1.00	1.5		2.1
WB	0.29	31.9	9.3	0.50	0.20	3.2		12.4
YB	0.54	15.3	8.3	0.52	0.25	2.0		10.3
SM	0.41	12.4	5.1	0.55	0.15	1.0		6.1
RM	0.45	11.9	5.4	0.50	0.15	0.9		6.2
Other hardwoods	0.40	0.7	0.3	0.50	1.00	0.4		0.6
	0.30	120.0	35.9			10.7	available biomass	46.6
							recovery rate	0.65
							recoverable biomass	30.3

* Densities are approximate
** NU = non-use rate
*** MPT = merchantable part of the tree

Note:

BF: balsam fir	TA: trembling aspen
JP: jack pine	BPO: balsam poplar
LA: larch	

Table 3b. Calculation of profit margin for biomass producer

1		Roadside cost of wood without biomass	$/m³	25.00
2		Roadside cost of wood with biomass	$/m³	28.00
3	2 - 1	Additional cost of wood	$/m³	3.00
4	3 x total col 3 (Table 3a)	Additional cost of wood	$/ha	360
5		Site preparation without biomass	$/ha	400
6		Site preparation with biomass	$/ha	100
7	6 - 5	Additional cost, site preparation	$/ha	-300
8	4 + 7	Additional cost, wood + preparation	$/ha	60
9	8 / recoverable biomass (30.3 DMT/ha)	Additional cost, wood + preparation	$/DMT	1.98
10		Chipping biomass	$/DMT	4.00
11		Transportation of biomass, $/DMT	$/DMT	12.00
12	9 + 10 + 11	Total cost, biomass	$/DMT	17.98
13		Selling price to fuel consumer	$/DMT	23.00
14	13 - 12	Profit to biomass producer	$/DMT	5.02

ESTIMATED COST OF BIOMASS

Calculating the cost of harvesting forest biomass is a delicate task that can only be done as part of a well-defined feasibility study, taking into account the harvesting systems already used by the operators involved in the project, changes that must be made to these systems to make them more efficient, the stands to be harvested to salvage biomass, existing operating conditions, possible silvicultural work, transportation distances, and so on.

No useful cost figures can be provided in a general study such as this.

One general remark should, however, be made: research, development and extensive analysis on various types of equipment and methods of harvesting biomass have been conducted in Europe, mainly in France, Sweden and Finland. If ever a feasibility study were to be carried out on an energy biomass project in Quebec, we would have to look to Europe, particularly to France since its hardwood forests are quite similar to our own, to find the expertise and the yield and cost figures to make a proper study.

Given our terms of reference for this study, several remarks should be made regarding calculation of the cost of harvesting biomass.

In the previous chapter, we saw how the volume of this biomass could be calculated. Here we will see what costs and factors must be considered to arrive at an accurate estimate of the roadside cost per dry metric tonne.

Various attitudes can be adopted towards the cost of harvesting biomass. We might consider that biomass recovery is a necessary operation to put harvested areas back into production and protect against forest fires, and that only the handling and chipping of biomass at the roadside should be considered as additional production costs.

We might also consider that this operation is not necessary to putting a cutting site back into production or, if it is, that this could be achieved at a lower cost using other methods, such as windrowing logging waste with a bulldozer.

In these two cases, we will attempt to estimate the *net additional cost* of biomass salvage.

The first element to be considered has to do with the differential cost of logging with and without biomass recovery. This differential may be determined by estimating the direct roadside cost with and without biomass harvesting for a given cutting method and by the whole-tree method. The difference between these two costs would be the ***gross additional cost*** of biomass harvesting.

Let us look briefly, as an example, at the cost factors involved in the ***whole-tree*** method and see which of them would be affected by biomass recovery.

a) Felling

Biomass recovery has little or no effect on the cost of felling trees normally cut by the operator, but there is an increase in cost if the trees not used by the operator must be felled to produce biomass. The additional felling cost would thus depend on the volume of these non-commercial trees. If the volume was 30 m³/ha and the cost of felling $4 per m³, the additional felling cost per hectare would be $120.

b) Hauling

Biomass recovery would also affect hauling costs. For a harvested volume of 120 m³/ha without biomass recovery and 150 m³ with biomass, if the cost of hauling biomass is $8 per m³, the additional hauling cost would be $240/ha.

c) Site preparation cost and additional net cost

Recovering biomass may also result in gains in site preparation for scarification and reforesting. If the gain is $300/ha, the additional net roadside cost would thus be:

	$/ha
Felling	120
Hauling	240
Site preparation	-300
Net additional cost	60

d) Net additional cost per tonne dry weight

The net additional cost per tonne of dry fibre is simply obtained by dividing the net cost per hectare by the quantity of wood recovered. If this quantity is $30.3 DMT/ha, the net additional cost per tonne dry weight is thus $1.98.

e) Cost of chipping and transport of biomass

The cost of handling and chipping biomass at the roadside, expressed in $/DMT, should be added to the cost calculated above to find the additional total cost of biomass delivered on trucks. If this cost is $4.00/DMT, the total on-truck cost will be $5.98/DMT.

To this cost must now be added the cost of transporting the biomass. If this is $12.00/DMT, the total cost of biomass delivered to the fuel consumer will be $17.98/DMT.

With a selling price of $23.00/DMT, the biomass harvester will thus make a profit of $5.02/DMT.

f) Differential cost for best method of operation available

In the above example, the additional net cost of biomass was determined by comparing the product cost with and without biomass recovery for a given logging method, whole-tree logging. It might happen, however, that if biomass is not recovered, a more efficient method might be used, the cost of which would be lower than the method required if biomass is recovered.

This might be the case with the **whole-trunk** method, which involves delimbing and cross-cutting trees at the cutting site rather than at the roadside. The additional cost should be calculated by comparing the cost of the best available method without biomass recovery with that of the method used with a view to recovery.

In concluding this short chapter, we would remind readers that analysis of biomass recovery cost, to be valid, should first and foremost be based on what is known as the ***total cost concept***. Under this concept, all direct and indirect costs related to the decision as to whether or not to produce biomass should be taken into consideration during the financial analysis. Silvicultural costs are thus a factor in this decision and should not be neglected, as is often the case.

The analysis should also conform to current practices in industrial engineering and operational research; these rules are too often neglected in Canada as compared with the practice in Europe. A superficial cost study that is not aimed at simplifying working techniques (time and motion study), ensuring that workers have adequate training and optimizing the values of decision variables (e.g. density and quality of road network), will result in an ***overestimate of actual operating costs*** and accordingly reject methods and equipment that might have ensured the viability of a biomass recovery operation.

Optimizing management decisions should be carried out at two levels: the forest management parcel and the management unit.

The first level, handled in ECO-4 by Module 1, is aimed at determining the best management scenario for each parcel in the forest area on the basis of the decision criterion used, maximum net present value (max NPV), and taking into account the possibility of integrating the recovery of available biomass into the silvicultural treatments envisaged.

The second level, handled in ECO-4 by Module 2, involves estimating the supply of traditional forest products and biomass based on implementation of the scenarios chosen in the first level of analysis.

This chapter will deal with the first level, while the second will be covered in the next chapter.

Method

It seems clear at the outset that evaluating the various management scenarios for each forest parcel to be developed is the most fundamental and complex stage in the preparation of a forest management plan (FMP), but it is also one that is very commonly neglected at present. Much attention is paid to yield simulation techniques, even when the data and management choices used in these simulations are in most cases highly questionable.

How, indeed, can we make appropriate choices if we ignore three of the four dimensions of management (economics, space and time), by neglecting to take into account the size of woodlots and the various products available (hardwood and softwood lumber, pulpwood, biomass, etc.) How can we obtain reliable yield data from application of various silvicultural strategies if we do not have a reliable growth and yield model?

The method used here is an attempt to fill these gaps. To provide a clear description of it, we have chosen five different cases, shown in the tables on the following pages. The reader is encouraged to refer to Tables 4a to 4e while reading the material that follows.

Table 4a. Financial evaluation of a forest management parcel - Case 1

STRATUM	Name	Age	Economic function	Coefficient	Value
156	WBHS	0			
			wood cost	a- $/ha	100
COMPARTMENT 1	Trafficability	Distance, km		b- $\$/\text{m}^3$	19.32
	1.00	100		c- $/tree	0.38
product 1 (priority)	FSJ		cartage cost	a- $\$/\text{m}^3$	3.44
product 2 (secondary)	intolerant hardwood			b- $\$/\text{m}^3/\text{km}$	0.044
			road construction	$/km	10,000
BIOMASS			timber value, product 1	a- $\$/\text{m}^3$	45.00
DMT/m^3 harvested, crown	0.12			b- $/tree	1.25
density, product 2	0.40				
recovery rate	0.65				

Case 1 : biomass profit = 0; no subsidy

rotation 1

Scenario	T1	T0
Treatment	CT+CC	CC
Interest rate	0.04	0.04
1. PCT		
year	0	
cost $/ha		
2. CT		
year	30	
harvest, m^3/ha	29	
trees/m^3	8.5	
fixed cost, $/ha	100	
fixed + variable cost, $/ha	1,213	
biomass, DMT/ha	10.7	
cost biomass, $/DMT	20.00	
cost biomass, $/ha	214	
3. CC		
year	50	50
harvest, m^3/ha	111	111
proportion product 1	0.70	0.35
proportion harvested, product 2	0.00	0.00
trees / m^3	3.8	6.6
wood cost, $/ha	2,423	1,357
wood cost, $\$/\text{m}^3$	31.18	34.80
biomass, DMT/ha	40.7	
cost biomass, $/DMT	20.00	
cost biomass, $/ha	814	
4. Selling price		
wood CT, $\$/\text{m}^3$	25.00	
wood CC, P1, $\$/\text{m}^3$	40.25	36.75
wood CC, P2, $\$/\text{m}^3$	0.00	0.00
biomass, $/DMT	20.00	
5. NPV rotation 1		
pres. value CT, $/ha	311	0
pres. value CC, $/ha	555	221
pres. cost PCT, $/ha	0	0
pres. cost CT, $/ha	440	
pres. cost CC, $/ha	455	191
NPV rotation 1, $/ha	-30	30

rotation 2 and more

Scenario	T1	T0
Treatment	CT+CC	CC
Interest rate	0.04	0.04
1. PCT		
year	0	
cost, $/ha	0	
2. CT		
year	30	
harvest, m^3/ha	29	
trees/m^3	8.5	
fixed cost, $/ha	100	
fixed + variable cost, $/ha	1,113	
biomass, DMT/ha	6	
cost biomass, $/DMT	20.00	
cost biomass, $/ha	123	
3. CC		
year	50	50
harvest, m^3/ha	111	111
proportion product 1	0.70	0.35
proportion harvested, product 2	0.00	0.00
trees / m^3	3.8	6.6
wood cost, $/ha	2,423	1,357
biomass, DMT/ha	31.18	34.80
cost biomass, $/DMT	23	
cost biomass, $/ha	20.00	
	468	
4. Selling cost		
wood CT, $\$/\text{m}^3$	25.00	
wood CC, $\$/\text{m}^3$	40.25	36.75
wood CC, P2	0.00	0.00
biomass, $/DMT	20.00	
5. NPV, rotation 2+		
pres. value CT, $/ha	44	0
pres. value CC, $/ha	71	31
pres. value PCT, $/ha	0	0
pres. value CC, $/ha	54	0
pres. cost CC, P$/ha	57	27
NPV rotation 2+, $/ha	5	5
6. TOTAL NPV	-26	35

Best scenario	**T0**	
7. Target NPV	**35**	**$/ha**
8. Simulated NPV	**-26**	**$/ha**
9. Profit margin, biomass	**0.00**	**$/DMT**

Table 4b. Financial evaluation of a forest management parcel - Case 2

STRATUM	Name	Age
156	WBHS	0
COMPARTMENT 1	Trafficability	Distance, km
	1.00	100
product 1 (priority)	FSJ	
product 2 (secondary)	intolerant hardwood	
BIOMASS		
DMT/m^3 harvested, crown	0.12	
density, product 2	0.40	
recovery rate	0.65	

Economic function	Coefficient	Value
wood cost	a- \$/ha	100
	b- \$/m^3	19.32
	c- \$/tree	0.38
cartage cost	a- \$/m^3	3.44
	b- \$/m9/km	0.044
road construction	\$/km	10,000
timber value, product 1	a- \$/m^3	45.00
	b- \$/tree	1.25

Case 2 : biomass profit = 0; subsidy \$195/ha

rotation 1

Scenario	T1	T0
Treatment	CT+CC	CC
Interest rate	0.04	0.04
1. PCT		
year	0	
cost \$/ha	0	
2. CT		
year	30	
harvest, m^3/ha	29	
trees/m^3	8.5	
fixed cost, \$/ha	-95	
fixed + variable cost, \$/ha	1,113	
biomass, DMT/ha	6	
cost biomass, \$/DMT	20.00	
cost biomass, \$/ha	123	
3. CC		
year	50	50
harvest, m^3/ha	111	111
proportion product 1	0.70	0.35
proportion harvested, product 2	0.00	0.00
trees / m^3	3.8	6.6
wood cost, \$/ha	2,423	1,357
wood cost, \$/m^3	31.18	34.80
biomass, DMT/ha	23	
cost biomass, \$/DMT	20.00	
cost biomass, \$/ha	468	
4. Selling price		
wood CT, \$/m^3	25.00	
wood CC, P1, \$/m^3	40.25	36.75
wood CC, P2, \$/m^3	0.00	0.00
biomass, \$/DMT	20.00	
5. NPV rotation 1		
pres. value CT, \$/ha	44	0
pres. value CC, \$/ha	71	221
pres. cost PCT, \$/ha	0	0
pres. cost CT, \$/ha	54	
pres. cost CC, \$/ha	57	191
NPV rotation 1, \$/ha	5	30

rotation 2 and more

Scenario	T1	T0
Treatment	CT+CC	CC
Interest rate	0.04	0.04
1. PCT		
year	0	
cost, \$/ha	0	
2. CT		
year	30	
harvest, m^3/ha	29	
trees/m^3	8.5	
fixed cost, \$/ha	-95	
fixed + variable cost, \$/ha	1,018	
biomass, DMT/ha	10.7	
cost biomass, \$/DMT	20.0	
cost biomass, \$/ha	214	
3. CC		
year	50	50
harvest, m^3/ha	111	111
proportion product 1	0.70	0.35
proportion harvested, product 2	0.00	0.00
trees / m^3	3.8	6.6
wood cost, \$/ha	2,423	1,357
wood cost, \$/m^3	31.18	34.80
biomass, DMT/ha	40.7	
cost biomass, \$/DMT	20.0	
cost biomass, \$/ha	814	
4. Selling cost		
wood CT, \$/m^3	25.00	
wood CC, \$/m^3	40.25	36.75
wood CC, P2	0.00	0.00
biomass, \$/DMT	20.00	
5. NPV, rotation 2+		
pres. value CT, \$/ha	311	0
pres. value CC, \$/ha	555	221
pres. value PCT, \$/ha	0	0
pres. value CC, \$/ha	380	0
pres. cost CC, P\$/ha	455	191
NPV rotation 2+, \$/ha	30	30
6. TOTAL NPV	35	35

Best scenario	**T0**	
7. Target NPV	**35**	**\$/ha**
8. Simulated NPV	**-26**	**\$/ha**
9. Profit margin, biomass	**0.00**	**\$/DMT**

Table 4c. Financial evaluation of a forest management parcel - Case 3

STRATUM	Name	Age
156	WBHS	0
COMPARTMENT 1	Trafficability	Distance, km
	1.00	100
product 1 (priority)	FSJ	
product 2 (secondary)	intolerant hardwood	
BIOMASS	1.12	
DMT/m³ harvested, crown	0.40	
density, product 2	0.65	
recovery rate		

Economic function	Coefficient	Value
wood cost	a- \$/ha	100
	b- \$/m³	19.32
	c- \$/tree	0.38
cartage cost	a- \$/m³	3.44
	b- \$/m³/km	0.044
road construction	\$/km	10,000
timber value, product 1	a- \$/m³	45.00
	b- \$/tree	1.25

Case 3 : biomass profit = \$9.60/DMT, subsidy \$0/ha

rotation 1

Scenario	T1	T0
Treatment	CT+CC	CC
Interest rate	0.04	0.04
1. PCT		
year	0	
cost \$/ha		
2. CT		
year	30	
harvest, m³/ha	29	
trees/m³	8.5	
fixed cost, \$/ha	100	
fixed + variable cost, \$/ha	1,213	
biomass, DMT/ha	10.7	
cost biomass, \$/DMT	20.00	
cost biomass, \$/ha	214	
3. CC		
year	50	50
harvest, m³/ha	111	111
proportion product 1	0.70	0.35
proportion harvested, product 2	0.00	0.00
trees / m³	3.8	6.6
wood cost, \$/ha	2,423	1,357
wood cost, \$/m³	31.18	34.80
biomass, DMT/ha	40.7	
cost biomass, \$/DMT	20.00	
cost biomass, \$/ha	814	
4. Selling price		
wood CT, \$/m³	25.00	
wood CC, P1, \$/m³	40.25	36.75
wood CC, P2, \$/m³	0.00	0.00
biomass, \$/DMT	29.60	
5. NPV rotation 1		
pres. value CT, \$/ha	311	0
pres. value CC, \$/ha	610	221
pres. cost PCT, \$/ha	0	0
pres. cost CT, \$/ha	440	
pres. cost CC, \$/ha	455	191
NPV rotation 1, \$/ha	25	30

rotation 2 and more

Scenario	T1	T0
Treatment	CT+CC	CC
Interest rate	0.04	0.04
1. PCT		
year	0	
cost, \$/ha	0	
2. CT		
year	30	
harvest, m³/ha	29	
trees/m³	8.5	
fixed cost, \$/ha	100	
fixed + variable cost, \$/ha	1,113	
biomass, DMT/ha	6	
cost biomass, \$/DMT	20.00	
cost biomass, \$/ha	123	
3. CC		
year	50	50
harvest, m³/ha	111	111
proportion product 1	0.70	0.35
proportion harvested, product 2	0.00	0.00
trees / m³	3.8	6.6
wood cost, \$/ha	2,423	1,357
wood cost, \$/m³	31.18	34.80
biomass, DMT/ha	23	
cost biomass, \$/DMT	20.00	
cost biomass, \$/ha	468	
4. Selling cost		
wood CT, \$/m³	25.00	
wood CC, \$/m³	40.25	36.75
wood CC, P2	0.00	0.00
biomass, \$/DMT	29.60	
5. NPV, rotation 2+		
pres. value CT, \$/ha	44	0
pres. value CC, \$/ha	76	31
pres. value PCT, \$/ha	0	0
pres. value CC, \$/ha	54	0
pres. cost CC, P\$/ha	57	27
NPV rotation 2+, \$/ha	10	5
6. TOTAL NPV	35	35

Best scenario	**T0**	
7. target NPV	35	**\$/ha**
8. simulated NPV	35	**\$/ha**
9. profit margin, biomass	9.60	**\$/DMT**

Table 4d. Financial evaluation of a forest management parcel - Case 4

STRATUM	Name	Age
156	WBHS	0
COMPARTMENT 1	Trafficability	Distance, km
	1.00	100
product 1 (priority)	FSJ	
product 2 (secondary)	intolerant hardwood	
BIOMASS		
DMT/m³ harvested, crown	0.12	
density, product 2	0.40	
recovery rate	0.65	

Economic function	Coefficient	Value
wood cost	a- $/ha	100
	b- $/m³	19.32
	c- $/tree	0.38
cartage cost	a- $/m³	3.44
	b- $/m³/km	0.044
	$/km	10,000
timber value, product 1	a- $/m³	45.00
	b- $/tree	1.25

Case 4 : biomass profit = $5.00/DMT, subsidy $95/ha

rotation 1

Scenario	T1	T0
Treatment	CT+CC	CC
Interest rate	0.04	0.04
1. PCT		
year	0	
cost $/ha		
2. CT		
year	30	
harvest, m³/ha	29	
trees/m³	8.5	
fixed cost, $/ha	5	
fixed + variable cost, $/ha	1,118	
biomass, DMT/ha	10.7	
cost biomass, $/DMT	20.00	
cost biomass, $/ha	214	
3. CC		
year	50	50
harvest, m³/ha	111	111
proportion product 1	0.70	0.35
proportion harvested, product 2	0.00	0.00
trees / m³	3.8	6.6
wood cost, $/ha	2,423	1,357
wood cost, $/m³	31.18	34.80
biomass, DMT/ha	40.7	
cost biomass, $/DMT	20.00	
cost biomass, $/ha	814	
4. Selling price		
wood CT, $/m³	25.00	
wood CC, P1, $/m³	40.25	36.75
wood CC, P2, $/m³	0.00	0.00
biomass, $/DMT	25.00	
5. NPV rotation 1		
pres. value CT, $/ha	311	0
pres. value CC, $/ha	583	221
pres. cost PCT, $/ha	0	0
pres. cost CT, $/ha	411	
pres. cost CC, $/ha	455	191
NPV rotation 1, $/ha	28	30

rotation 2 and more

Scenario	T1	T0
Treatment	CT+CC	CC
Interest rate	0.04	0.04
1. PCT		
year	0	
cost, $/ha	0	
2. CT		
year	30	
harvest, m³/ha	29	
trees/m³	8.5	
fixed cost, $/ha	5	
fixed + variable cost, $/ha	1,113	
biomass, DMT/ha	6	
cost biomass, $/DMT	20.00	
cost biomass, $/ha	123	
3. CC		
year	50	50
harvest, m³/ha	111	111
proportion product 1	0.70	0.35
proportion harvested, product 2	0.00	0.00
trees / m³	3.8	6.6
wood cost, $/ha	2,423	1,357
wood cost, $/m³	31.18	34.80
biomass, DMT/ha	23	
cost biomass, $/DMT	20.00	
cost biomass, $/ha	468	
4. Selling cost		
wood CT, $/m³	25.00	
wood CC, $/m³	40.25	36.75
wood CC, P2	0.00	0.00
biomass, $/DMT	25.00	
5. NPV, rotation 2+		
pres. value CT, $/ha	44	0
pres. value CC, $/ha	73	31
pres. value PCT, $/ha	0	0
pres. value CC, $/ha	54	0
pres. cost CC, P$/ha	57	27
NPV rotation 2+, $/ha	7	5
6. TOTAL NPV	35	35

Best scenario	**T0**	
7. target NPV	**35**	**$/ha**
8. simulated NPV	**35**	**$/ha**
9. profit margin, biomass	**5.60**	**$/DMT**

Table 4e. Financial evaluation of a forest management parcel - Case 5

STRATUM	Name	Age
156	WBHS	0
COMPARTMENT 1	Trafficability	Distance, km
	1.00	100
product 1 (priority)	FSJ	
product 2 (secondary)	intolerant hardwood	
BIOMASS		
DMT/m^3 harvested, crown	0.12	
density, product 2	0.40	
recovery rate	0.65	

Economic function	Coefficient	Value
wood cost	a- \$/ha	100
	b- \$/m^3	19.32
	c- \$/tree	0.38
cartage cost	a- \$/m^3	3.44
	b- \$/m^3/km	0.044
	\$/km	10,000
timber value, product 1	a- \$/m^3	45.00
	b- \$/tree	1.25

Case 5 : biomass profit = \$0.00/DMT; subsidy \$0/ha, market for intolerant hardwoods

rotation 1

Scenario	T1	T0
Treatment	CT+CC	CC
Interest rate	0.04	0.04
1. PCT		
year	0	
cost \$/ha		
2. CT		
year	30	
harvest, m^3/ha	29	
trees/m^3	8.5	
fixed cost, \$/ha	100	
fixed + variable cost, \$/ha	1,213	
biomass, DMT/ha	8.4	
cost biomass, \$/DMT	20.00	
cost biomass, \$/ha	169	
3. CC		
year	75	50
harvest, m^3/ha	182	111
proportion product 1	0.10	0.35
proportion harvested, product 2	0.70	0.00
trees / m^3	3.8	6.6
wood cost, \$/ha	4,000	1,357
wood cost, \$/m^3	30.11	34.80
biomass, DMT/ha	52.5	
cost biomass, \$/DMT	20.00	
cost biomass, \$/ha	1,051	
4. Selling price		
wood CT, \$/m^3	35.00	
wood CC, P1, \$/m^3	40.25	36.75
wood CC, P2, \$/m^3	40.00	0.00
biomass, \$/DMT	20.00	
5. NPV rotation 1		
pres. value CT, \$/ha	472	0
pres. value CC, \$/ha	336	221
pres. cost PCT, \$/ha	0	0
pres. cost CT, \$/ha	426	
pres. cost CC, \$/ha	267	191
NPV rotation 1, \$/ha	116	30

rotation 2 and more

Scenario	T1	T0
Treatment	CT+CC	CC
Interest rate	0.04	0.04
1. PCT		
year	0	
cost, \$/ha	0	
2. CT		
year	30	
harvest, m^3/ha	29	
trees/m^3	8.5	
fixed cost, \$/ha	100	
fixed + variable cost, \$/ha	1,113	
biomass, DMT/ha	4	
cost biomass, \$/DMT	20.00	
cost biomass, \$/ha	87	
3. CC		
year	75	50
harvest, m^3/ha	182	111
proportion product 1	0.10	0.35
proportion harvested, product 2	0.70	0.00
trees / m^3	3.8	6.6
wood cost, \$/ha	4,000	1357
wood cost, \$/m^3	30.11	34.80
biomass, DMT/ha	27	
cost biomass, \$/DMT	20.00	
cost biomass, \$/ha	539	
4. Selling cost		
wood CT, \$/m^3	35.00	
wood CC, \$/m^3	40.25	36.75
wood CC, P2	40.00	0.00
biomass, \$/DMT	20.00	
5. NPV, rotation 2+		
pres. value CT, \$/ha	25	0
pres. value CC, \$/ha	16	31
pres. value PCT, \$/ha	0	0
pres. value CC, \$/ha	20	0
pres. cost CC, P\$/ha	13	27
NPV rotation 2+, \$/ha	10	5
6. TOTAL NPV	126	35

Best scenario	**T0**	
7. target NPV	35	**\$/ha**
8. simulated NPV	35	**\$/ha**
9. profit margin, biomass	5.60	**\$/DMT**

This is an analysis of a forest management parcel made up of a mixed, generally hardwood stand containing fir, white spruce and intolerant hardwoods such as white birch and red maple. This type of stand is common in Management Unit 12 in Quebec.

The cases studied may be summarized as follows:

Cases 1-4: it is assumed there is no market for sawmill quality intolerant hardwoods. This situation is very common in Quebec.

Commercial thinning is planned at 30 years with a view to increasing softwood lumber production, followed by clear-cutting at 50 years.

Case 5: it is assumed that there is a market for sawmill quality hardwoods, e.g. Félix Huard inc. in Luceville, Que.

Commercial thinning is planned at 30 years with a view to increasing production of sawmill quality hardwoods, followed by clear-cutting at 75 years.

Cases 1-5: The five CT/CC cases are compared with the case of clear-cutting at 50 years to promote softwood lumber production. This is the extensive management hypothesis most commonly used by the MRN for this type of stand.

In the case of an intensive scenario, we assume that the available biomass will be recovered at a rate of 65%, while in that of extensive management, biomass is not recovered.

Case 1: Biomass recovery generates neither profits nor losses; the price paid by the power plant is thus equal to the cost of biomass recovery. Moreover, the operator receives no subsidy. In this case, it will be seen that there is no profit in thinning and the operator will choose extensive management.

Case 2: Biomass recovery generates neither profits nor losses; thinning is subsidized to make intensive management as attractive as extensive management. Given the positive effect of this type of management on yield, the operator will choose this option.

Case 3: Thinning is not subsidized; it is then assumed that biomass recovery should generate a profit margin for the operator, making intensive management as attractive as extensive management.

Case 4: The profit margin generated by biomass recovery is set in advance at a maximum value decided by the power plant. We must then determine the amount of the subsidy that must be paid as an incentive to the operator to practise thinning.

Case 5: No profit or loss for biomass recovery; no subsidy for thinning.

The forestry and financial analysis method may be summarized as follows (Table 4a):

a) Upper left:

- Stratum and compartment number, giving the parcel number.
- Trafficability of compartment, which is the correction factor to be applied to the cost of timber to take into account problems related to the land. Here the factor chosen is 1.00, which corresponds to average conditions.
- Delivery distance of traditional products has been estimated at 100 km, more or less average for common areas in Management Unit 12.
- Biomass quantities were obtained from simulations in Module 1.

b) Upper right

- Cost functions (harvesting, transportation, road network) used to estimate cost of timber at destination, both for commercial thinning and clear-cutting.
- Selling price functions (unit prices) compared with timber size.

c) Lower left

- Calculation of **first rotation** costs and earnings, intensive scenario (T1) and extensive scenario (T0) using classic financial analysis techniques.
- Discount rate without inflation; the figure chosen is 4%.
- Yield data for CT and CC from simulations in Module 1.
- Selling price of lumber as calculated using price function. For thinning, the price is simply entered and not calculated.
- Selling price and harvesting cost of biomass, with the difference determining the profit margin attributable to biomass recovery, remain the two unknowns of the project. See further on for how these are handled.

d) Lower right

- Calculation of costs and earnings for subsequent rotations, to infinity.
- Note that data in the left and right parts do not have to be similar even though for this project it was assumed they were.

Biomass recovery was included in the analysis based on the following reasoning:

- The scenario that maximized total NPV (rotations 1 and 2+) was first determined; this is normally Scenario T0 (extensive).
- The net cost of thinning was then introduced, i.e. the cost of thinning less the subsidy to the operator.
- The profit margin was next calculated by simulation (difference between price paid to biomass producer by the power plant and the FOB plant cost of biomass); this margin is required by the operator if the NPV of the intensive scenario is to be equal to that of the extensive scenario. This is the break-even margin whereby, using the max NPV criterion, either T1 or T0 may be chosen.
- If the producer can realize this profit margin, he would logically choose the intensive scenario because of the positive effect on the supply of timber.
- In such a case, and provided the power plant can agree to the required margin while ensuring its own viability, biomass recovery will have the effect of reducing or eliminating government subsidies.
- The cost of harvesting biomass ($20/DMT) shown in the table is only an example, since this value is an unknown for the project; but whatever value we use, this will in no way affect the profit margin required to make the intensive scenario viable. The only adjustment required will be to the selling price of the biomass.

Results

Detailed results of the simulations are shown in Tables 4a to 4e; these may be summarized as follows:

Case 1: Extensive management (T0) is the best scenario and should be chosen, since it yields a positive net present value (NPV). Intensive management (T1) yields a negative NPV and should thus be rejected.

Case 2: A $195 subsidy should be paid to the operator as an incentive to choosing T1; however, it should be noted that the operator contributes to the cost of thinning by investing $293/ha ($725 income from thinned timber less costs of $1018).

Case 3: The operator should be guaranteed a profit margin of $9.60/DMT as the result of biomass recovery if government subsidies are to be completely eliminated.

Case 4: If the maximum profit margin for biomass recovery is set at $5.00/DMT, a subsidy of $95/ha should be paid for thinning; this is a decrease of about 50% over Case 2, which assumed no profit margin.

Case 5: Intensive management (T1) is the best scenario and requires neither profit margin on biomass recovery nor a subsidy. The existence of a market for sawmill quality hardwood would be sufficient to making thinning profitable. Biomass recovery will be carried out provided the price paid by the power plant is not less than the cost of such recovery.

The following conclusions may be drawn from the above cases:

- Where there is an attractive market for sawmill quality intolerant hardwoods, intensive management (CT) is viable and the price of biomass to the power plant should correspond to the cost of its recovery. This conclusion also applies to tolerant hardwoods (YB, SM).
- Where there is no attractive market for sawmill quality intolerant hardwoods (which is often the case in Quebec), intensive management (CT) is not viable and must be subsidized by government.
- Biomass recovery might wholly or partially replace the amount of subsidies to be paid to the operator; however, only a detailed feasibility study would allow us to determine to what extent this approach might be attractive. In the case of Management Unit 12, the existence of a market for hardwood, combined with a reasonable transportation distance and easy trafficability leads us to believe that integrating biomass recovery into the harvesting of traditional forest products might be a highly interesting approach.

Other simulated cases

To take our study somewhat further, we carried out 24 additional simulations, introducing pre-commercial thinning (PCT) in addition to commercial thinning, four types of stand: S, MS, MH and H, and three sets of hypotheses: pessimistic, probable and optimistic, to examine timber yields, selling prices for traditional products, costs of harvesting and transporting these products and trafficability.

A summary of these simulations is shown in Table 5, while the values for the above three hypotheses are shown in Table 6. In the latter, there is an example of total NPV calculation based on Simulation 1.

Simulations 1 to 15 deal with precommercial thinning, while Simulations 16 to 24 involve commercial thinning.

Simulations 1-8 (PCT) - probable hypothesis MS

Simulations 1 and 2: As in the case of traditional calculations, we do not take into account the effect of treatment on growth increment, and thus PCT is not profitable and, to make it viable, we would have to guarantee the operator a profit margin on biomass recovery in the order of $10.50/DMT, which seems excessive. Based on these simulations, therefore, PCT is not a viable approach.

Simulation 3: This simulation is similar to the previous two, except that it does take into account growth increment and its beneficial effect on product value. In this case, PCT becomes viable and requires no subsidy or contribution of biomass recovery to benefit the operator.

These results show the importance of introducing changes in tree girth in yield forecasts.

Simulation 4: This simulation is based on the hypotheses of Case 3 and proposes a sensitivity test on transportation distance and trafficability. The simulated conditions render PCT unprofitable, which shows the importance of using spatial variables when preparing forest management choices.

Simulation 5: This simulation is aimed at determining, for average trafficability (1.00), the break-even distance, i.e. the distance that allows application of PCT with no subsidy or biomass contribution to the operator's profits. In this example, the break-even distance is 150 km.

Simulation 6: Same as Case 5, except that trafficability is set at 1.10 (10% more difficult than average). In this case, assuming no subsidy, the contribution of biomass to the operator's profits should be $5.70/DMT.

Simulations 7 and 8: These two cases simulate different types of trafficability. For difficult trafficability (1.10), the break-even distance is 100 km, while for easy trafficability (0.9), it is 195 km. Once again, we see the importance of considering spatial parameters when evaluating management options.

Table 5. Summary of the simulations

Simulation No.	Stratum	Treatments	Hypothesis	Effect of treatments	Distance km	Trafficability	NVP $/ha		Margin biomass $/m³	Subsidy $/ha	Observation
							T1	T0			
1	SH	PCT/CC	probable - 1	1.5	100	1.00	85	150	0.00		Does not take into account girth increment
2	SH	PCT/CC	probable - 1	1.5	100	1.00	150	150	10.50		Does not take into account girth increment
3	SH	PCT/CC	probable - 2	1.5	100	1.00	231	150	0.00		Takes into account girth increment
4	SH	PCT/CC	probable - 2	1.5	137	1.10	137	155	0.00		Distance and trafficability increased
5	SH	PCT/CC	probable - 2	1.5	150	1.00	171	171	0.00		Break-even distance for average trafficability
6	SH	PCT/CC	probable - 2	1.5	150	1.10	143	143	5.70		Compensation for increased trafficability
7	SH	PCT/CC	probable - 2	1.5	100	1.10	167	167	0.00		Break-even distance for difficult trafficability
8	SH	PCT/CC	probable - 2	1.5	195	0.90	175	175	0.00		Break-even distance for easy trafficability
9	SH	PCT/CC	pessimistic - 2	1.3	0	1.00	-66	165	0.00		Pessimistic yield and economy
10	SH	PCT/CC	pessimistic - 2	1.3	100	0.80	168	168	5.00	330	Easy trafficability, max. margin 5$/m³, 330$ subsidy, Operator's cost = 270$
11	SH	PCT/CC	optimistic - 2	1.7	100	1.00	789	259	0.00		High yield, favourable economy, high viability
12	SH	PCT/CC	optimistic - 2	1.7	396	1.35	46	46	0.00		High break-even distance, extreme trafficability
13	HS	PCT/CC	probable - 2	1.5	100	1.00	155	100	0.00		Softwood conversion: 35% T0 to 70% T1
14	H	PCT/CC	probable - 2	1.5	100	1.00	37	68	0.00		Higher hardwood value for T1 not considered
15	H	PCT/CC	probable - 2	1.5	100	1.00	205	68	0.00		Considers higher hardwood value for T1
16	S	CT/CC		1.5	100	1.00	337	135	0.00		
17	SH	CT/CC		1.5	100	1.00	184	78	0.00		
18	HS intol.	CT/CC		1.5	100	1.00	23	23	24.00		Proportion S = 0.2
19	HS intol.	CT/CC		1.5	100	1.00	51	51	21.50		Proportion S = 0.3
20	HS intol.	CT/CC		1.5	100	1.00	76	76	17.50		Proportion S = 0.4
21	HS intol.	CT/CC		1.5	100	1.00	104	104	15.50		Proportion S = 0.5
22	HS intol.	CT/CC		1.5	100	1.00	132	132	6.00		Proportion S = 0.6
23	HS tol.	CT/CC		1.5	100	1.00	84	19	0.00		Proportion S = 0.4
24	HS tol.	CT/CC		1.5	100	1.00	92	14	0.00		Proportion S = 0.3
25	HS mature deterior.	CT/CC									Assessment of 5 different cases presented in detail in body of report (Tables 7a to 7e)

Table 6. Financial evaluation of a forest management parcel - Simulation data from pessimistic, probable and optimistic hypotheses

	STRATUM	**Mixed S**		**HYPOTHESES**		
	Simulated hypotheses	Probable - 1		Pessimistic	Probable	Optimistic
	cost PCT, $/ha	500		600	500	400
	fixed cost CT, $/ha	0		0	0	0
	effect treat. on m³/ha CT	1.5		1.3	1.5	1.7
SIMULATION DATA	propor. P2 harvested	0.00		0.0	0.0	0.0
	selling price CT, $/m³	0.00		0	0	0
	selling price (a), P1, $/m³	55.00		50	55	60
	selling price, P2, $/m³	0.00		0	0	0
	selling price biomass, $/DMT	0.00			variable	
	distance, km	100			variable	
	trafficability	1.00				
	road cost	10,000		8,000	10,000	12,000
Scenario	**T1**	**T0**	**T1-T0**			
	PCT+CC	CC				
age maturity	45	50		50	45	40
m.a.i.*	3.63	2.18				
trees/m³	6.6	6.6		5.0	3.3	2.5
selling price, $/m³	46.75	46.75				
proportion P1	0.80	0.60			variable	
timber cost, $/m³	31.20	32.73				
TOTAL NPV, $/ha	**85**	**150**	**-65**			

* mean annual increment

Simulations 9 and 10 - Pessimistic hypothesis, SH

Simulation 9: Here, yields are 20% less than with the probable hypothesis, and product selling prices are 10% lower. The net present value of PCT is thus negative.

Simulation 10: Same as 9, but easy trafficability is assumed. If the maximum profit margin from biomass recovery is set at $5.00/DMT, the government would have to subsidize PCT at the rate of $330/ha, while the operator invests $270/ha. ***We feel that this sharing of investment between the beneficiaries of forest management - government, traditional forest operator and biomass operator - might be an interesting avenue to explore.***

Simulations 11 and 12 - Optimistic hypothesis, SH

Yields are 20% higher than those with the probable hypothesis and selling prices are 10% higher. In this case, PCT becomes highly profitable, even for extreme trafficability (1.35) and long distances (break-even distance of 396 km). Cases 9 and 11 show the sensitivity of results to the forestry and financial parameters of the analysis.

Simulations 13-15 - Probable hypothesis, HS and H

Simulation 13: Simulate the case of a mixed stand tending to hardwoods that is to be converted to a mixed stand tending to softwoods. The intensive scenario (PCT) is viable due to the positive effect of thinning on the proportion of softwoods at the final cutting. Modifications brought about by silvicultural treatments on the composition of a stand often have a considerable impact on the viability of such treatments.

Simulations 14 and 15: Simulate the case of a hardwood stand. Case 14 does not take into account the increase in value of hardwood lumber due to thinning, while Case 15 does. The intensive scenario is not viable in Case 14 and become quite profitable in Case 15, which shows the importance of providing yield estimates by product and considering the value of these products when preparing management decisions.

Simulations 16 and 17 - Probable hypothesis, CT, S and SH

These two cases apply to softwood stands or those with a high softwood tendency. Commercial thinning per se is viable here, requiring no subsidy or contribution to profits from biomass recovery.

Simulations 18-22 - Probable hypothesis, CT, intolerant HS, no market for hardwoods

These cases apply to mixed stands of mainly intolerant hardwoods in which we want to increase the softwood content due to the lack of a market for hardwood lumber.

By varying the proportion of softwoods from 0.20 to 0.60, we see that the lower the proportion of softwoods, the higher the profit margin on biomass recovery has to be to make thinning viable. This margin varies between \$6.00/m^3 (proportion S = 0.6) and \$24.00/m^3 (proportion 0.2).

These simulations appear to show that, unless there is a sawmill lumber market for intolerant hardwoods, biomass recovery cannot alone make commercial thinning profitable; however, it can contribute to significantly decreasing government subsidies for this treatment.

Simulations 23 and 24 - Probable hypothesis, CT, intolerant or tolerant HS, market for hardwoods

These two cases show the importance of having a market for hardwood lumber. CT encourages both hardwoods and softwoods and is aimed at producing sawmill quality in the case of hardwoods. Thinning is done at 30 years and clear-cutting at 75. In the case of clear-cutting only (T0), the cutting age is also 75 years.

We see here that thinning is viable per se, requiring neither subsidy nor biomass contribution to the operator's profit. The effect of thinning on tree girth and consequently on the value of lumber is largely responsible for the attraction of this treatment.

Simulation 25 - case of a mature, deteriorated HS stand

This is an analysis of a mature mixed stand tending to hardwoods (e.g. maple-yellow birch C3 70), severely deteriorated by previous logging operations. This type of stand is common throughout the mixed and hardwood forest areas of southern Quebec, both in private and public forests. It is extremely difficult to put back into good condition.

The priority production objective chosen is sawmill quality hardwoods. Conversion of these stands to softwoods seems unreasonable to us, since this involves a costly battle with nature and is hard to justify from an ecological standpoint.

The following management strategy is recommended and simulated below:

First rotation: clear-cutting in two stages (shelterwood cutting) over a 4-5 year period, with the first cutting removing about 40% of trees, followed two years later by partial scalping of the cutting site to encourage colonization of yellow birch by exposing inorganic soil. About 2 or 3 years after colonization, a final cut is made, protecting established regeneration.

Second rotation: at 50 years, commercial thinning is carried out to ensure production of large-diameter trees of good quality. At 80 years, the site is clear-cut.

Tables 7a to 7e present five different simulations:

Simulation 1: no financial assistance

Here it is assumed that the operator obtains no financial assistance in the form of subsidies or profit margin from recovery of biomass. Using the max NPV criterion, we see that with this hypothesis, the extensive strategy (T0) is preferable to the intensive strategy (T1).

However, for the operator, application of the criterion will result in a loss of $370/ha. Logically, this parcel will thus be rejected from calculation of the economic yield from the area. Note that, by definition, the economic yield contains only parcels with a positive or null NPV.

We also observe that the intensive strategy (CT/CC) in the second rotation is most attractive from an economic point of view. Thus, because the parcel shows negative NPVs in the first rotation, by rejecting it, we deprive ourselves of a management strategy that would be attractive in the long term. This is a typical example of the negative effects of a decision based on short-term considerations, although such a decision is quite understandable, at the expense of what should be done over the long term.

Table 7a. Financial evaluation of a forest management parcel - Simulation 1

STRATUM	Name	Age
156	YB-M C3 70	80
	deteriorated	
COMPARTMENT 1		distance, km
	Trafficability	100
product 1	1.00	
product 2	FSJ	
	pulp hardwoods	
BIOMASS		
DMT/m^3 harvested, crown		
density, product 2	0.15	
recovery rate	0.50	
	0.65	

Economic function	Coefficient	Value
wood cost	a - $/ha	100
	b - $/m^3	19.32
	c - $/tree	0.38
cartage cost	a - $/m^3	3.44
	b - $/m^3/km	0.044
road construction	$/km	10,000
timber value, product 1	a - $/m^3	45.00
	b - $/tree	1.25

Simulation 1: government subsidy

rotation 1			rotation 2 and more		
Scenario	T1	T0	Scenario	T1	T0
treatments	CT+CC	CC	treatments	CT+CC	CC
interest rate	0.04	0.04	interest rate	0.04	0.04
1. PCT			1. PCT		
year	0		year	0	
cost $/ha			cost $/ha	0	
2. CT			2. CT		
year	1		year	50	
harvest, m^3/ha	60		harvest, m^3/ha	30	
trees/m^3	4.0		trees/m^3	9.0	
fixed cost, $/ha	200		fixed cost, $/ha	100	
fixed - variable cost $/ha	2,401		fixed - variable cost $/ha	1,157	
biomass, DMT/ha	15.6		biomass, DMT/ha	5	
cost biomass, $/DMT	20.00		cost biomass, $/DMT	20.00	
cost biomass, $/ha	313		cost biomass, $/ha	100	
3. CC			3. CC		
year	5	1	year	80	80
harvest, m^3/ha	97	150	harvest, m^3/ha	210	210
proportion product 1	0.20	0.20	proportion product 1	0.20	0.20
proportion harvested, product 2	0.70	0.70	proportion harvested, product 2	0.80	0.80
trees/m^3	3.8	4.0	trees/m^3	3.0	6.0
wood cost, $/ha	2,309	3,470	wood cost, $/ha	5,192	5,393
wood cost, $/m^3	31.32	30.43	wood cost, $/m^3	29.43	3,057
subsidy $/ha	0	0			
biomass, DMT/ha	32.2		biomass, DMT/ha	17	
cost biomass, $/DMT	20.00		cost biomass, $/DMT	20.00	
cost biomass, $/ha	643		cost biomass, $/ha	340	
4. Selling price			**4. Selling price**		
wood CT, $/m^3	25.00		wood CT, $/m^3	25.00	
wood CC, P1, $/m^3	45.00	45.00	wood CC, P1, $/m^3	45.00	45.00
wood CC, P2, $/m^3	20.00	20.00	wood CC, P2, $/m^3	45.00	35.00
biomass, $/DMT	20.00		biomass, $/DMT	20.00	
5. NPV, rotation 1			**5. NPV, rotation 1**		
pres. value CT $/ha	2,223	0	pres. value CT $/ha	175	0
pres. value CC $/ha	2,139	2,913	pres. value CC $/ha	295	275
pres. cost PCT, $/ha	0	0	pres. cost PCT, $/ha	0	0
pres. cost CT, $/ha	2,609		pres. cost CT, $/ha	145	0
pres. cost CC, $/ha	2,426	3,326	pres. cost CC, $/ha	197	225
NPV rotation 1, $/ha	-673	-423	NPV rotation 1, $/ha	133	52
			6. TOTAL NPV	-540	-370

Best scenario	T0	
7. target NPV		**$/ha**
8. simulated NPV	**-370**	**$/ha**
9. profit margin, biomass	**0.00**	**$/DMT**

Table 7b. Financial evaluation of a forest management parcel - Simulation 2

STRATUM	Name	Age
156	YB-M C3 70 deteriorated	80
COMPARTMENT 1	Trafficability	distance, km
	1.00	100
product 1	FSJ	
product 2	pulp hardwoods	
BIOMASS		
DMT/m^3 harvested, crown	0.15	
density, product 2	0.50	
recovery rate	0.65	

Economic function	Coefficient	Value
wood cost	a - \$/ha	100
	b - \$/m^3	19.32
	c - \$/tree	0.38
cartage cost	a - \$/m^3	3.44
	b - \$/m^3/km	0.044
road construction	\$/km	10,000
timber value, product 1	a - \$/m^3	45.00
	b - \$/tree	1.25

Simulation 2: government subsidy

rotation 1			**rotation 2 and more**		
Scenario	T1	T0	Scenario	T1	T0
treatments	CT+CC	CC	treatments	CT+CC	CC
interest rate	0.04	0.04	interest rate	0.04	0.04
1. PCT			1. PCT		
year	0		year	0	
cost \$/ha			cost \$/ha	0	
2. CT			2. CT		
year	1		year	50	
harvest, m^3/ha	60		harvest, m^3/ha	30	
trees/m^3	4.0		trees/m^3	9.0	
fixed cost, \$/ha	200		fixed cost, \$/ha	100	
fixed - variable cost \$/ha	,2401		fixed - variable cost \$/ha	1,157	
biomass, DMT/ha	15.6		biomass, DMT/ha	5	
cost biomass, \$/DMT	20.00		cost biomass, \$/DMT	20.00	
cost biomass, \$/ha	313		cost biomass, \$/ha	100	
3. CC			3. CC		
year	5	1	year	80	80
harvest, m^3/ha	97	150	harvest, m^3/ha	210	210
proportion product 1	0.20	0.20	proportion product 1	0.20	0.20
proportion harvested, product 2	0.70	0.70	proportion harvested, product 2	0.80	0.80
trees/m^3	3.8	4.0	trees/m^3	3.0	6.0
wood cost, \$/ha	2,309	3,470	wood cost, \$/ha	5,192	5,393
wood cost, \$/m^3	31.32	30.43	wood cost, \$/m^3	29.43	30.57
subsidy \$/ha	820	0			
biomass, DMT/ha	32.2		biomass, DMT/ha	17	
cost biomass, \$/DMT	20.00		cost biomass, \$/DMT	20.00	
cost biomass, \$/ha	643		cost biomass, \$/ha	340	
4. Selling price			**4. Selling price**		
wood CT, \$/m^3	25.00		wood CT, \$/m^3	25.00	
wood CC, P1, \$/m^3	45.00	45.00	wood CC, P1, \$/m^3	45.00	45.00
wood CC, P2, \$/m^3	20.00	20.00	wood CC, P2, \$/m^3	45.00	35.00
biomass, \$/DMT	20.00		biomass, \$/DMT	20.00	
5. NPV, rotation 1			**5. NPV, rotation 1**		
pres. value CT \$/ha	2,223	0	pres. value CT \$/ha	175	0
pres. value CC \$/ha	2,139	2,913	pres. value CC \$/ha	295	275
pres. cost PCT, \$/ha	0	0	pres. cost PCT, \$/ha	0	0
pres. cost CT, \$/ha	2,609		pres. cost CT, \$/ha	145	0
pres. cost CC, \$/ha	1,752	3,326	pres. cost CC, \$/ha	197	225
NPV rotation 1, \$/ha	1	-423	NPV rotation 1, \$/ha	133	52
			6. TOTAL NPV	134	-370

Best scenario	T1	
7. target NPV	0	**\$/ha**
8. simulated NPV	1	**\$/ha**
9. profit margin, biomass	0.00	**\$/DMT**

Table 7c. Financial evaluation of a forest management parcel - Simulation 3

STRATUM	Name	Age
156	YB-M C3 70 deteriorated	80
COMPARTMENT	Trafficability	distance, km
1	1.00	100
product 1	FSJ	
product 2	pulp hardwoods	

BIOMASS	
DMT/m³ harvested, crown	0.15
density, product 2	0.50
recovery rate	0.65

Economic function	Coefficient	Value
wood cost	a - $/ha	100
	b - $/m³	19.32
	c - $/tree	0.38
cartage cost	a - $/m³	3.44
	b - $/m³/km	0.044
road construction	$/km	10,000
timber value, product 1	a - $/m³	45.00
	b - $/tree	1.25

Simulation 3: subsidy and biomass profit

rotation 1

Scenario	T1	T0
treatments	CT+CC	CC
interest rate	0.04	0.04
1. PCT		
year	0	
cost $/ha		
2. CT		
year	1	
harvest, m³/ha	60	
trees/m³	4.0	
fixed cost, $/ha	200	
fixed - variable cost $/ha	2,401	
biomass, DMT/ha	15.6	
cost biomass, $/DMT	20.00	
cost biomass, $/ha	313	
3. CC		
year	5	1
harvest, m³/ha	97	150
proportion product 1	0.20	0.20
proportion harvested, product 2	0.70	0.70
trees/m³	3.8	4.0
wood cost, $/ha	2,309	3,470
wood cost, $/m³	31.32	30.43
subsidy $/ha	500	0
biomass, DMT/ha	32.2	
cost biomass, $/DMT	20.00	
cost biomass, $/ha	643	
4. Selling price		
wood CT, $/m³	25.00	
wood CC, P1, $/m³	45.00	45.00
wood CC, P2, $/m³	20.00	20.00
biomass, $/DMT	30.00	
5. NPV, rotation 1		
pres. value CT $/ha	2,223	0
pres. value CC $/ha	2,403	2,913
pres. cost PCT, $/ha	0	0
pres. cost CT, $/ha	2,609	
pres. cost CC, $/ha	2,015	3,356
NPV rotation 1, $/ha	2	-423

rotation 2 and more

Scenario	T1	T0
treatments	CT+CC	CC
interest rate	0.04	0.04
1. PCT		
year	0	
cost $/ha	0	
2. CT		
year	50	
harvest, m³/ha	30	
trees/m³	9.0	
fixed cost, $/ha	100	
fixed - variable cost $/ha	1,157	
biomass, DMT/ha	5	
cost biomass, $/DMT	20.00	
cost biomass, $/ha	100	
3. CC		
year	80	80
harvest, m³/ha	210	210
proportion product 1	0.20	0.20
proportion harvested, product 2	0.80	0.80
trees/m³	3.0	6.0
wood cost, $/ha	5,192	5,393
wood cost, $/m³	29.43	30.57
biomass, DMT/ha	17	
cost biomass, $/DMT	20.00	
cost biomass, $/ha	340	
4. Selling price		
wood CT, $/m³	25.00	
wood CC, P1, $/m³	45.00	45.00
wood CC, P2, $/m³	45.00	35.00
biomass, $/DMT	30.00	
5. NPV, rotation 1		
pres. value CT $/ha	175	0
pres. value CC $/ha	301	275
pres. cost PCT, $/ha	0	0
pres. cost CT, $/ha	145	0
pres. cost CC, $/ha	197	225
NPV rotation 1, $/ha	140	52
6. TOTAL NPV	142	-370

Best scenario	T1	
7. target NPV	0	$/ha
8. simulated NPV	2	$/ha
9. profit margin, biomass	10.00	$/DMT

Table 7d. Financial evaluation of a forest management parcel - Simulation 4

STRATUM	Name	Age
156	YB-M C3 70 deteriorated	80
COMPARTMENT 1	Trafficability	distance, km
	1.00	100
product 1	FSJ	
product 2	pulp hardwoods	
BIOMASS		
DMT/m^3 harvested, crown	0.15	
density, product 2	0.50	
recovery rate	0.65	

Economic function	Coefficient	Value
wood cost	a - $\$/ha$	100
	b - $\$/m^3$	19.32
	c - $\$/tree$	0.38
cartage cost	a - $\$/m^3$	3.44
	b - $\$/m^3/km$	0.044
road construction	$\$/km$	10,000
timber value, product 1	a - $\$/m^3$	45.00
	b - $\$/tree$	1.25

Simulation 4: no subsidy; biomass profit

rotation 1

Scenario	T1	T0
treatments	CT+CC	CC
interest rate	0.04	0.04
1. PCT		
year	0	
cost $\$/ha$		
2. CT		
year	1	
harvest, m^3/ha	60	
trees/m^3	4.0	
fixed cost, $\$/ha$	200	
fixed - variable cost $\$/ha$	2,401	
biomass, DMT/ha	15.6	
cost biomass, $\$/DMT$	20.00	
cost biomass, $\$/ha$	313	
3. CC		
year	5	1
harvest, m^3/ha	97	150
proportion product 1	0.20	0.20
proportion harvested, product 2	0.70	0.70
trees/m^3	3.8	4.0
wood cost, $\$/ha$	2,309	3,470
wood cost, $\$/m^3$	31.32	30.43
subsidy $\$/ha$	0	0
biomass, DMT/ha	32.2	
cost biomass, $\$/DMT$	20.00	
cost biomass, $\$/ha$	643	
4. Selling price		
wood CT, $\$/m^3$	25.00	
wood CC, P1, $\$/m^3$	45.00	45.00
wood CC, P2, $\$/m^3$	20.00	20.00
biomass, $\$/DMT$	30.00	
5. NPV, rotation 1		
pres. value CT $\$/ha$	2,223	0
pres. value CC $\$/ha$	2,403	2,913
pres. cost PCT, $\$/ha$	0	0
pres. cost CT, $\$/ha$	2,609	
pres. cost CC, $\$/ha$	2,426	3,336
NPV rotation 1, $\$/ha$	-409	-423

rotation 2 and more

Scenario	T1	T0
treatments	CT+CC	CC
interest rate	0.04	0.04
1. PCT		
year	0	
cost $\$/ha$	0	
2. CT		
year	50	
harvest, m^3/ha	30	
trees/m^3	9.0	
fixed cost, $\$/ha$	100	
fixed - variable cost $\$/ha$	1,157	
biomass, DMT/ha	5	
cost biomass, $\$/DMT$	20.00	
cost biomass, $\$/ha$	100	
3. CC		
year	80	80
harvest, m^3/ha	210	210
proportion product 1	0.20	0.20
proportion harvested, product 2	0.80	0.80
trees/m^3	3.0	6.0
wood cost, $\$/ha$	5,192	5,393
wood cost, $\$/m^3$	29.43	30.57
biomass, DMT/ha	17	
cost biomass, $\$/DMT$	20.00	
cost biomass, $\$/ha$	340	
4. Selling price		
wood CT, $\$/m^3$	25.00	
wood CC, P1, $\$/m^3$	45.00	45.00
wood CC, P2, $\$/m^3$	45.00	35.00
biomass, $\$/DMT$	30.00	
5. NPV, rotation 1		
pres. value CT $\$/ha$	175	0
pres. value CC $\$/ha$	301	275
pres. cost PCT, $\$/ha$	0	0
pres. cost CT, $\$/ha$	145	0
pres. cost CC, $\$/ha$	197	225
NPV rotation 1, $\$/ha$	140	52
6. TOTAL NPV	-269	-370

Best scenario	**T1**	
7. target NPV	**-410**	**$\$/ha$**
8. simulated NPV	**-409**	**$\$/ha$**
9. profit margin, biomass	**10.00**	**$\$/DMT$**

Table 7e. Financial evaluation of a forest management parcel - Simulation 5

STRATUM	Name	Age
156	YB-M C3 70 deteriorated	80
COMPARTMENT 1	Trafficability	distance, km
	1.00	100
product 1	FSJ	
product 2	pulp hardwoods	
BIOMASS		
DMT/m^3 harvested, crown	0.15	
density, product 2	0.50	
recovery rate	0.65	

Economic function	Coefficient	Value
wood cost	a - $/ha	100
	b - $/$m^3$	19.32
	c - $/tree	0.38
cartage cost	a - $/$m^3$	3.44
	b - $/$m^3$/km	0.044
road construction	$/km	10,000
timber value, product 1	a - $/$m^3$	45.00
	b - $/tree	1.25

Simulation 5: no subsidy, biomass profit, easy operating conditions

rotation 1

Scenario	T1	T0
treatments	CT+CC	CC
interest rate	0.04	0.04
1. PCT		
year	0	
cost $/ha		
2. CT		
year	1	
harvest, m^3/ha	60	
trees/m^3	4.0	
fixed cost, $/ha	200	
fixed - variable cost $/ha	2,019	
biomass, DMT/ha	15.6	
cost biomass, $/DMT	20.00	
cost biomass, $/ha	313	
3. CC		
year	5	1
harvest, m^3/ha	97	150
proportion product 1	0.20	0.20
proportion harvested, product 2	0.70	0.70
trees/m^3	3.8	4.0
wood cost, $/ha	1,820	2,724
wood cost, $/$m^3$	24.69	23.89
subsidy $/ha	0	0
biomass, DMT/ha	32.2	
cost biomass, $/DMT	20.00	
cost biomass, $/ha	643	
4. Selling price		
wood CT, $/$m^3$	25.00	
wood CC, P1, $/$m^3$	45.00	45.00
wood CC, P2, $/$m^3$	20.00	20.00
biomass, $/DMT	25.00	
5. NPV, rotation 1		
pres. value CT $/ha	2,223	0
pres. value CC $/ha	2,271	2,913
pres. cost PCT, $/ha	0	0
pres. cost CT, $/ha	2,242	
pres. cost CC, $/ha	2,025	2,619
NPV rotation 1, $/ha	228	295

rotation 2 and more

Scenario	T1	T0
treatments	CT+CC	CC
interest rate	0.04	0.04
1. PCT		
year	0	
cost $/ha	0	
2. CT		
year	50	
harvest, m^3/ha	30	
trees/m^3	9.0	
fixed cost, $/ha	100	
fixed - variable cost $/ha	955	
biomass, DMT/ha	5	
cost biomass, $/DMT	20.00	
cost biomass, $/ha	100	
3. CC		
year	80	80
harvest, m^3/ha	210	210
proportion product 1	0.20	0.20
proportion harvested, product 2	0.80	0.80
trees/m^3	3.0	6.0
wood cost, $/ha	4,062	4,223
wood cost, $/$m^3$	23.03	23.94
biomass, DMT/ha	17	
cost biomass, $/DMT	20.00	
cost biomass, $/ha	340	
4. Selling price		
wood CT, $/$m^3$	25.00	45.00
wood CC, P1, $/$m^3$	45.00	35.00
wood CC, P2, $/$m^3$	45.00	
biomass, $/DMT	25.00	
5. NPV, rotation 1		
pres. value CT $/ha	175	0
pres. value CC $/ha	298	275
pres. cost PCT, $/ha	0	0
pres. cost CT, $/ha	122	0
pres. cost CC, $/ha	157	176
NPV rotation 1, $/ha	203	103
6. TOTAL NPV	431	398

Best scenario	**T1**	
7. target NPV	**431**	**$/ha**
8. simulated NPV	**431**	**$/ha**
9. profit margin, biomass	**5.00**	**$/DMT**

This decision not to act on deteriorated stands, as the result of this evaluation, corresponds well to today's reality, since this type of stand is generally left out of current management plans.

Simulation 2

Since the government should normally be concerned with the long-term improvement of Quebec's forest resources, it is natural for it to intervene financially in the development of these deteriorated stands, particularly since it derives major revenues from forestry activities in the form of taxes.

In this simulation, we determine the subsidy in \$/ha that should be paid to the operator as an incentive to applying the recommended strategy. It is assumed that this subsidy should correspond to an amount that will make NPV = \$0 in the first rotation. If the operator does not lose money, he will agree to apply the strategy, given the interest it presents in the second rotation and the beneficial effect that might be obtained by including this parcel in the yield from cutting in this area.

The subsidy required to attain the objective is \$820/ha.

Simulation 3

This simulation is aimed at determining the effect of a profit margin resulting from recovery of available biomass on the subsidy to be paid to the operator.

If the operator has a profit of \$10/DMT, the subsidy required to reach the objective (NPV = \$0) would be \$500/ha instead of \$820/ha.

Simulation 4

Government financial constraints, combined with those increasingly imposed by free-trade agreements between Canada, the United States and Mexico, make any government assistance to forestry operations ever more difficult and suspect.

Simulation 4 gives two hypotheses: subsidies are eliminated, the operator takes a 50% share of the cost of treatment (an investment of \$410/ha), and the remainder of the required investment comes from profits from available biomass recovery.

This hypothesis whereby the operator will make an investment effort seems plausible since the strategy is profitable in the second rotation and, in certain cases (depending on the age structure of the forest), the operator may see an immediate increase in yield.

It should be emphasized that the allowable cut effect in no way changes the intrinsic value of the strategy envisaged and should not be a direct consideration in the evaluation. However, this effect remains a significant reality for the operator and may influence forest management decisions. It will thus be easier to convince the operator to invest in these areas if there is the promise of an immediate increase in the annual volume harvested.

The allowable cut effect may thus serve as a major argument to convince operators to invest funds in silvicultural treatment. It should, however, be borne in mind that this is merely an incentive, not one of the criteria used in evaluating choices.

Simulation 5

It may be seen in Simulations 3 and 4 (Tables 7c and 7d) that the profit margin derived from biomass recovery was $10/DMT. It may, however, happen that the consumer of this biomass - the power producer for example - is unable to guarantee the operator this profit margin. As well, the allowable cut effect may be nil and the traditional forest products producer may thus be financially unable to invest in silviculture.

Simulation 5 assumes a maximum margin of $5/DMT, a subsidy of $0 and an investment of $0 by the sawmill operator. To ensure the feasibility of these hypotheses, logging conditions were modified by using easy trafficability (0.80) and a transportation distance of 50 km instead of trafficability of 1.00 and a distance of 100 km.

It will be seen from the table for Simulation 5 that T0 is preferable to T1 for Rotation 1 and that T1 is preferable to T0 for Rotation 2. Total NPV for these two rotations favours Strategy T1.

It will also be seen that the NPV for the extensive strategy (T0) is positive while it was negative for more difficult operating conditions. This parcel, which was rejected from the economic production area under the latter conditions, is now retained given the more favourable conditions. This simulation shows the importance of introducing spatial development values in preparing choices, and the same is true for economic and temporal factors.

Based on a short-term decision, the operator would choose the extensive strategy. However, since the difference between the NPVs for the two strategies is small, the operator should choose the intensive strategy in light of the interest of this strategy in the second rotation.

Conclusions

Many other simulations could be carried out, but those presented here nevertheless yield interesting conclusions.

1. In softwood and mixed-softwood stands, silvicultural treatment is often valid in its own right and thus should not require either government subsidies or profits to the operator as a result of salvaging biomass.

2. The above conclusion does, however, depend on the spatial parameters of the forest management parcel, mainly transportation distance and trafficability. For long distances (over 100 km) and difficult terrain (trafficability of 1.10), silviculture is often not worthwhile and would thus require government assistance and/or a profit margin for the operator from biomass recovery.

3. This first conclusion assumes that we take into account girth increment in trees and the effect of this increment on selling prices and timber costs. If this increment is not considered, the financial analysis will show (mistakenly) that silviculture is not profitable.

4. In mixed stands tending to hardwoods, silviculture is not profitable if there is no market for sawmill quality hardwoods, or if these stands contain only low-quality hardwoods (deteriorated stands). Where there is no market and no possibility of creating one, the priority should go to production of softwoods in stands where the proportion of softwoods is greater than 30%. Thinning carried out with a view to increasing softwood volume will require considerable investments ($1000/ha or more), given the presence of a large volume of non-commercial hardwoods in the thinnings. Major subsidies would be needed to ensure appropriate strategies are applied. Biomass recovery might, however, contribute to decreasing the size of subsidies needed.

5. In mixed stands where softwoods account for less than 30% and in pure hardwood stands, silviculture is not worthwhile if there is no market for sawmill quality hardwoods. Conversion to softwoods is not an option given the prohibitive cost and the negative ecological impact.

   Harvesting trees for the sole purpose of producing biomass or pulpwood is not covered by this study but, in our experience, it does not seem likely that this would be profitable, except in unusually favourable conditions such as short transportation distances or very easy trafficability.

   A "do nothing" strategy seems to be the best approach in most cases, as long as no market has been developed for the wood produced.

6. Where there is a market for sawmill quality lumber, silvicultural treatment in undeteriorated MH and H stands is often beneficial in its own right and should call for no financial assistance except in the case of remote stands on difficult terrain.

   For deteriorated stands, financial assistance for silvicultural treatment in the form of subsidies or profits from biomass recovery may be necessary, although the amount of such assistance will vary with the extent of deterioration.

   Conclusion 6 assumes, as in the case of softwoods, that the various economic, spatial and temporal dimensions of forestry management are correctly taken into consideration, along with the effect of girth increment on the value of lumber and on operating costs.

Validity of investment theory

A common criticism of traditional financial analysis, or investment theory, is that, through the mechanism of discounting, it unduly understates the value of future assets that, in forestry, will generally only become available in the far-distant future. The result is that many forest management projects fail the profitability test at a 4% interest rate.

This criticism may be well founded up to a certain point, but it does not really question the intrinsic value of financial analysis as an evaluation tool. It might be better to look at the way this type of analysis is used and to what use the results are put to determine what corrections should be made.

The first and most important correction is to take into account the girth or diameter increment of trees and the effect of this increment on the selling prices (unit prices) of all products and on operating costs. It also appears essential to introduce spatial data into the analysis through appropriate compartmentalization of forest management.

The second correction that might be made would be to consider in the evaluation all financial input (wages, taxes, indirect income) from increased silvicultural activity rather than merely the increase in the profits of an operation.

It should be emphasized in this connection that an investment that fails the profitability test (at the business level) will require for its implementation some measure of government assistance that would be difficult to justify in the current climate of weak public finances, even where the investment might bring significant social benefits. This is a highly complex question that would involve an improvement in the state of government finances.

The third correction we might consider would be to include in the economic production area forest management parcels with negative NPVs but whose value is above a minimum level deemed acceptable by both operators and government on the basis of economic and other considerations. Thus a management strategy that yields a negative NPV over the long run might nevertheless be justifiable for extra-economic reasons, particularly if we take into account the uncertainty linked to figures used in very long-term evaluations.

A fourth possible correction would be to distinguish, as we did when evaluating a deteriorated hardwood stand, between first rotation results and those of subsequent rotations, the former corresponding to the short term and the latter to the long term. The high cost of restoring a stand often shows a loss in the first rotation that would mask the interest a given strategy might present over the long term if the two horizons were considered together. A separate evaluation of the short and long term would make it possible to better orient management decisions.

The last possible correction that might be made would be to consider the relative profitability values rather than absolute figures as a factor in choosing strategies, for example the increase in net present value due to intensive management per dollar invested in this strategy. Forest management parcels and the most appropriate strategies for each would then be classified on the basis of this criterion in decreasing order and parcels would be chosen in that order until the maximum silviculture budget established at the outset had been exhausted.

This procedure would enable us to answer the question of how to spend the funds made available for silviculture, but not to determine how much to spend, which is above all a political decision. How much to spend is a multi-level decision, with the economy not necessarily being the most important level, which is often beyond the control of forest managers, whose role is mainly limited to wisely investing the funds made available by various sources.

In conclusion, the methods and criteria of investment theory remain valid in preparing forest management choices and may be used with confidence provided we can correctly interpret and use the results.

SUPPLY OF BIOMASS AND HARDWOOD SAW TIMBER IN COMMON AREA 1202

The last stage in this study involves estimating the supply of recoverable biomass and commercial timber in a given area.

The case selected as an example of application of the approach involves undeteriorated mixed and hardwood stands in Lower St. Lawrence Common Area 1202. The reasons underlying the choice of this location were presented at the beginning of the report; however, some additional details should be added.

The undeteriorated mixed and hardwood stands in this common area contain a large percentage of white birch, yellow birch, sugar maple and red maple, so sawmill quality hardwoods may be considered a high-value product that should be of interest to foresters in assessing various management strategies.

The demand for this raw material is from Félix Huard inc., which operates a modern hardwood sawmill in Luceville, Quebec. The company's annual requirement for sawmill quality hardwoods is estimated at 45,000 m^3. The supply of quality hardwood in the supply area assigned to Félix Huard inc. is insufficient to meet this demand. Part of the imbalance is due to past over-harvesting of hardwoods and the resulting deterioration of the forest. This imbalance is also due to the management strategies chosen by the MRN to calculate the allowable cut in this area.

A large proportion of the mixed and hardwood stands in Common Area 1202 is thus managed with a view to production of fir-spruce-jack pine (FSJ) in 50-55 year rotations. Harvesting stands of this age may be appropriate for softwoods, but certainly not for sawmill quality hardwoods, which reach maturity at between 80 and 90 years. At 50 years, the diameter of hardwoods is only suitable for production of pulpwood.

Félix Huard inc. thus proposes, for the stands currently earmarked for production of FSJ, a mixed management strategy targeting both softwoods and hardwoods. The overall strategy proposed would involve commercial thinning at 50 years, which would remove approximately 35% of the merchantable volume, followed by clear-cutting around 85 years. This thinning would give priority to cutting fir and lower quality hardwoods, leaving the spruce and good-quality hardwoods to grow.

In this chapter, we will examine the potential interest of incorporating biomass recovery into thinning and clear-cutting in Common Area 1202. We will also look at the synergy effect this recovery might have on the supply of traditional products and energy biomass.

Potential scenarios

To achieve our objective, we will simulate three management scenarios (or strategies). Scenario 0 will represent the status quo, or development of strata in 50-year rotations; Scenario 1 will use the strategy proposed by Félix Huard inc. of commercial thinning at 50 years and clear-cutting at 85 years, while Scenario 2 will include precommercial thinning at 15 years followed by commercial thinning at 50 years and clear-cutting at 85 years.

Simulation hypotheses

The general hypotheses used for the three scenarios may be summarized as follows:

1. Multiplier effect of CT on girth increment: 1.5
2. Multiplier effect of PCT on yield at maturity: 1.2
3. Yields: simulated in Module 1
4. Unit prices of timber, FOB plant, \$/m^3: CC \$41; CT/CC \$51; PCT/CT/CC \$53
5. Timber cost FOB plant: CC \$37; CT/CC \$35; PCT/CT/CC \$33
6. Unit price of thinned wood: \$37/m^3
7. Silviculture costs: PCT \$600/ha; CT \$1900/ha
8. Profit margin for sawmill operator related to biomass recovery: unknown at outset
9. DMT/m^3 (recovery rate of 65%): FSJ 0.07, hardwoods 0.25
10. Proportion saw timber at stand maturity: CC 25%; CT/CC 35%; PCT/CT/CC 45%
11. Discount rate: 4%
12. Planning horizon: 120 years
13. Allowable cut calculation: using Module 2 approach.

A complete example of a simulation is shown in Table 8. Briefly, for each of the scenarios, we determine the quantities of timber and biomass available for harvesting for the entire horizon chosen, i.e. 120 years. We also estimate earnings and expenses related to harvesting the available wood and the cost of silvicultural work. We then generate a **cash flow schedule** for the entire horizon, discounting at 4%, which will give an estimate of the net present value (NPV) for each scenario. Estimating the available quantities of timber and biomass throughout the horizon will also allow us to calculate allowable cuts.

Two series of simulations were carried out, the first without considering recoverable biomass, and the second assuming that this biomass is harvested and used.

Method of determining supply functions

The approach chosen to determine the desired supply functions, that is, supply of timber and supply of biomass, based on the profit margin associated with biomass recovery left to the sawmill operator, is illustrated using six graphs (Figures 3 to 7). This presentation will enable the reader to easily follow the approach which, it should be emphasized, is not a common one. The results of the simulation are presented in the form of summaries in Tables 9a to 9g.

Readers are invited to refer to Figures 3 to 7 while reading the text.

1. Net present value based on allowable cut (Figure 3)

Figure 3 shows the net present value based on the allowable cut of sawmill quality hardwoods in Common Area 1202 (mixed and hardwood stands only). Note that the allowable cut ranges from 9,842 m^3/year (Scenario 0, 50 years, CC) and 19,950 m^3/year (Scenario 2 - PCT/CT/CC), and that the NPV varies between $247/ha (Scenario 0) and $88/ha (Scenario 2).

It will be seen that the net present value decreases with the increase in allowable cut. Scenario 0 (status quo) maximizes NPV, while Scenario 2 (the most intensive) maximizes allowable cut. On a purely financial basis, the operator should thus choose the status quo, while from a forestry point of view Scenario 2 should be chosen. This example shows the contradictory conclusions that may be reached depending on whether we are working from an economic or a biophysical standpoint.

2. Silvicultural credits required and available (Figure 4)

To encourage the use of silvicultural treatments and increasing allowable cut, the MRN subsidizes silviculture in the form of credits on cutting rights. We might then ask what credits should be granted to encourage companies to invest in treatment for its different stands.

Table 8. Economic yield and financial analysis of Common Area (CA) 1202

Scenario	Group	Name	Treatment	Year	Silvic. cost $/ha	ha available	Proportion treated	ha treated	Silvic. cost $ NPV	m³/ha-FSJ	m³/ha-YB-M	m³ FSJ	m³ YB-M	Biomass DMT	Timber value $/m³	Cost $/m³	Profit timber $/ NPV	Profit biomass $ NPV	Net value $ NPV
0	1	SH B 50	CC	1		6168	1.00	6168	0	41.8	49.9	257822	307783	94993	41	37	2175406	0	2175406
0	2	H B 50	CC	1		2032	1.00	2032	0	11.0	110.1	22352	223723	57495	41	37	946443	0	966443
0	3	HS D 50	CC	1		11166	1.00	11166	0	4.7	101.7	52480	1135582	287569	38	37	1142368	0	1142368
0	6	SH B 30	CC	25		960	1.00	960	0	41.8	49.9	40128	47904	14785	41	37	128648	0	132089
0	7	H B 30	CC	25		708	1.00	708	0	11.0	110.1	7788	77951	20033	41	37	128618	0	128648
0	8	HS 10	CC	45		674	1.00	674	0	4.7	101.7	3168	68546	17358	41	37	49109	0	49109
0	9	H 10	CC	45		1158	1.00	1158	0	11.0	110.1	20438	204566	52572	41	37	154081	0	15081
0	1	SH B 50	CC	55		6168	1.00	6168	0	41.8	49.9	40128	47904	14785	41	37	261662	0	261662
0	2	H B 50	CC	55		2032	1.00	2032	0	11.0	110.1	22352	223723	57495	41	37	113840	0	133840
0	3	HS D 50	CC	55		11166	1.00	11166	0	4.7	101.7	52480	1135582	287569	41	37	549264	0	549624
0	10	HS 0	CC	55		92	1.00	92	0	4.7	101.7	432	9336	2369	41	37	4529	0	4529
0	6	SH B 30	CC	80		960	1.00	960	0	41.8	49.9	40128	47904	13785	41	37	15277	0	15277
0	7	H B 30	CC	80		708	1.00	708	0	11.0	110.1	7788	77951	20033	41	37	14879	0	14879
0	8	HS 10	CC	100		674	1.00	674	0	4.7	101.7	3168	68546	17358	41	37	5680	0	5680
0	9	H 10	CC	100		1858	1.00	1858	0	11.0	110.1	20438	204566	52572	41	37	17820	0	17820
0	1	SH B 50	CC	110		6168	1.00	6168	0	41.8	49.9	257822	307783	94993	41	37	30263	0	30263
0	2	H B 50	CC	110		2032	1.00	2032	0	11.0	110.1	22352	223723	57495	41	37	13166	0	13166
0	3	HS D 50	CC	110		11166	1.00	11166	0	4.7	101.7	52480	1135582	287569	41	37	63567	0	63567
0	10	HS 0	CC	110		92	1.00	92	0	4.7	101.7	432	9356	2369	41	37	524	0	524
1	1	SH B 50	CT	1	1900	6168	.00	0	0	33.4	9.9	0	0	0	37		0	0	0
1	2	H B 50	CT	1	1900	2032	.00	0	0	8.8	22.0	0	0	0	37		0	0	0
1	3	HS D 50	CC	1		11166	.00	0	0	4.7	101.7	0	0	0	38	37	0	0	0
1	1	SH B 50	CC	20		6168	.00	0	0	15.1	72.1	0	0	0	51	35	0	0	0
1	2	H B 50	CC	20		2032	.00	0	0	15.9	169.0	0	0	0	51	35	0	0	0
1	6	SH B 30	CT	20	1900	960	.00	0	0	33.4	9.9	0	0	0	37		0	0	0
1	7	H B 30	CT	20	1900	708	.00	0	0	8.8	22.0	0	0	0	37		0	0	0
1	8	HS 10	CT	40	1900	674	.00	0	0	10.6	17.6	0	0	0	37		0	0	0
1	9	H 10	CT	40	1900	1858	.00	0	0	8.8	22.0	0	0	0	37		0	0	0
1	3	HS D 50	CT	50	1900	11166	.00	0	0	8.8	22.0	0	0	0	37	35	0	0	0
1	10	H 0	CT	50	1900	92	.00	0	0	8.8	22.0	0	0	0	37		0	0	0
1	6	SH B 30	CC	55		960	.00	0	0	15.1	72.1	0	0	0	51	35	0	0	0
1	7	H B 30	CC	55		708	.00	0	0	15.9	159.0	0	0	0	51	35	0	0	0
1	1	SH B 30	CT	70	1900	6168	.00	0	0	33.4	9.9	0	0	0	37		0	0	0
1	2	H B 50	CT	70	1900	2032	.00	0	0	8.8	22.0	0	0	0	37		0	0	0
1	8	HS 10	CC	75		674	.00	0	0	19.1	127.0	0	0	0	51	35	0	0	0
1	9	H 10	CC	75		1858	.00	0	0	15.9	159.0	0	0	0	51	35	0	0	0
1	3	HS D 50	CC	85		11166	.00	0	0	15.9	159.0	0	0	0	51	35	0	0	0
1	10	H 0	CC	85		92	.00	0	0	15.9	159.0	0	0	0	51	35	0	0	0
1	1	SH B 50	CC	100		6168	.00	0	0	15.1	72.1	0	0	0	51	35	0	0	0
1	2	H B 50	CC	100		2032	.00	0	0	15.9	159.0	0	0	0	51	35	0	0	0
1	6	SH B 30	CT	105	1900	960	.00	0	0	33.4	9.9	0	0	0	37		0	0	0
1	7	H B 30	CT	105	1900	708	.00	0	0	8.8	22.0	0	0	0	37		0	0	0

2	1	SH B 50	CT	1	1900	6168	.00	0	0	33.4	9.9	0	0	0	37		0	0	0
2	2	H B 50	CT	1	1900	2032	.00	0	0	8.8	22.0	0	0	0	37		0	0	0
2	3	HS D 50	CC	1		11166	.00	0	0	4.7	101.7	0	0	0	38	37	0	0	0
2	8	HS 10	PCT	5	600	674	.00	0	0			0	0	0			0	0	0
2	9	H 10	PCT	5	600	1858	.00	0	0			0	0	0			0	0	0
2	3	HS D 50	PCT	15	600	11166	.00	0	0			0	0	0			0	0	0
2	10	H 0	PCT	15	600	92	.00	0	0			0	0	0			0	0	0
2	1	SH B 50	CC	20		6168	.00	0	0	15.1	72.9	0	0	0	51	33	0	0	0
2	2	H B 50	CC	20		2032	.00	0	0	15.9	159.0	0	0	0	51	33	0	0	0
2	6	SH B 30	CT	20	1900	960	.00	0	0	33.4	9.9	0	0	0	37		0	0	0
2	7	H B 30	CT	20	1900	708	.00	0	0	8.8	22.0	0	0	0	37		0	0	0
2	1	SH B 50	PCT	35	600	6168	.00	0	0			0	0	0			0	0	0
2	2	H B 50	PCT	35	600	2032	.00	0	0			0	0	0			0	0	0
2	6	SH B 30	CC	40		960	.00	0	0	15.9	159.0	0	0	0	51	33	0	0	0
2	7	H B 30	CC	40		708	.00	0	0	15.9	159.0	0	0	0	51	33	0	0	0
2	8	HS 10	CT	40	1900	674	.00	0	0	10.6	17.6	0	0	0	39		0	0	0
2	9	H 10	CT	40	1900	1858	.00	0	0	8.8	22.0	0	0	0	39		0	0	0
2	3	HS D 50	CT	50	1900	11166	.00	0	0	10.6	26.4	0	0	0	39		0	0	0
2	10	H 0	CT	50	1900	92	.00	0	0	8.8	22.0	0	0	0	39		0	0	0
2	6	SH B 30	PCT	55	600	960	.00	0	0			0	0	0			0	0	0
2	7	H B 30	PCT	55	600	708	.00	0	0			0	0	0			0	0	0
2	8	HS 10	CC	60		674	.00	0	0	19.1	127.0	0	0	0	52	33	0	0	0
2	9	H 10	CC	60		1858	.00	0	0	15.9	159.0	0	0	0	52	33	0	0	0
2	1	SH B 50	CT	70	1900	6168	.00	0	0	40.1	11.1	0	0	0	39		0	0	0
2	2	H B 50	CT	70	1900	2032	.00	0	0	10.1	26.4	0	0	0	39		0	0	0
2	3	HS D 50	CC	70		11166	.00	0	0	19.1	190.8	0	0	0	52	33	0	0	0
2	8	HS 10	PCT	75	600	674	.00	0	0			0	0	0			0	0	0
2	9	H 10	PCT	75	600	1858	.00	0	0			0	0	0			0	0	0
2	3	HS D 50	PCT	85	600	11166	.00	0	0			0	0	0			0	0	0
2	10	H 0	CC	85		92	.00	0	0	15.9	159.0	0	0	0	52	33	0	0	0
2	6	SH B 30	CT	90	1900	960	.00	0	0	33.4	9.9	0	0	0	39		0	0	0
2	7	H B 30	CT	90	1900	708	.00	0	0	10.6	26.4	0	0	0	39		0	0	0
2	10	H 0	PCT	100	600	92	.00	0	0			0	0	0			0	0	0
2	1	SH B 50	CC	105		6168	.00	0	0	18.1	86.5	0	0	0	53	33	0	0	0
2	2	H B 50	CC	105		2032	.00	0	0	19.1	190.8	0	0	0	53	33	0	0	0
2	8	HS 10	CT	110	1900	674	.00	0	0	12.7	31.7	0	0	0	39		0	0	0
2	9	H 10	CT	110	1900	1858	.00	0	0	10.6	26.4	0	0	0	39		0	0	0
2	1	SH B 50	PCT	120	600	6168	.00	0	0			0	0	0			0	0	0
2	2	H B 50	PCT	120	600	2032	.00	0	0			0	0	0			0	0	0

Note:

MU	CA	Hectares	Scenario	Bio., $/DMT	DMT/m^3 FSJ	DMT/m^3, YB-M	NPV $	NPV $/ha	Yield, YB-M, m^3/year	Proportion saw	YB-M saw, m^3/year	MAI saw	DMT/year	$/year silvic.	Gross profit $	Silvic. cost $
12	1202	23568	0	0.00	0.07	0.25	5818974	247	39369	0.25	9842	0.42	10394	0	5818974	0

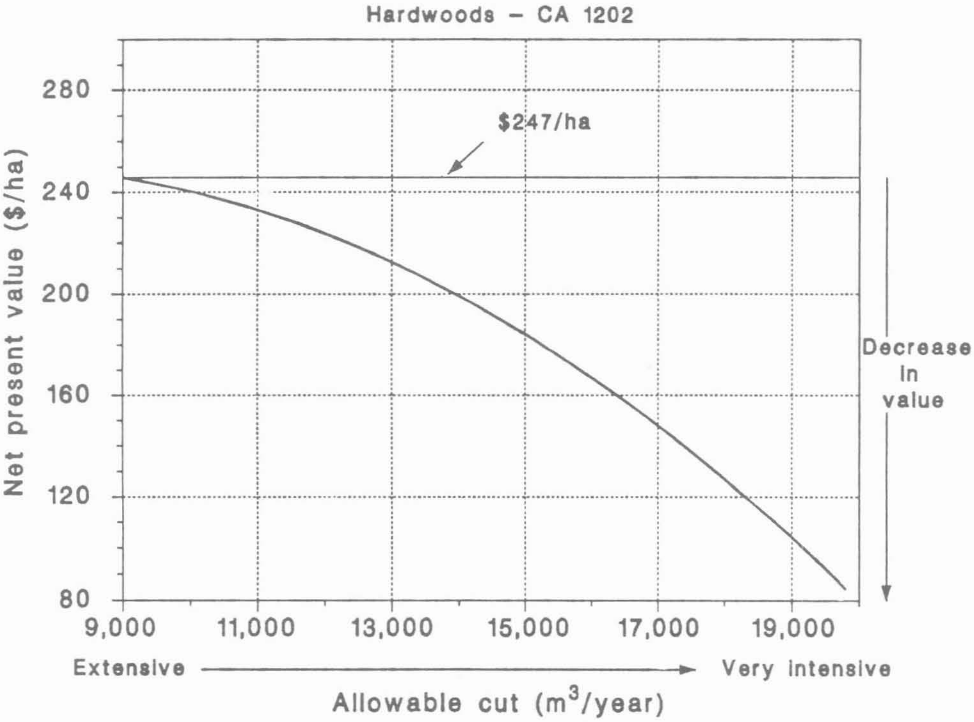


Figure 3. Net present value (NPV) based on allowable cut.

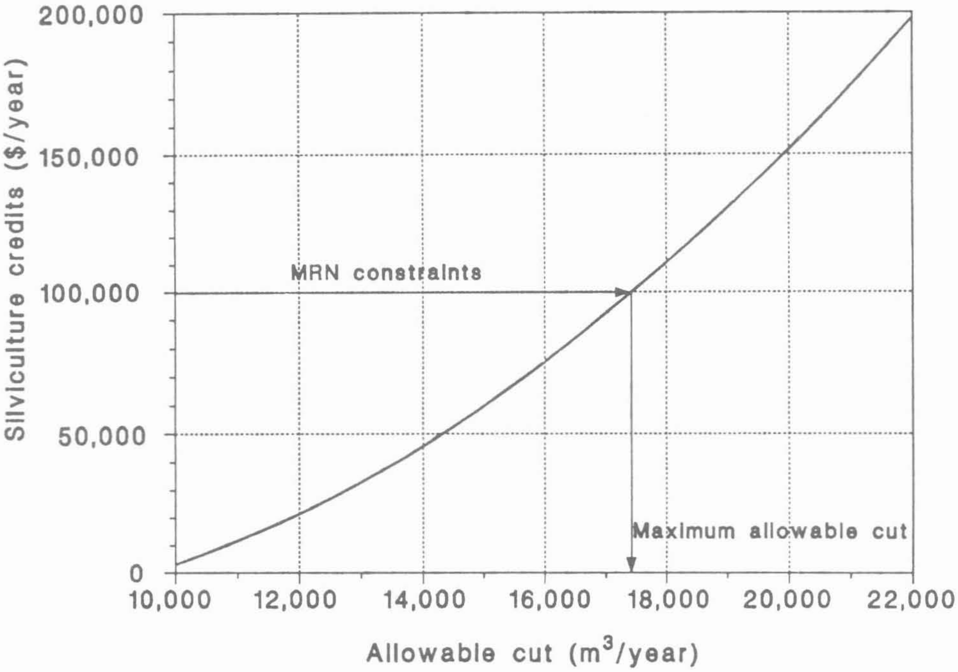


Figure 4. Silvicultural credits required and available.

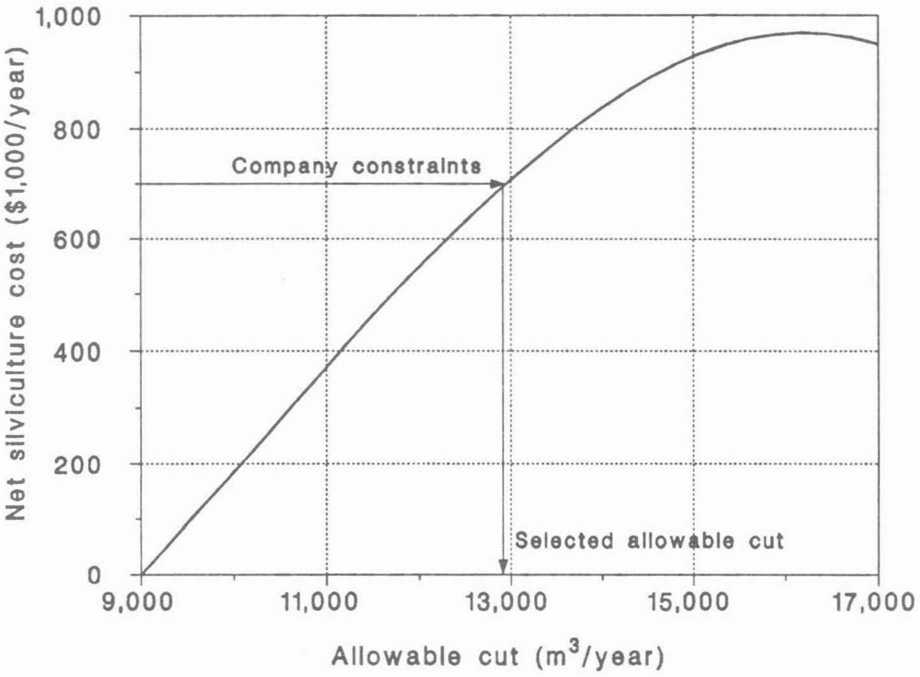


Figure 5. Sawmill-quality YB-M function.

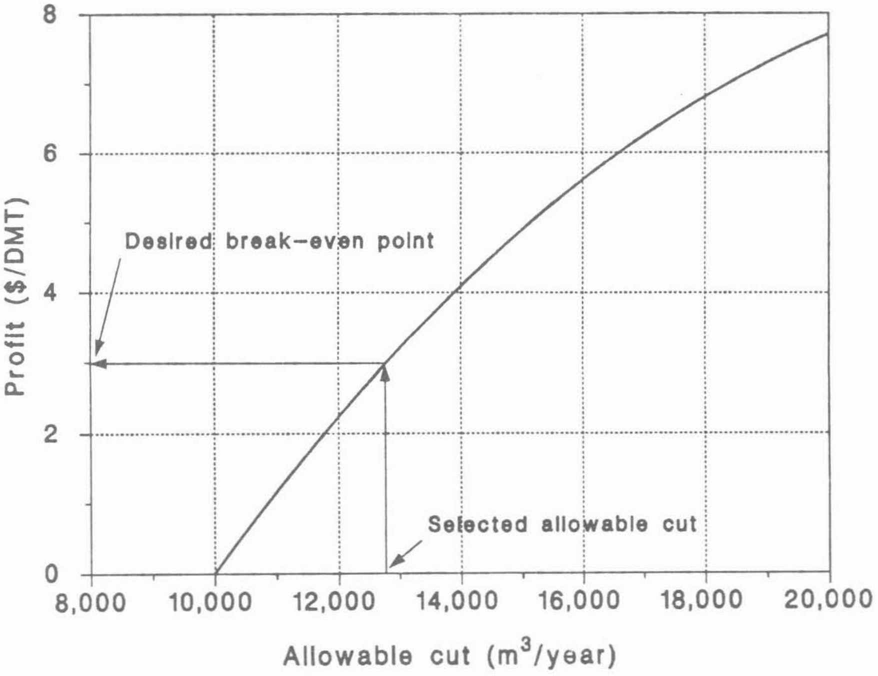


Figure 6. Supply of sawmill-quality YB-M vs. profit margin.

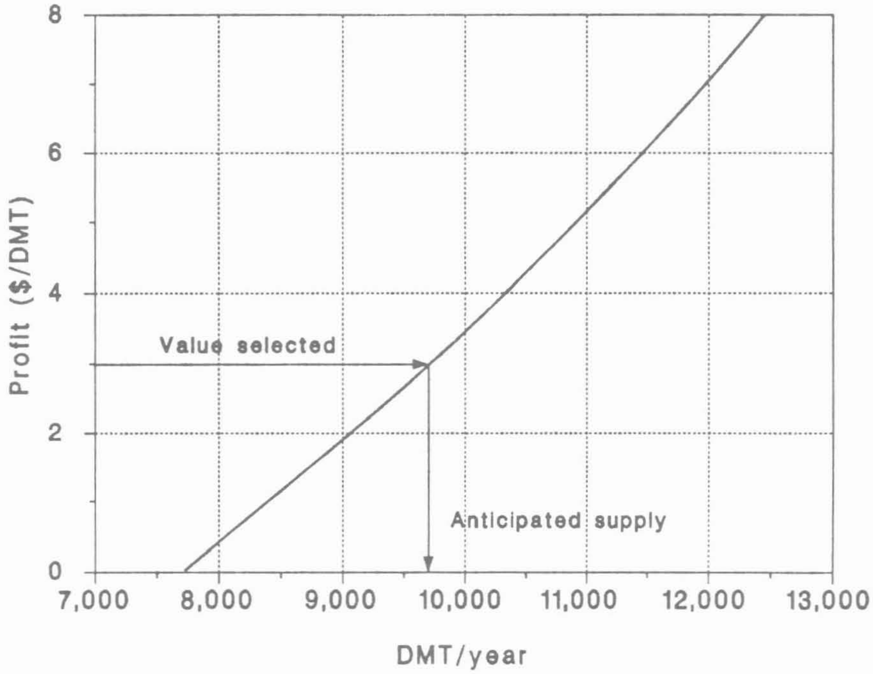


Figure 7. Biomass supply.

We assumed that the company would be prepared to invest funds in silviculture provided the NPV of the best scenario ($247/ha for Scenario 0) was not affected by these investments. We thus estimated, on the basis of the target allowable cut, the annual credit that should be granted to attain this objective.

Scenario 2, to which corresponds a maximum allowable cut of some 20,000 m³/year, would require the MRN to grant annual credits in the order of $150,000 to the company to obtain an NPV of $247/ha.

It is possible that the government may have constraints linked to such credits. If $100,000 is the maximum that can be granted to the company in the form of silviculture credits, the ***maximum allowable cut*** for the management unit would then correspond to $17,500 m³/year.

Table 9a. Recap of simulation - Economic yield and financial analysis - Simulation 1

Management Unit	12
Common area	1202
Hectares	23,568
Scenario	**0**
Biomass, \$/DMT	
DMT/m³, FSJ	0.00
DMT/m³, YB-M	0.00
NPV \$	5,818,974
NPV, \$/ha	**247**
Allowable cut YB-M, m³/year	39,369
Proportion sawmill	0.25
Sawmill YB-M m³/year	**9,842**
MAI sawmill	0.42
DMT/year	**0**
Cost silvic. operator, \$/year	**0**
Subsidy, \$/year	0
Total silvic. cost	0

Table 9b. Recap of simulation - Economic yield and financial analysis - Simulation 2

Management unit	12
Common area	1202
Hectares	23,568
Scenario	**1**
Biomass, \$/DMT	
DMT/m³, FSJ	0.00
DMT/m³, YB-M	0.00
NPV \$	5,078,235
NPV, \$/ha	**215**
Allowable cut YB-M, m³/year	36,104
Proportion sawmill	0.35
Sawmill YB-M m³/year	**12,636**
MAI sawmill	0.54
DMT/year	**0**
Cost silvic. operator, \$/year	**859,647**
Subsidy, \$/year	0
Total silvic. cost	859,647

Table 9c. Recap of simulation - Economic yield and financial analysis - Simulation 3

Management unit	12
Common area	1202
Hectares	23,568
Scenario	**0**
Biomass, $/DMT	
DMT/m³, FSJ	0.00
DMT/m³, YB-M	0.00
NPV $	5,813,459
NPV, $/ha	**247**
Allowable cut YB-M, m³/year	36,104
Proportion sawmill	0.25
Sawmill YB-M, m³/year	**12,636**
MAI sawmill	0.54
DMT/year	**0**
Cost silvic. operator, $/year	**830,235**
Subsidy, $/year	29,409
Total silvic. cost	859,647

Table 9d. Recap of simulation - Economic yield and financial analysis - Simulation 4

Management unit	12
Common area	1202
Hectares	23,568
Scenario	**2**
Biomass, $/DMT	**0.00**
DMT/m³, FSJ	0.00
DMT/m³, YB-M	0.00
NPV $	2,081,661
NPV, $/ha	**88**
Allowable cut YB-M, m³/year	44,334
Sawmill proportion	0.45
Sawmill YB-M, m³/year	**19,950**
MAI sawmill	0.85
DMT/year	**0**
Cost silvic. operator, $/year	**1,132,936**
Subsidy, $/year	0
Total silvic. cost	1,132,936

Table 9e. Recap of simulation - Economic yield and financial analysis - Simulation 5

Management unit	12
Common area	1202
Hectares	23,568
Scenario	**2**
Biomass, $/DMT	**0.00**
DMT/m^3, FSJ	0.00
DMT/m^3, YB-M	0.00
NPV $	5,832,690
NPV, $/ha	**247**
Allowable cut YB-M, m^3/year	44,334
Sawmill proportion	0.45
Sawmill YB-M, m^3/year	**19,950**
MAI sawmill	0.85
DMT/year	**0**
Cost silvic. operator $/year	**982,895**
Subsidy, $/year	150,041
Total silvic. cost	1,132,936

Table 9f. Recap of simulation - Economic yield and financial analysis - Simulation 6

Management unit	12
Common area	1202
Hectares	23,568
Scenario	**1**
Biomass, $/DMT	**3.00**
DMT/m^3, FSJ	0.07
DMT/m^3, YB-M	0.25
NPV, $	5,831,459
NPV, $/ha	**247**
Allowable cut YB-M, m^3/year	36,104
Proportion sawmill	0.35
Sawmill YB-M, m^3/year	**12,636**
MAI sawmill	0.54
DMT/year	**9,796**
Cost silvic. operator, $/year	**859,647**
Subsidy, $/year	0
Total silvic. cost	859,647

Table 9g. Recap of simulation - Economic yield and financial analysis - Simulation 7

Management unit	12
Common area	1202
Hectares	23,568
Scenario	**2**
Biomass, \$/DMT	**12.52**
DMT/m^3, FSJ	0.07
DMT/m^3, YB-M	0.25
NPV \$	5,832,690
NPV, \$/ha	**247**
Allowable cut YB-M, m^3/year	44,334
Proportion sawmill	0.45
Sawmill YB-M, m^3/year	**19,950**
MAI sawmill	0.85
DMT/year	**11,983**
Cost silvic. operator, \$/year	**1,132,936**
Subsidy, \$/year	0
Total silvic. cost	1,132,936

3. Sawmill quality YB-M supply function (Figure 5)

Silviculture credits permitting an NPV of \$247/ha cover only part of the true silviculture costs incurred by the operator. For Scenario 2, the total cost of silvicultural treatment was estimated at \$982,895/year. If we want an NPV of \$247/ha for this scenario, the government would have to give annual credits of \$150,041, leaving the company with an annual investment of \$832,854.

Using the results of simulation, we can determine a sawmill-quality YB-M supply function linking the target product yield to net silviculture costs (after subtracting credits) for the specific operation. We can see from Figure 5 that the annual silviculture cost to the company will be \$900,000/year if it wants to reach the maximum allowable cut previously estimated at 17,500 m^3/year.

4. Silviculture credits used

Like the MRN, the company too may have constraints on the funds that can be used for silviculture. Even though, with the credits available to the operator, silviculture may prove profitable at a rate of 4%, the company may lack the liquidities for such investments. If its maximum available funds amount to \$700,000/year, the allowable cut corresponding to this amount, the ***target allowable cut*** given financial constraints, will then be approximately 12,800 m^3/year.

The company would then use 30% of the silviculture credits available from the MRN, or about \$30,000/year.

5. Sawmill YB-M supply based on biomass value (Figure 6)

For a number of reasons, subsidies (a credit is a subsidy) are becoming less and less popular in our society: large government deficits, increasingly limiting free-trade regulations, and so on.

It seems unlikely that government investments in the development of forest resources will increase over time; in fact, they will probably tend to decrease. And yet, if there is any field that requires huge investments to enable society as a whole to derive the expected short- or long-term benefits from it, that field is certainly forest management. What is to be done?

As we saw in the last chapter, energy biomass may be one of the answers, if it is substituted for all or part of the current subsidy system. Everything of course depends on the profit margin the sawmill operator can make by recovering available biomass. If it can be shown that this profit margin is positive, it may then be invested in silviculture and thus, ***either with no subsidy or with a lower subsidy***, increase the supply of timber, while using in a beneficial and profitable way a raw material that is currently wasted.

In short, the profits of the biomass harvester could be used to create silviculture reserves.

Let us take a closer look at this.

For each simulation, we estimated the profit margin, in \$/DMT, required from this biomass to replace the amounts of credits granted by the MRN to enable the company to reach the NPV of the best simulated management strategy (Scenario 0), or \$247/ha.

To achieve this, we first determined, for each scenario, the annual quantity of recoverable biomass related to the harvesting of the YB-M allowable cut, and then divided the annual credits by that quantity. The figure thus obtained corresponded to the ***break-even profit margin*** for the biomass recovered. Below this margin, the operation would have an NPV of less than \$247/ha; while above the margin the NPV obtained would be greater than \$247/ha.

Figure 6, entitled ***Supply of sawmill-quality YB-M versus the break-even profit margin for biomass***, shows that, for the allowable cut selected by the company of 12,800 m^3/year, the margin should be \$3.00/DMT if it is to replace the credits. Any profit margin on biomass greater than \$3.00/DMT would make it possible to increase the sawmill YB-M allowable cut above 12,800 m^3/year, provided the ***profits thus realized are invested in silviculture*** and that the company succeeds in eliminating its financial constraints.

It should be emphasized here that applying Scenario 0, combined with biomass recovery with a profit margin of \$3.00/DMT, yields an NPV greater than \$247/ha. From a strictly financial standpoint, it would thus be better for the company not to invest profits generated by biomass recovery in silviculture.

The obligation to invest is based simply on the reasoning that, by doing so, the company has no financial losses compared with implementation of the best management strategy with no biomass recovery. It comes out a winner in this operation since its yield is increased and silviculture is paid for by harvesting a raw material that is currently wasted. The government also comes out a winner since this solution eliminates the subsidies it would otherwise have to pay and the use of forest biomass not currently being used to produce power (or other commodities) can only benefit society as a whole. These investments will also benefit future generations since we can pass on to them a forest in better condition.

In our view, this approach to biomass harvesting combined with that of traditional products seems reasonable and opens up new forest management avenues. Given the ever-increasing government constraints with respect to silvicultural investment, it can assist in realizing the twofold objective of forestry, which is to reconcile the short-term financial objectives of companies with the longer term, more altruistic objectives of society.

To terminate this study, we must now determine what profit margin a forest products producer can reasonably obtain from a concrete energy biomass consumption project. Depending on operating conditions and the margin that must be allowed to the biomass producer, the oil-equivalent of forest biomass price FOB the power plant might not be greater than the current price of oil. Only a specific feasibility study would enable us to answer these questions.

6. Biomass supply (Figure 7)

Figure 7 shows the biomass supply function, which is the relation between the profit margin to the biomass producer and the quantity of biomass produced annually, which depends on the supply of sawmill-quality YB-M calculated above.

It will be seen that, for the figure of $3.00/DMT, the supply of biomass is estimated at 9,800 dry metric tonnes for a 12,800 m^3/year allowable cut of hardwood saw timber, which represents a factor of 0.77 DMT/m^3 of saw timber. If we take into account all products harvested annually (hardwood pulp, FSJ), the biomass factor would be 0.21 DMT per m^3.

Overall conclusion

These results and conclusions are highly dependent on the hypotheses formulated at the outset, and thus must be taken with reservations and seen much more as a general trend and an example of application of the method used here, rather than figures on which we can actually depend. More reliable results could only be obtained by studying a concrete project.

It does, however, appear that, notwithstanding the uncertainties contained in this study, biomass recovery combined with the production of traditional forest products would be well worthwhile from several points of view, which we have attempted to illustrate in this report.

We thus feel it would be opportune to take this study a little further, particularly with respect to determining the actual profit margin that could be generated by biomass recovery, through a specific ***prefeasibility*** study, carried out according to the objectives and general approach used here.

APPENDIX 1
Pitfalls of forest management

This study of forest biomass recovery was carried out as part of the preparation of an overall forest management plan for a given area. It was conducted using a method, objectives and criteria that occasionally varied considerably from common practices used in drawing up such plans.

This difference in approach is in no way linked to the subject. It in fact corresponds to modifications that, in our view, should be made to the information, methods, objectives and criteria currently used in preparing forest management decisions. Preparation of these decisions entails a number of pitfalls that may lead to poor choices by forestry companies and communities.

We felt it would be useful here to briefly discuss the main weaknesses that characterize the preparation of decisions in the field of forest management and then outline remedies that appear necessary. These remedies form the basis of this study and constitute its main contribution to the field.

Purpose of management and framework of this study

Forest management of a given area is undertaken with a view to ***optimizing*** the use of ***all*** resources in that area in the best interests of ***companies*** and ***society as a whole.***

It should be emphasized that this study considers only the production of timber and attempts to optimize decisions only at the level of private companies. Despite the restrictive analysis framework imposed by these limits, the study nevertheless contains a method that could be easily adapted to all forest resources and the net benefits that society as a whole derives from their use.

In this study, optimization deals mainly with decision variables related to products to be produced, silvicultural treatments to be applied, cutting methods to be used and quantities of timber to be cut, whether in terms of traditional products or energy biomass.

The four dimensions of forest management

Forestry management basically covers four fundamental dimensions:

- **resources**
- **economics**
- **space**
- **time.**

It must be recognized that forestry management for the purposes of producing consumer goods is ***basically an economic activity***. If we ignore this fact, as is currently the case, this can only lead to errors in decision making. Optimizing the variables of an economic situation requires that we take into account objectives and criteria of an ***economic*** nature. Making decisions based solely on ***biophysical*** objectives and criteria is the main reason for many of the absurdities that characterize current forestry management.

Considering the economic dimension assumes the introduction of two other fundamental forest management variables generally ignored by developers: ***space*** and ***time***.

Forestry operations are always carried out over vast areas. The related spatial information must necessarily be introduced into the decision-making process since it may significantly influence decisions. It is easy to see that, all other things being equal, it would be more desirable to practice intensive management in a forest stand located near a forest products consumption centre rather than in a stand located farther away.

Forestry also always involves extended periods of time (100 years or more). Like spatial information, time-related information may also considerably affect decisions and should therefore be correctly evaluated. It should be clear to all that an asset that is available in a year is more valuable today than the same asset available in fifty years. All other things being equal, priority will thus be given to action that has the highest value today.

The delay before an asset becomes available has a price that is calculated by discounting future values according to the methods of ***investment theory***.

Forest management parcel

How can we introduce spatial information into the preparation of a forest management plan?

The first step is to realize that a given forest area can be divided into forest ***strata*** and management ***compartments.***

A stratum is formed by a series of stands having the same characteristics with respect to tree composition, age, height, density and site.

A management compartment is a segment of the area with specific characteristics related to the observed production potential and the desired management objectives, as well as the limitations mixed management of the area's resources imposes on forestry operations, the nature and origin of the demand for various products, the proximity and availability of labour, costs of building and maintaining a road network, the density of this network, how widely stands are scattered, degree of difficulty of terrain and cutting rights. A compartment almost always contains several strata and generally measures at least 500 hectares.

Drawing up a subdivision is one of the most important stages in the preparation of a forest management plan, and ***one which we feel is severely neglected*** at the present time. It forms the ***skeleton*** of the plan and is the element that will enable us to finalize our choice of the management strategy most appropriate for each parcel.

By definition, a given stratum in a given compartment forms what we call a ***forest management parcel.*** The parcel thus represents a stratum situated spatially by the compartment. ***It implicitly contains all the spatial information specific to the parcel in addition to that contained in the stratum itself.***

The parcel thus forms the heart of the forest management plan. Planning and optimizing management decisions necessarily involves a thorough forestry and economic analysis of each parcel of the area under study if we want to arrive at a sound management plan.

Management strategies

How do we plan management decisions for a given parcel?

Three levels of analysis are involved: the stratum, the parcel and the management unit.

Stratum

We first have to select and describe the management strategies that might be appropriate for each of the strata in the management unit.

In this study, a management strategy is defined as a sequence of silvicultural treatments and cuts in a given ***stratum***. Based on the stand table for the stratum in question, the strategy describes the various treatments envisaged, the age at which each will be applied, their cost and the quantity of timber that can be obtained by product, where applicable. Among these products, we of course include recoverable biomass.

Each of the strategies considered must then undergo a detailed forestry and economic analysis with a view to 1) generating production data that will then be extrapolated to the management unit level to calculate the quantities of various products available each year, and 2) optimizing the main decision variables such as choice of silvicultural treatment, logging system, products and financial rotation.

This type of analysis assumes that we take into consideration the specific financial factors for that stratum, particularly the market value of the various products and their cost.

Forest management parcel and management unit

The final choice of the most desirable strategy will not, however, be made at the stratum level, but for each of the forest management parcels, since as we have seen this choice depends on elements defined in the management ***compartment*** and constraints such as silviculture budget, scarcity of workers, availability of infrastructure and equipment found at the ***management unit*** level. This choice will be arrived at using a series of techniques for optimization under constraint, including additional analysis and linear programming.

Forest management objectives and decision-making criteria

It is impossible to make wise decisions unless we have the appropriate objectives and criteria for the decisions we want to make.

When dealing with forest management, we may base our decisions on two different sets of objectives and criteria, depending on whether we are working from the standpoint of a physical or an economic situation. The problem is that forest managers tend to use the physical world hypothesis when most of the decisions they have to make are economic in nature. The result is management decisions that are contrary to the objectives of both logging companies and the community.

Let us look at the facts.

Whatever hypothesis we use (physical reality or economic situation), the required decisions are considered, as we have seen, at three levels, the stratum, the forest management parcel and the management unit.

a) Objectives and criteria at the stratum level

For the stratum, the forest manager takes as the objective maximizing the production of timber per unit of time. The decision criterion used here is the ***mean annual increment*** (MAI) and the rotation age of the stratum will correspond to the age that will maximize the MAI. In setting harvesting priorities when calculating allowable cut, the forest manager will first cut the strata where the MAI decreases most rapidly, in line with the objective of maximizing production per unit of time.

At first glance, this objective and criterion may appear valid; however, to determine their validity, we must bear in mind the main objective of the company, which is to maximize its profits, or the objective of society in general, which is to maximize the net added value contributed to the economy by logging operations. In the majority of cases, however, maximizing MAI is contrary to the realization of these two objectives.

Let us look at the case of the logging company.

When the forest manager calculates the MAI for a stratum, he selects a group of species he judges to be a "priority" and ignores, for these priority species, the nature of the products that might be derived from them (pulpwood and saw timber). By doing this, he shortens the rotation ages and increases allowable cut - which is his goal - but at the same time he finds he is producing smaller size trees that are less desirable for the lumber industry and that, for the logging industry as a whole, are expensive to harvest.

When determining the rotation age of the stratum, he thus implicitly rejects "companion" species that may be important for the industry, particularly in mixed and hardwood forests. He also ignores the specific situation of the strata in the area to be developed, whereby girth increases with time, and that the market value of timber often increases with this girth increment and the cost of logging these trees decreases.

As a result, because of the objective and criterion selected at the outset, the forest manager tends to favour the production of ***small-diameter trees*** that, given the importance of the softwood industry in eastern Canada, tend to be mainly fir, spruce and jack pine (known in Quebec as FSJ).

The decision to cut mainly small softwoods (eastern Canada is mainly a shortwood producer), even in stands with a clear mixed orientation, is basically an economic one that the manager has basically taken without doing a thorough analysis.

It nevertheless has serious consequences for the very future of an industrial structure based on forest resources, as well as having sometimes disastrous consequences for the management of other forest resources, timber costs and the value of products, management costs and the ecological balance.

It may increase the risk of epidemics and forest fires that result from any monoculture, and may also increase the risk of pollution due to the use of insecticides to control competition from so-called "harmful" plants and species that are judged undesirable.

Clearly, and this can be easily demonstrated, maximizing MAI is not in the best interests of logging companies and society as a whole, and is even contrary to sound forest management. It is of prime importance to substitute for it another decision criterion that takes into account the value of ***all the products offered by nature and all the net benefits that companies and society may derive from them.***

This criterion is known as the ***net present value of economic benefits*** that may be generated at various ages of the stratum under management. ***The objective sought is to maximize this value.*** We saw earlier in this study how this value is calculated in actual cases and what tools we need to make a reliable calculation of it.

b) Objectives and criteria at the parcel level

For forest managers, the forest stratum is synonymous with the forest management parcel. The assumption is that there is only one compartment in a given area, that is, the management unit as a whole, and each stratum in the unit is thus equal to a parcel. The spatial information regarding each compartment in the unit is not explicitly taken into account, which we feel is a major weakness in the current process of preparing forest management plans. Space comprises a set of significant variables, such as transportation distance, difficulty of terrain, operating constraints of all sorts, and these may have a major influence on management choices.

c) Objectives and criteria at the management unit level

To determine whether a given type of treatment should be applied to a given management unit, forest managers in the government department responsible for this decision (MRN in Quebec) use a criterion known as the ***allowable cut effect***, or ACE.

If it is felt that the treatment in question will have the effect of immediately increasing the yield of the unit (allowable cut effect), the recommendation will be to apply it even if the actual economic value of this treatment proves to be ***negative***. If this is not the case, managers will reject application of the treatment whether or not the treatment would increase the net income of the company or of society as a whole.

In actual practice, this notion of value has no place in the concerns of forest managers, since the allowable cut effect is a strictly biophysical factor and thus neglects the financial or economic aspects of the decision, even though this decision is basically economic in nature.

It might be well to review the concept of allowable cut before going any further with the allowable cut effect.

The allowable cut in a given area is the quantity of timber that can be cut annually on a constant basis over the planning horizon chosen, normally 120 years. Foresters thus speak of ***sustained yield***, whereas in our view, to be in line with the real objectives of logging companies and society, they should instead speak of ***sustained values***.

As a first observation, allowable cut is always calculated, as in the case of MAI, on the basis of species deemed priorities and according to the maturity ages that maximize MAI, in line with the implicit objective of the forest manager, which is the maximum allowable cut for the species chosen. The allowable cut thus determined will in most cases result in the production of small trees, which are barely profitable for the industry, in particular for saw timber. We thus find in the calculation of allowable cut all the weaknesses already noted with respect to MAI.

When we introduce into our calculations an annual cut volume greater than the allowable cut, at some point in the horizon we will encounter a ***shortage***, when the mature and maturing stock is insufficient to supply the simulated volume. After this shortfall, the allowable cut will often tend to increase, but the forest manager is normally unaware of this.

The shortfall effect is fundamental to the allowable cut effect.

What exactly do we mean by allowable cut effect? It is simply the immediate increase in forest yield, calculated up to the point a shortage first occurs, resulting from application of a certain number of silvicultural treatments.

It should be noted that the application of silvicultural treatment always results in a positive allowable cut effect somewhere in the horizon; however, the only thing that counts for the forest manager is the effect that occurs before the first shortfall.

The allowable cut effect is the favourite tool of foresters to render profitable treatments that an economic analysis has judged unprofitable. Economists say that planting trees today and cutting them only fifty years later is not profitable for companies, because of the high per-hectare cost of planting and the high price that must be paid to make any profit (cost of waiting). At a rate of 4%, not accounting for inflation, most silvicultural treatments fail the profitability test for the private sector, thus explaining why they are generally subsidized.

Where there is no profit, foresters reply that the benefits of reforestation (or other silvicultural treatments) do not come in the far-distant future but occur immediately, as shown by the allowable cut effect. What was not profitable for some thus becomes profitable for others. Who is right?

It is easy to show that the allowable cut effect - which is in any case incomplete in biophysical terms since it considers only the product deemed a priority and ignores the allowable cut effect after shortfall - is just as deficient a decision criterion as MAI, since it implicitly contains all the same weaknesses, in addition to those specific to it.

This criterion does not explicitly take into account factors that should normally guide management decisions, such as site productivity, the variety and value of the species making up the different strata, proximity to the labour force and consumption centres. It ignores the value of all the products the forest supplies. It is closely linked to the age structure of the stands making up a given forest, a structure that is often ***accidental*** and ***artificial*** due to the subjective subdivision the forest manager makes of the forest in a given area.

In Figure 9, we see that the net present value of economic benefits corresponding to a maximum allowable cut effect is often much lower than it was before this effect was obtained.

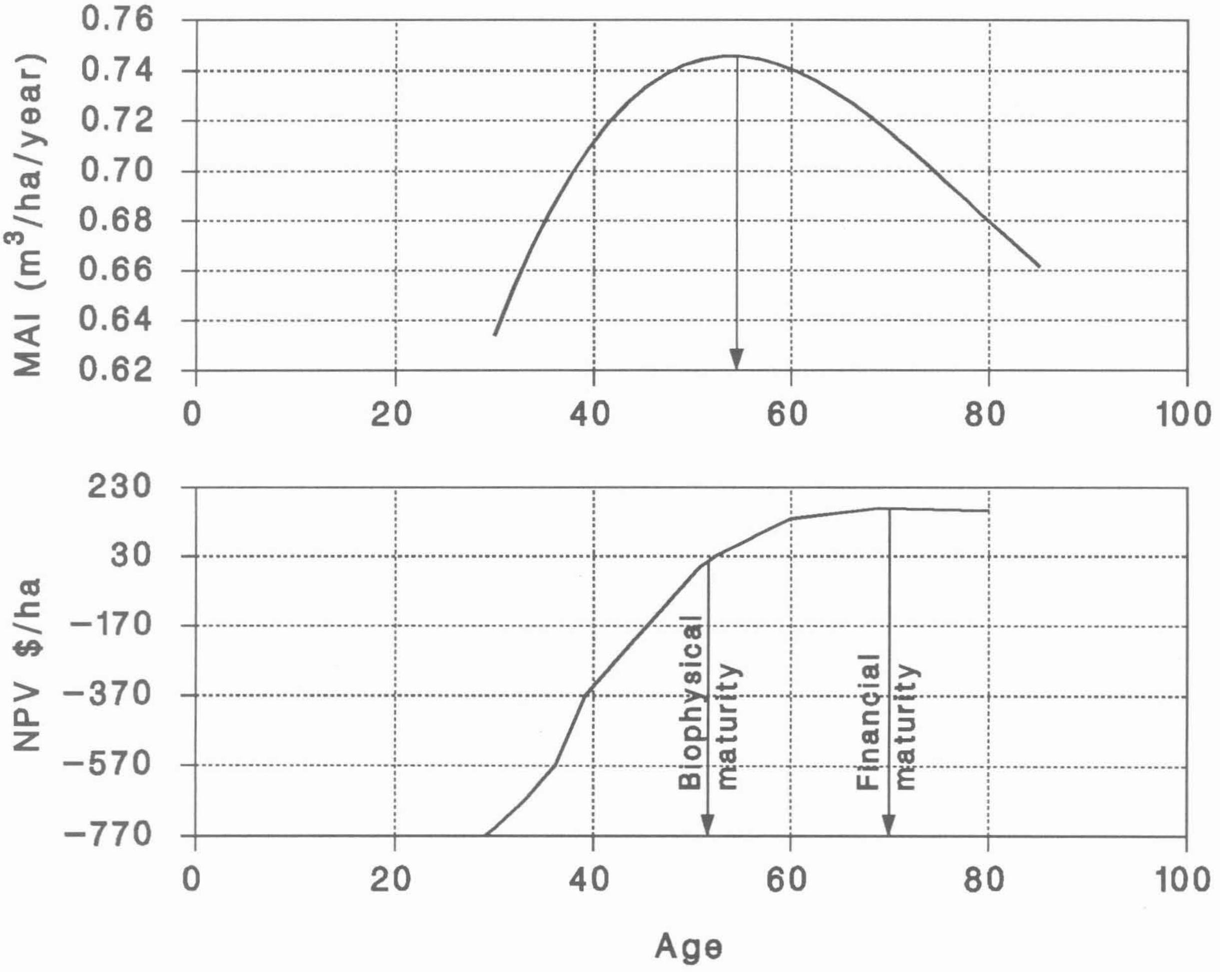


Figure 8. Age at maturity of WBFS B4 30 stratum.

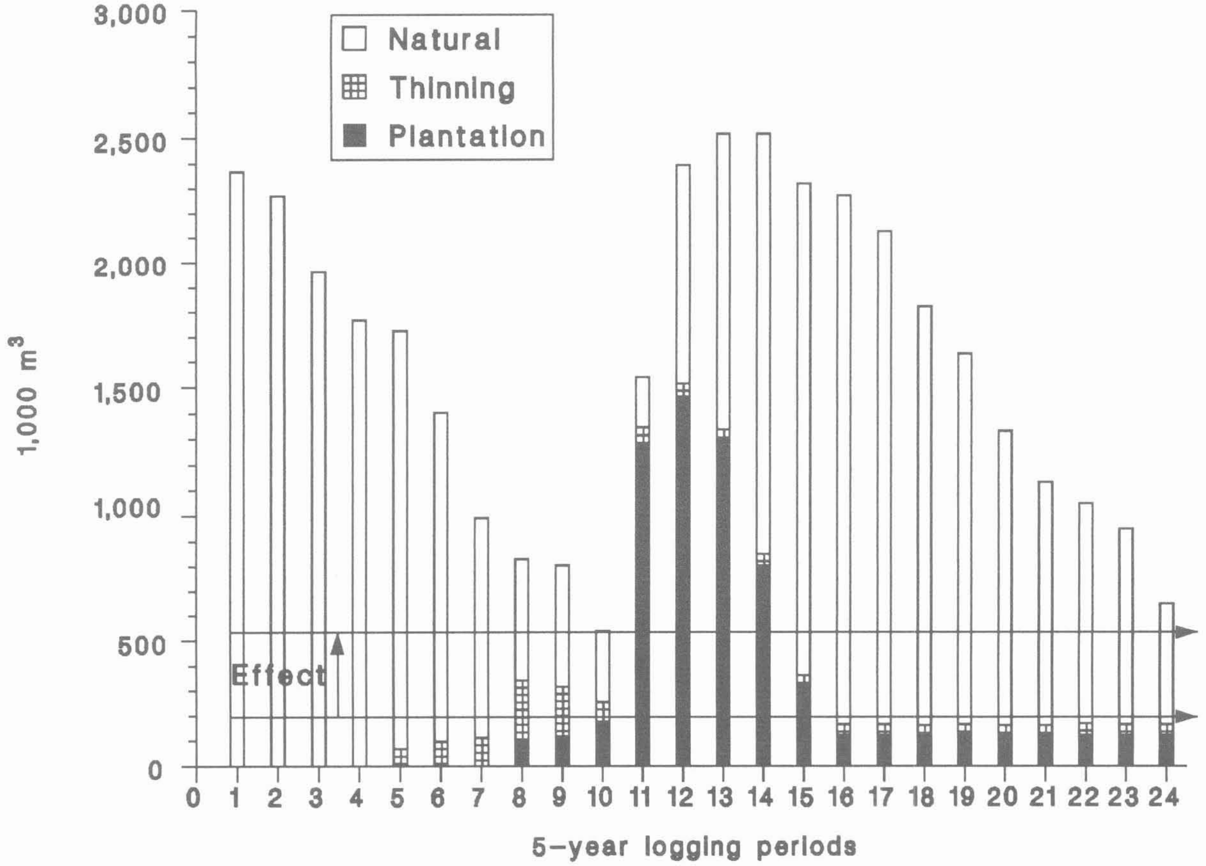


Figure 9. Allowable cut effect - MU 12.

In eastern Canada, with the exception of New Brunswick, Nova Scotia and Prince Edward Island, the remote northern areas, those with low productivity, often have a higher net allowable cut than the closer, high productivity units in the south, for purely temporary reasons (particular age structure due to forest abnormalities). The risk, or potential risk, is that, based on the criterion of maximizing the allowable cut effect of the product deemed a priority, we have an absurd situation whereby the majority of the silvicultural treatments applied annually in eastern Canadian forests are concentrated on these less productive, more remote sites.

We could formulate a number of criticisms of economic analysis, but the fact remains that the results always correspond to the common-sense reaction, that it is preferable to give priority to reforestation on the best and closest sites and give priority to treatments that will bring profits in the shortest time. Used properly, which is not always the case, economic analysis is, we feel, the most efficient tool available for correctly planning and optimizing forest management decisions.

Optimization of decision variables and possible options

Preparation of a forest management plan raises the question of optimizing decision variables within the limits of the many constraints involved. Currently, the question of optimization is completely ignored by foresters, except to determine the age of strata at maturity and the choice of treatments, which are based on two objectives we have found to be invalid, maximizing MAI and ***allowable cut effect.***

By failing to attempt to optimize the value of so-called "controllable" forest management variables (such as age of financial maturity, choice of treatment, density and quality of road networks, etc.), we feel that forest managers ***completely evade their primary role***, which is to maximize the benefits gained from the use of forest resources by both companies and society.

Briefly, then, the three main (although not the only) weaknesses of current forestry management are: 1) maximization of MAI and allowable cut effect, 2) almost complete failure to consider spatial and temporal information, and 3) failure to optimize decision variables. This is what our study attempts to avoid, by proposing an approach that constantly refers to ***economics*** as the fundamental dimension of forest management and works to determine the true value of the various decision variables involved in the preparation of a forest management plan.

APPENDIX 2
ECO-4 System

The general structure of the PC version of the ECO-4 forest management system is similar to Version 4.1.1 for Macintosh.

Programming for PC provided an opportunity to simplify and improve the system in a number of ways, particularly with respect to the growth of strata, cut priority criteria prior to allowable cut calculation and the supply function, and financial calculations.

In summary, ECO-4:

. Considers the four basic dimensions of forest management:

- **forestry**
- **economics**
- **space**
- **time.**

. Allows us to <u>optimize</u> applied forestry choices within a company's operating constraints.

. Includes two utilities and two modules, all autonomous and perfectly integrated:

- **Utility 1 - strata combination**
- **Utility 2 - consultation of outside files**
- **MODULE 1 - growth of strata and evaluation of parcels**
- **MODULE 2 - timber supply and overall management plan.**

. Is applicable both to small private forests and large public forests.

. Can be used for both the long term (100 years and over) and the short term (1-25 years).

. Closely simulates the management context and is easy to use.

. Allows us to meet both the objectives of private enterprise and those of governments and society.

Forestry and financial evaluations, sorting procedures, exclusions, calculations and various ratios are determined by a calculation unit known as CELLULE, which forms the heart of the system.

In Quebec, forests are divided into development strata (SYLVA strata) and compartments (using the MRN plan). Each of the strata in an area can be developed and managed according to various production scenarios. A scenario would include a production objective and a sequence of silviculture treatments or technological innovations over the course of a planning horizon.

By definition, a forest management parcel corresponds to a specific stratum in a given compartment, managed according to a specific production scenario. If the management unit (Timber Supply and Forest Management Agreement or private management unit) contains 250 strata, 3 scenarios per stratum and 200 compartments, it would then contain 200,000 forest management parcels.

In SYLVA, the FLM-SU file gives the gross area (in hectares) of these parcels for a given management unit.

Each parcel is subjected to detailed forestry and financial analysis in ECO-4. The parcels thus analysed form a database that can be accessed in preparing and optimizing all types of forest management choices, calculating cut allowances based on various operating constraints and cutting priorities, and preparing silviculture and operating plans for various planning horizons.