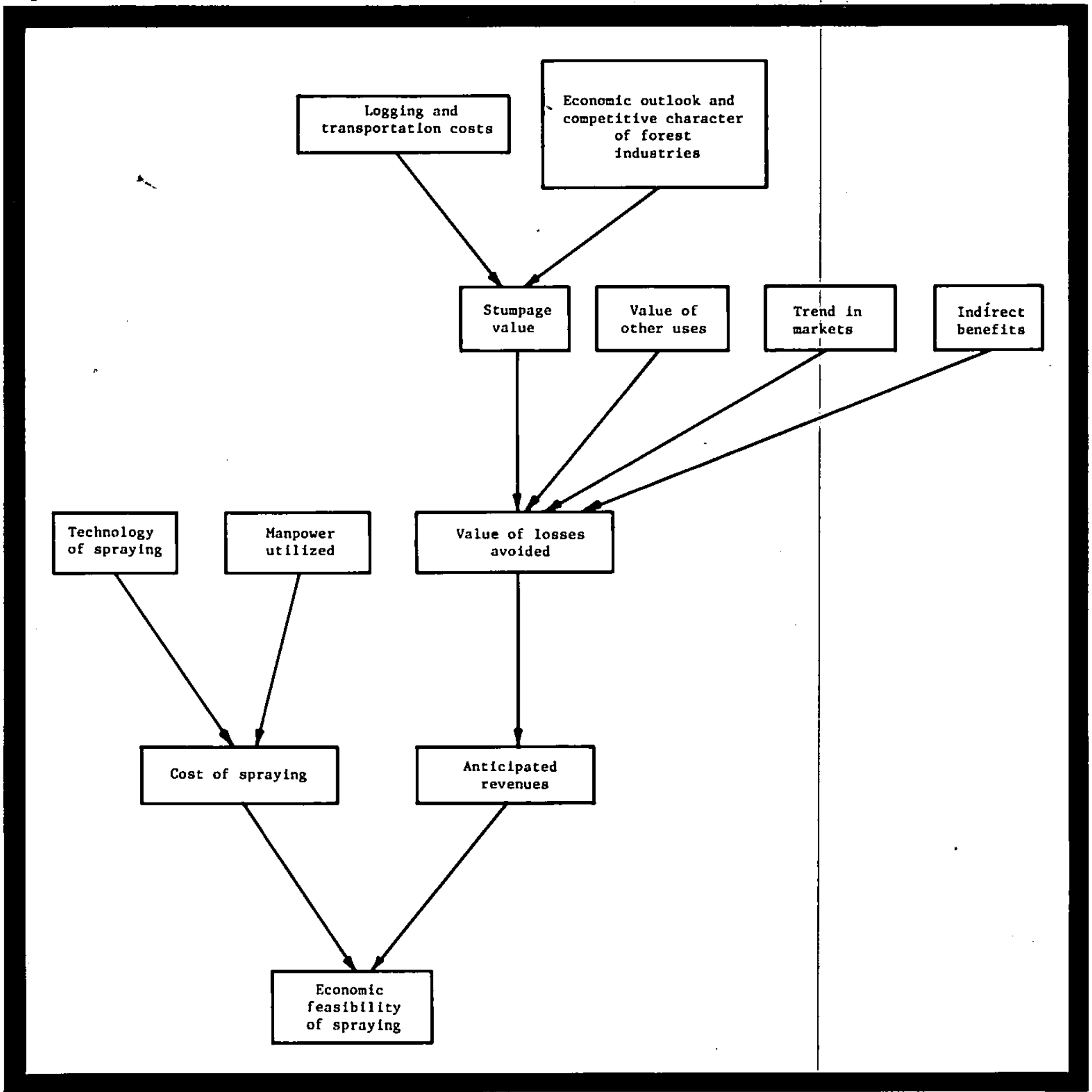
GOUVERNEMENT DU QUÉBEC
MINISTÈRE DES TERRES ET FORÊTS
DIRECTION GÉNÉRALE DES FORÊTS
SERVICE DE LA RECHERCHE

MÉMOIRE No. 33E

ECONOMIC FEASIBILITY OF CONTROLLING THE CURRENT SPRUCE BUDWORM OUTBREAK IN QUEBEC

by Jean-Paul Nadeau



JEAN-PAUL NADEAU received a B.Sc.Appl. (Forestry) from Laval University in 1963. After two years of work for the Quebec Department of Lands and Forests in the Roberval area, he undertook in 1965, studies in forest economics at Laval. In 1968, he received an M.A. in economic sciences from Syracuse University and in 1969, a Ph.D. (Forest Economics) from the same institution. He then entered the Economic Studies Service of the Quebec Department of Lands and Forests and in 1970, he transferred to the Research Service where he is head of the Forest Economics division.

ECONOMIC FEASIBILITY OF CONTROLLING THE CURRENT SPRUCE BUDWORM OUTBREAK IN QUEBEC

by

JEAN-PAUL NADEAU

MEMOIRE N^{O} 33E

GOVERNMENT OF QUEBEC
DEPARTMENT OF LANDS AND FORESTS
FORESTRY BRANCH
RESEARCH SERVICE

1977

* English version of a paper read at the Conference on Plant Protection Economy, Brussels, Belgium, May 15-15, 1973, under the patronage of the European and Mediterranean Plant Protection Organization.

This research paper is also available in French under the title: *Aspects économiques de la lutte contre la présente épidémie de tordeuse des bourgeons de l'épinette au Québec.* (*Mémoire n^o 33F*).

Dépôt légal

Bibliothèque nationale du Québec

SUMMARY

Even though insect outbreaks have been known for centuries in Canadian forests, the economics of control measures was almost completely ignored till recently. This paper presents the highlights and main results of an economic study prepared in 1972 under the auspices of the Quebec Department of Lands and Forests Research Service, concerning the feasibility of aerial spraying against spruce budworm. This study arrives at a general pest control policy by comparing nine spraying alternatives in terms of economic criteria. The marginal approach of economic analysis is used. One pre-condition set was that spraying policy must be integrated with other forest policies. The study is based upon certain assumptions concerning entomology, forest management, and economics.

One of the most economically feasible spraying options indicated an 8% rate of return on investment in terms of direct value saved (stumpage value only). It calls for the spraying of softwood and mixedwood stands, for two successive years, then a halt to spraying for two years, and so on till the end of the outbreak.

Without treatment, the minimum annual loss in the outbreak area in Quebec could present, over the next forty year period, the following picture:

1- Over two million cunits of timber destroyed (*5,6 millions cubic metres*)

2- 12,6 million dollars in lost stumpage dues from public forests;

3- 14,7 million dollars in lost taxes;

4- 63,2 million dollars in lost salaries and wages;

5- 17 000 fewer jobs.

RESUME

Même si le phénomène des épidémies d'insectes forestiers date de quelque siècles au Canada, l'aspect économique de ces épidémies fut à peu près ignoré jusqu'à récemment. Ce mémoire présente les grandes lignes et quelques-uns des résultats d'une étude économique réalisée au cours de l'année 1972 au Service de la recherche du ministère des Terres et Forêts du Québec, concernant la rentabilité des arrosages aériens contre la Tordeuse des bourgeons de l'épinette.

Cette étude proposait une politique globale de lutte à partir de la comparaison de neuf alternatives ou choix possibles d'arrosage en termes de critères économiques. L'approche marginale y était utilisée.

La politique d'arrosage doit être intégrée aux autres politiques forestières et gouvernementales.

L'étude repose sur des hypothèses de base concernant l'entomologie, l'aménagement forestier et l'économique.

L'une des alternatives d'arrosage les plus rentables en valeurs directes rapporte 8 p. 100 sur l'investissement. Cette alternative

consiste en une séquence caractérisée par deux années d'arrosage suivies d'une période de deux années sans arrosage, de tous les peuplements résineux et mélangés.

Sans intervention de lutte, l'épidémie actuelle au Québec pourrait représenter, sur une base annuelle et pour une durée de plus de quarante ans, des pertes minimales de:

1- *Plus de deux millions de cunits* de bois* (5,6 millions de mètres cubes);
2- *$12,6 millions en termes de droits de coupe sur les forêts publiques;*
3- *$14,7 millions en termes de taxes, impôts, etc.;*
4- *$63,2 millions en termes de salaires;*
5- *17 000 emplois.*

---

* *1 cunit* = 100 pi^3 = *2,83* m^3

TABLE OF CONTENTS

LIST OF TABLES

Table		page

LIST OF FIGURES

INTRODUCTION

Insect outbreaks have been occuring for centuries in Canada, but until now, the economic aspect of these outbreaks was almost completely ignored. The spruce budworm is considered to be the most important national forestry problem in Canada. Although this insect is found in several Canadian provinces, outbreaks occur principally in Quebec and New Brunswick (Blais, 1968). The first economic study on the feasibility of aerial sprayings against spruce budworm (*Choristoneura fumiferana* Clem.) in Canada was made in 1958 by Dorion. He considered only two alternatives (spraying and not spraying) to protect Gaspesian softwood forests (eastern part of the province of Quebec) for a ten-year period. This study showed that on the basis of stumpage value saved, aerial spraying with insecticide against spruce budworm was economically feasible. Wilson (1966), using the same alternatives, came to the same conclusion in his study of spraying against spruce budworm in New Brunswick, viewing it as a 40-year endeavour.

The study by Nadeau *et al.*, 1972, is the first detailed analysis on the economic feasibility of controlling a spruce budworm outbreak in Canada, and has been conducted in collaboration with one forest entomologist and two forest managers. Furthermore, this study compares nine spraying alternatives on the basis of economic criteria and demonstrates that the decision to control a budworm outbreak should be based on sound economic values.

The purpose of this paper is to present only the highlights of the economic study by Nadeau *et al.*, 1972. The following aspects are discussed: purpose of the study, the spruce budworm problem, methods of analysis, integration of aerial spraying policy with other governmental forest policies, assumptions made, compilation of timber volumes saved, economic equations used, and finally, direct and total feasibility of aerial spraying.

PURPOSE OF THE STUDY

The general purpose of this study is to:

1- Define the elements of a general aerial spraying policy for the Quebec Department of Lands and Forests;

2- Analyze the economic, management, and entomological factors involved in determining a sound future policy with respect to the control of budworm outbreaks in Quebec.

More specifically, it:

1- Defines spraying alternatives as a function of the period of time between successive spray applications and choice of stands;

2- Evaluates the amount of timber volume which would be saved by adopting each alternative;

3- Evaluates in dollars the losses which could be avoided by adopting each alternative;

4- Determines whether the government should spray or not spray against budworm and, if so;

   a) defines under which stand conditions respecting frequency of spray application, stumpage values, indirect benefits, costs, etc., aerial spraying appears economically feasible for government in terms of direct, indirect, and total values;

   b) determines the maximum investment the government should make in spraying operations;

   c) evaluates the rate of return on investment for each alternative as a function of different economic criteria;

THE SPRUCE BUDWORM CONTROL PROBLEM IN QUEBEC

In Quebec, spruce budworm affects the major source of timber supply for the forest industries. Between 150 and 200 million cords of timber (*544 and 725 million cubic metres*) have been destroyed in Quebec during the past two outbreaks registered in this century. The current outbreak could destroy extensive balsam fir and white spruce stands throughout the Province. Since 1968, more than twenty-six million acres of forest land (*10,5 million hectares*) have been infested by spruce budworm in this province. Until 1988, more than forty-six million acres of forest (*18,6 million hectares*) will probably be attacked by the insect. Without treatment, more than one hundred million cords of wood (*three hundred sixty two million cubic metres*) could be destroyed during the next decade.

Unless preventative measures are taken, annual damages for the next forty years could amount to minimum losses of:

1- More than two million cunits of wood (*5,6 million cubic metres*);

2- $12,6 million in stumpage dues;

3- $14,7 million in taxes;

4- $63,2 million in salaries;

5- 17 000 jobs.

The budworm problem is an economic one which concerns the Government, the Department of Lands and Forests and all users of the forest. The solution to the problem will require a considerable investment. Is this investment economically justified?

CHAPTER I

METHODS OF ANALYSIS

1- GENERAL ECONOMIC APPROACH

The major decision rule with respect to a general policy of aerial spraying against spruce budworm in Quebec is as follows:

The maximum outlays economically justifiable for aerial spraying against spruce budworm must be less than the value of loss prevented by the treatment.

The value of prevented loss is a potential value which is not confined to the stumpage value of timber, but to its potential value to all users.

Furthermore, this economic analysis takes into consideration the biological (that is, entomological, and forest management) aspects of the problem. Pest control is considered to be an integral part of forest management, spraying costs being part of forest management costs. Indeed, timber losses caused by an outbreak have to be included in the computation of annual allowable cut. It was understood that the final decision with respect to the control of an insect outbreak would be based mainly on economic values; the pest control policy would require that an infested forest be protected only to the extent that the control cost would not exceed the otherwise anticipated loss. Furthermore, the investment in pest control must return the same rate as an investment made in other forest production activities or, for that matter, non-forest production activities.

The major steps followed with respect to the recent study on the economic feasibility of aerial spraying against spruce budworm in Quebec are the following:

1- Determination of spraying alternatives as a function of the time period between applications, and of the category of stands treated;

2- Determination of spraying options by comparing each alternative with the basic one which consists in not spraying;

3- Valuation in terms of present worth of the net allowable cut and of the spraying cost (at various discount rates) corresponding to each alternative; valuation of the marginal allowable cut saved (i.e. the marginal revenue representing the prevented loss of timber volume) corresponding to each option;

4- Valuation of direct, indirect, and total losses prevented by aerial spraying for each option using various discount rates;

5- Financial valuation of each option in terms of various economic criteria for various discount rates (direct, indirect, and total feasibility);

6- Classification of options and choice of the most economically feasible option, taking into account an appropriate minimum discount rate.

These major steps required that the following minor steps be taken:

1- Establishment of a schedule of values saved (prevented losses);

2- Establishment of a schedule of treatment costs;

3- Determination of an appropriate alternative rate of return;

4- Capitalization of values saved;

5- Capitalization of spraying costs scheduled;

6- Calculation of the internal rate of return on investment, the benefit-cost ratio, and the net present value indicated for each option.

2- GENERAL CRITERIA FOR ECONOMIC VALUATION OF THE PEST CONTROL PROGRAM

The decision to spray large areas of forests represents a substantial change. Because not all changes are desirable, it is necessary to decide which tests a change must pass to be desirable (Marty, 1972). The major tests are the folowing:

1- Feasibility.

Aerial application of insecticides against spruce budworm must be physically and technically feasible. Furthermore, there must be sufficient manpower and funds available to perform the operation.

2- Productivity.

The aerial spraying program must help all concerned groups, that is, the Government, the Department of Lands and Forests, and all other users, to achieve their objectives more fully.

3- Acceptability

The aerial spraying program must be acceptable to all persons who can influence the final decision process, both inside and outside the administrative unit of the provincial government.

4- Effectiveness

Finally, the measures taken must be physically effective without being too costly.

3- SPRAYING ALTERNATIVES

Since the objective of the control program is to find the most economically feasible solution, it is necessary to consider several alternatives based on the period of time between consecutive sprayings, and on the selection of stands to be protected. Nine alternatives and eight options were defined in order to compare the values of prevented losses with the corresponding additionnal costs of spraying. The alternatives and options that were finally retained are given in Table 1.

In order to compare additional expenditures and additional revenues corresponding to each alternative, it is necessary to define options. As mentioned earlier, one alternative is to accept the first alternative to do nothing; which costs nothing. Against this alternative, the others can be compared. Thus, for eight of the nine alternatives the additionnal costs of control must be compared with the corresponding values of prevented losses or anticipated revenues.

TABLE 1

Spraying alternatives and options related to stands and time intervals between spraying operations

Spraying alternative number	Spraying option number	Identification of alternatives and options
1		No spraying
2	1	Spraying of all softwoods and mixedwoods, every year.
3	2	Spraying of all softwoods and mixedwoods, every second year.
4	3	Spraying of all softwoods and mixedwoods, every third year.
5	4	Spraying, every year, stands having more than 5 cunits per acre (*34,72* m^3/ha) of balsam fir (*Abies balsamea*) and white spruce (*Picea glauca*), and stands having 3 and 4 cunits per acre (*20,83* and *20,83* m^3/ha) of balsam fir and white spruce, when this volume represents more than 25% of the volume of all species.
6	5	Same procedure as alternative 5, but every second year.
7	6	Same procedure as alternative 5, but every second year.
8	7	Spraying for two years in a row all softwoods and mixedwoods, followed by a period of two years without treatment.
9	8	Spraying for two years in a row, followed by a period of two years without treatment, the stands described in alternative 5.

4- FINANCIAL CRITERIA

The comparison of alternatives was made on the basis of the three following economic criteria:

1- Net present value;

2- Benefit-cost ratio;

3- Internal rate of return on investment.

5- STRATEGIC VARIABLES

A benefit-cost analysis of a forest pest control program requires that strategic variables be determined. Any qualitative or quantitative factor which has a direct or indirect effect on the economic feasibility of treatment (that is, on the yield of infested stands, on control costs and on anticipated revenues) must be considered.

Biological variables include the insect and the associated factors identified by epidemiology. Physical variables include the land and the forest (forest type, growth, net or gross allowable cut, etc.). Technological variables include the choice of an insecticide, its application, and the ultimate use to be made of the wood.

Cost variables depend upon the technology of pest control and the technology of wood transformation at the mill. Anticipated revenue variables include stumpage values, values of the final products, and the amount of indirect benefits generated by forestry activity. Finally, a minimum discount rate must be selected.

6- INTEGRATION OF PEST CONTROL POLICY WITH OTHER GOVERNMENT FORESTRY POLICIES

The pest control policy against spruce budworm in Quebec must be considered in the context of other governmental forestry policies. In effect, it is necessary to integrate the spraying policy not only with other forest protection activities but also with other general forestry policies concerning forest management, timber allocation, multiple use of the forest, and financial aid to industrial development.

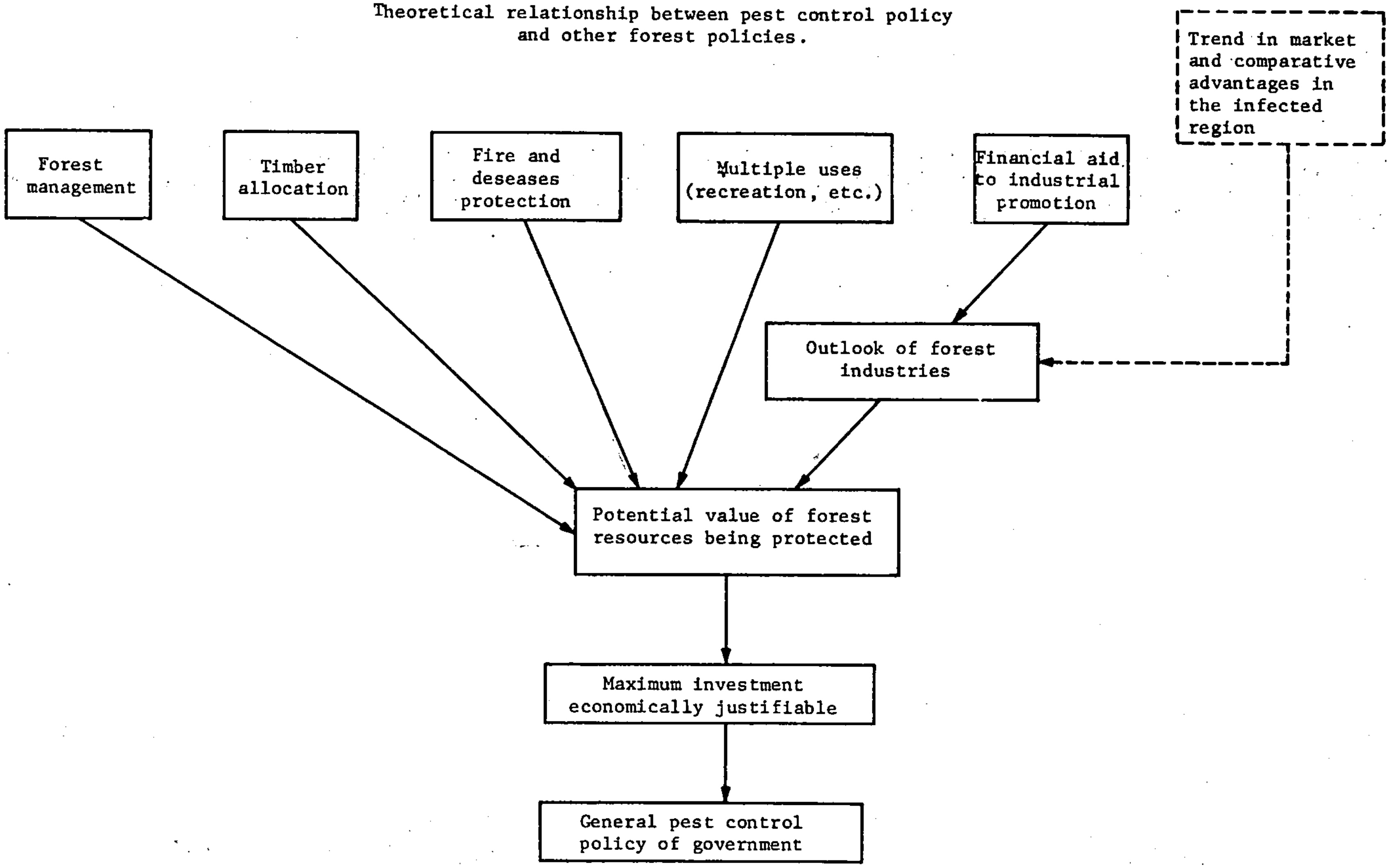
The theoretical relationship between these various policies is illustrated in Figure 1. The maximum expenditure which can be economically justified to control the spruce budworm depends on the potential value of the forest threatened. This value is determined to a great extent by government policies on forest management, timber allocation, aid to the development of forest industry, and other forest protection policies.

Thus, intensive forest management increases timber volumes and values, so that the economic feasibility of aerial treatment is increased. The potential value of the forest is also a function of its utilization, which is determined by the timber allocation policy in effect between the government and users.

The policy of financial assistance to industry affects that of pest control, because it is useless to protect against insect damage a forest for which there are no funds to finance its utilization by industry. In summary, then, in addition to protecting the forest, it is necessary to ensure its utilization.

FIGURE 1

Theoretical relationship between pest control policy and other forest policies.



CHAPTER II

BASIC ASSUMPTIONS

The benefit-cost analysis of the proposed pest control program against spruce budworm in Quebec is based upon certain assumptions which influence the analytical framework of the study. In an analysis such as this, a great deal of uncertainty and risk is involved concerning the values of parameters because one must often simply assume certain values as facts. The assumptions that are made can be grouped under three headings: entomology, forest management, and economics.

Assumptions with respect to the entomological aspect apply to the following: the time interval between consecutive outbreaks, the rate of tree mortality by species related to years of defoliation, the evaluation of losses over time and by region, and the efficiency of current methods of control. The following specific assumptions have been made:

1- The outbreak will last for ten years;

2- A period of thirty years will pass before the next outbreak;

3- The total period of analysis covers forty years;

4- The outbreak will progress from west to east;

5- The extent of current damage is known;

6- The current pest control methods are relatively effective based on the results of the 1972 operations;

7- The assumed rate of tree mortality due to defoliation is realistic;

8- The rate of loss in volume is acceptable for the purpose of this analysis.

Let us consider briefly loss increment and tree mortality. According to McLintock (1955), one year of severe defoliation (loss of current year's needles) on balsam fir will cause a loss in radial increment. It can be assumed that white spruce undergoes an equivalent loss. It is also possible to assume, on the basis of observations made for different tree heights (McLintock, 1955), that the loss in volume is proportional to the loss in radial increment, and the following rates of loss in volume can be used (Table 2):

Table 2

Loss in volume per year of defoliation

Year of defoliation	Loss of increment in volume (as a percentage of normal increment)
First year	30%
Additional years	60%*

* Minimum amount of loss

Mortality rates used here are adapted from research done in Western Quebec by the U.S. Forest Service during a previous outbreak (McLintock, 1955). These rates are shown in Table 3. Other studies made in Canada confirm these data and indicate that our own data are rather conservative.

Table 3

Rate of mortality for various periods of consecutive defoliation

Continuous years of defoliation	Rate of mortality (expressed as a percentage of the original stand)	
	Balsam fir	White spruce
One	0	0
Two	0	0
Three	0	0
Four	1	0
Five	4	1
Six	15	5
Seven	25	7
Eight	15	5
Nine	5	2
TOTAL	65	20

The assumptions made with respect to forest management based upon the current spruce budworm outbreak in Quebec include the following: the impact of the insect on the quantity of timber harvested, on the increment, and on the areas being infested;

on the possibility of pest control through cutting techniques; and finally, on timber yield.

It was also necessary to make some assumptions with respect to certain economic and financial variables. The economic feasibility of a pest control program is determined by cost-revenue relationships (figure 2). The economic values which are used are presented below.

The unit cost of spraying is presently $0.70 per acre; it is assumed that this figure will increase at a rate of 3 p. 100 per year. The same rate is assumed for revenues.

Anticipated direct revenues resulting from a pest control program can be expressed in terms of the prevaling stumpage value, and total values can be determined by adding the indirect benefits to this stumpage value. The stumpage value used here is $3.64 per cunit (unit of 100 cubic feet)(*$1.28 per* m^3) for sawtimber, and $5.88 per cunit (*2.07 per* m^3) for pulpwood (balsam fir and spruce). The values of indirect benefits used in this analysis are presented in Tables 4 and 5. Data on revenues are applied to timber volumes saved, and compared to control cost data in order to determine the economic feasibility of the pest control program.

FIGURE 2

Interrelationship between economic variables considered in the computations of the economic feasibility of aerial spraying

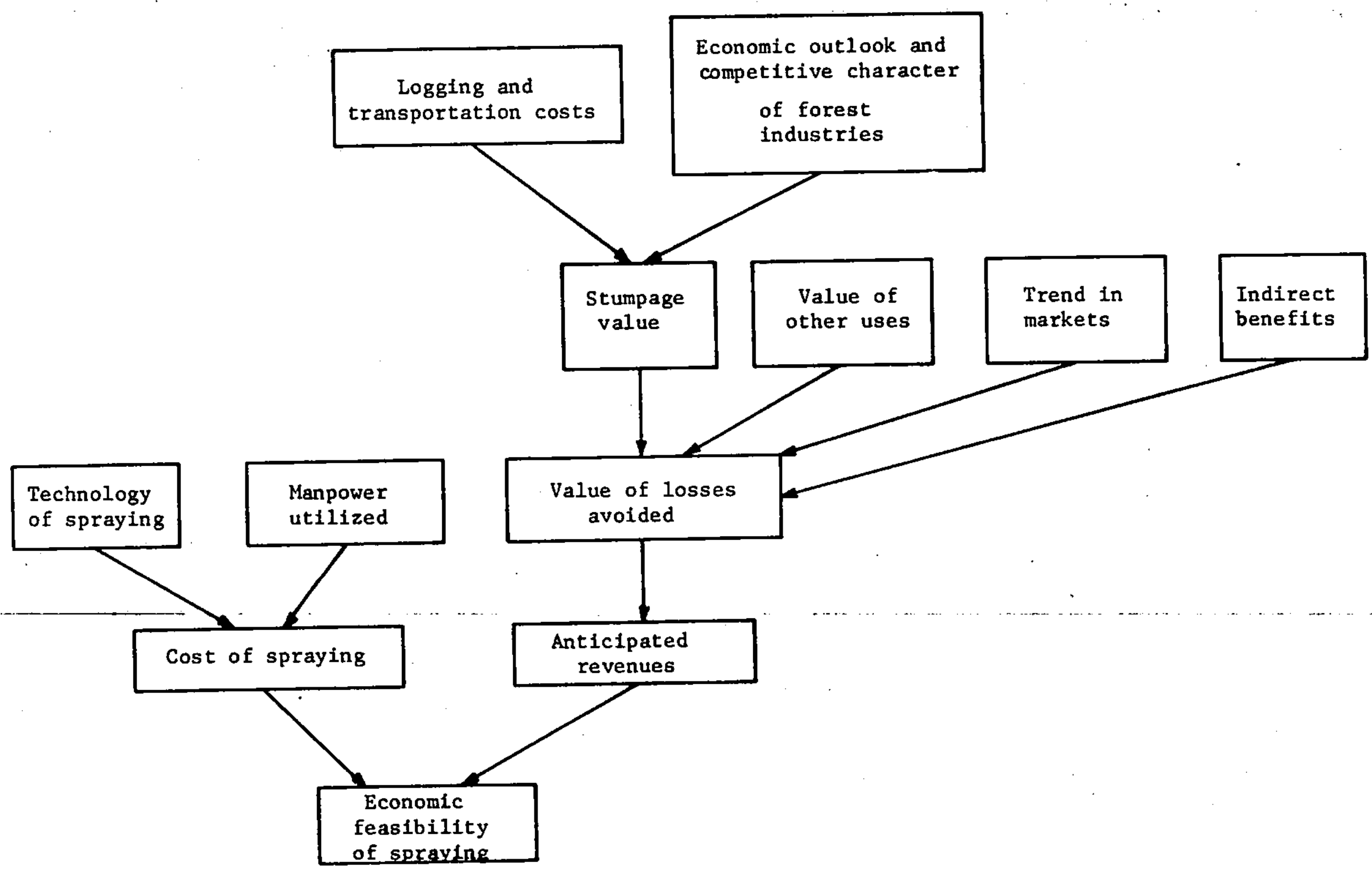


TABLE 4

Contribution to federal, provincial and municipal governments in dollars per cunit of timber processed by various forest industries (Lussier, 1969)

	Contribution			Total contribution
	Federal	Provincial	Municipal	
Sawmilling	$ 6.18	$ 3.44	$ 0.04	$ 9.66
Pulp and paper	$10.58	$ 6.89	$ 1.16	$18.63

TABLE 5

Amount of manpower used in various sectors of forest activities in man-years per cunit of timber (Lussier, 1969)

Sector of activity	Manpowed used			
	Man-years/1 000 cunits[1]			Employment per cunit[2]
	Direct	Indirect	Total	
Logging	3.32	0.16	3.48	---
Sawmilling	5.51	3.61	9.12	0.0091
Pulp and paper	3.05	4.21	7.26	0.0083

[1] Technology in 1965.
[2] Technology in 1961.

CHAPTER III

TIMBER VOLUMES SAVED BY THE CONTROL PROGRAM, SCHEDULE OF COSTS AND REVENUES

Taking into consideration the net allowable cut corresponding to each spraying alternative and the losses in growth and mortality due to defoliation, over a forty-year period, we have calculated the timber volumes to be saved through chemical treatment. The marginal allowable cut increase was also calculated for each spraying option over a forty-year period. For example, the timber volume saved in the first option is obtained by substracting the allowable cut in the first alternative from that of the second one, and so on. The marginal allowable cut indicated varies from option to option.

Nine schedules of net allowable cut, and eight schedules of marginal allowable cut and of anticipated revenues over a forty-year period were used. A schedule of spraying costs was prepared for each alternative, taking into account the spraying frequency and the treated area. Schedules were also prepared of anticipated revenues over a forty-year period, using stumpage values (direct feasibility) and indirect benefit values from logging and transformation (indirect and total feasibility).

Comparison of the eight spraying options was made using three economic criteria and several discount rates. A rate of 8 p. 100 was considered to be a realistic minimum.

CHAPTER IV

ECONOMIC MODELS AND THEORITICAL BASIS OF ANALYSIS

Before presenting the results of the study, it is worth describing briefly the major elements of economic theory which underly this analysis.

Since the decision to invest in aerial sprayings against spruce budworm in Quebec is to be an economic one, where investment in pest control will be considered to be warranted only if treatment costs are expected to be less than the value of losses prevented, it is worthwhile identifying certain basic notions encompassed in economic, financial, and decision theory, in the search for a solution to the spruce budworm control problem in Quebec.

More specifically, let us briefly consider the following:

1- Controlling spruce budworm outbreaks as an investment decision-making problem;

2- The marginal approach employed in major economic models;

3- Decision-making steps and decision rules;

4- Selected economic criteria.

1- CONTROLLING SPRUCE BUDWORM OUTBREAKS AS A PROBLEM IN INVESTMENT DECISION-MAKING

The decision on whether to undertake aerial treatment with insecticides as a defense against spruce budworm outbreaks is part of the total investment decision problem regarding forest management in Quebec. Budgetary constraints demand an optimum allocation of resources in order to satisfy future timber needs and other uses of the forest. Regarding spraying costs, there is a time lapse to be considered between initial outlays and the flow of benefits in the form of maintained, long term productivity. That is to say, an initial investment of short duration is required (purchase of insecticides, rental of airplanes and equipment, hiring of people, etc.) in order to maintain the long term productivity of the forest (source of raw supply for industry, etc.). The total feasibility of the project must be evaluated taking into account a minimum discount rate and this involves assessing the relative merits of the nine mutually exclusive spraying alternatives defined earlier. In this analysis, the choices according to the objectives of those who are involved in making the final decision (the Department of Lands and Forests and the government in general) must be assigned priorities. The ranking of choices will be made on the basis of acceptable economic criteria.

2- MARGINAL APPROACH AND MAJOR ECONOMIC MODELS

The search for the most economically feasible solution to the problem of aerial sprayings against spruce budworm is based on the concept of changes at the margin, in the sense that additional cost increments (spraying costs) must be compensated for by increments in additional revenues. The equilibrium point is reached where the additional cost increment (marginal costs) is equal to the additional revenue increment (marginal revenue). Below this point, the additionnal spraying cost is less than the benefit value of prevented damages to the forest and it is advantageous to invest more in the spraying operation. Beyond the equilibrium point, the additional cost of spraying exceeds the incremental benefit of the treatment.

The general economic relationship is as follows:

$$C_0 \leqslant R_0$$

Where:

C_0 = additional investment in the operation, the value of which is capitalized to the year zero, for each option.

R_0 = marginal revenue of the operation, capitalized to the year zero, for each option (that is, the timber volume saved multiplied by the stumpage value).

This equation was employed to assess each spraying option, in terms of direct, indirect, and total values given various discount rates.

The other main economic equations used in this study are the following ones:

1- C_0 maximum = R_0 (by option and for direct, indirect, and total values).

The present value of the maximum total investment for spraying operations during the ten-year outbreak period is equal to the present value of prevented losses otherwise expected over the next forty years.

2- Mean net annual benefit per acre.

$$MNAB = \left[NPV\ (1 + K)^{L}\right] \left[(K)/(1 + K)^{L-1}\right]$$ (by option and for direct, indirect and total values).

Where:

$MNAB$ = mean net annual benefit per acre.

NPV = net present value per acre.

K = discount rate.

L = number of years.

The mean net annual benefit per acre ($MNAB$) resulting from spraying operations is equivalent to an annual net revenue flow for the next forty years from an asset (e.g. an annuity) now having a capitalized value equal to NPV.

3- Internal rate of return on investment.

$$IRR = K \text{ for which } C_0 = R_0$$

Where:

IRR = the internal rate of return on the investment.

The internal rate of return on an investment is the discount rate for which the present value of costs is equal to the present value of revenues. A project is considered acceptable if the rate of return indicated is greater than the cost of capital.

4- Maximization of the net present value. The net present value of a project must be positive for it to qualify as an acceptable investment. The project having the greatest net present value is preferred.

$R_0 - C_0 > 0$

5- Benefit-cost ratio.

$R_0 / C_0 \geqslant 1$

The benefit-cost ratio of a project or option must be greater than or equal to one, otherwise the project is unacceptable.

3- DECISION-MAKING STEPS (DIAGRAM) AND DECISION RULES

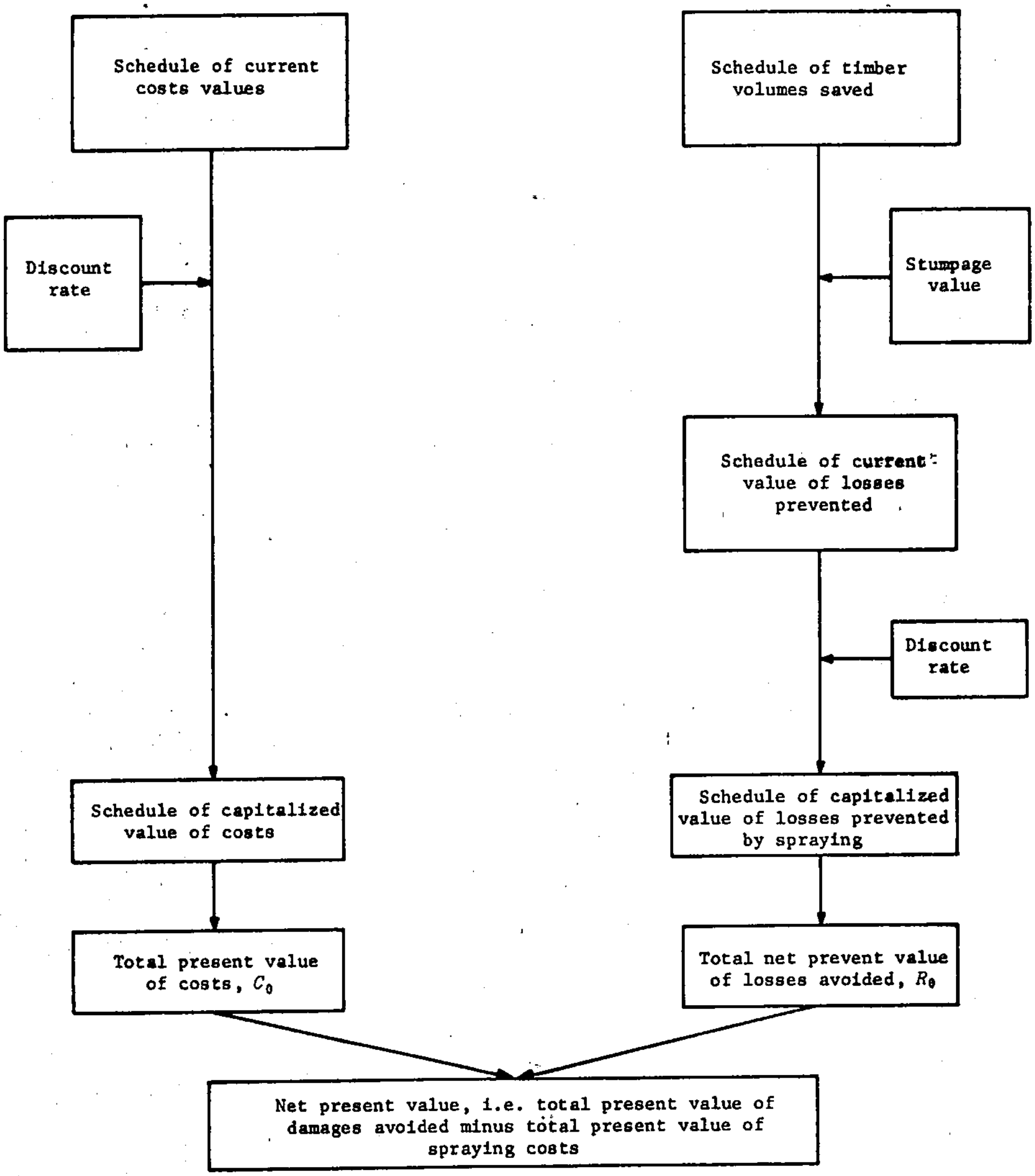
The application of marginal analysis used in this study can be summarized by a diagram (figure 3) showing the various steps in the decision-making process. The following data are required to complete the steps: minimum discount rates, schedules of control costs and of losses prevented by spraying operations. A schedule is shown of current and capitalized values of spraying costs over the next ten years for various interest rates for each option. Similarily, a schedule is shown of timber volumes saved and corresponding current and capitalized values of losses over the next forty years prevented by spraying operations. The net present value is obtained by susbtracting the total present value of costs from that of prevented losses.

The decision rules are the following ones:

1- The total present value of costs must be less than the total present value of prevented losses, that is, $C_0 < R_0$;

FIGURE 3

Diagram showing the decision-making steps using the net present value criterion



Decision rules: $C_0 < R_0$

$NPV > 0$

2. The net present value of an option must be positive and greater than that of other options, that is, $NPV > 0$.

In the case of the internal rate of return on investment criterion, the decision rule is to retain an option when the rate of return is greater than the opportunity cost of capital. As to the benefit-cost ratio, the decision rule is to reject a project when the ratio is less than one.

4. ECONOMIC CRITERIA USED IN THIS STUDY

Even though the maximization of net present value criterion is considered to be the most valid for this study, the internal rate of return and benefit-cost ratio criteria are also used for purposes of comparison. All three criteria are considered acceptable because they all consider the timing of the cash flows which are expected to occur during the life of the project. However, while they always agree as to the acceptability of a given investment option, they do not always agree on the order of preference when a number of options are being compared.

CHAPTER V

RESULTS OF THE ECONOMIC ANALYSIS

A short summary of the economic study on the control program against the spruce budworm in Quebec is presented in Tables 6 to 11. If, for example, a discount rate of 8 p. 100 and total values (direct and indirect benefits) are considered, then options 1, 2, 7 and 3 are preferred in that order (Table 6). In terms of direct feasibility and a discount rate of 8 p. 100, only options 3, 6 and 7 are ecomically feasible (Table 7). The options are compared using the benefit-cost ratio in Tables 8 and 9. For instance, at a rate of 8 p. 100, the preferred order of choice would be options 3, 6 and 7 respectively, in terms of direct feasibility (Table 8). In terms of total values all options appear acceptable, although not equally so, for all selectioned discount rates (Table 9). The options are compared on the basis of internal rate of return on investment in Tables 10 and 11. In terms of direct values, the preference order is for options 3, 6 and 7 respectively (Table 10). Finally, when total benefits are considered, all

TABLE 6

Total net prevent values of options for various discount rates, given stumpage values of \$3.64/cunit (*\$1.28/m³*) for sawtimber and \$5.88/cunit (*\$2.07/m³*) for pulpwood

Net present values

Spraying options no.	Discount Rates					
	2%	4%	6%	7%	8%	10%
	$	$	$	$	$	$
1	663 552 092	411 691 822	265 445 226	215 989 570	177 179 496	121 875 853
2	602 977 356	378 668 418	247 997 598	203 666 518	168 792 600	118 892 934
3	533 442 155	336 115 311	221 012 542	181 914 782	151 130 065	107 017 642
4	296 103 277	182 327 959	116 401 073	94 153 419	76 722 448	51 950 123
5	272 198 653	170 058 243	110 648 183	90 523 714	74 710 702	52 128 841
6	243 428 784	152 773 570	99 956 134	82 036 459	67 939 582	47 770 802
7	545 693 109	343 074 683	224 922 670	184 804 116	153 225 688	107 002 612
8	252 689 420	158 326 771	103 360 837	84 717 226	70 054 349	49 084 758

TABLE 7

Direct net present values of options for various discount rates given stumpage value of $3.64/cunit (*$1.28/m*^{3}) for sawtimber and $5.88/cunit (*$2.07/m*^{3}) for pulpwood

Net present values

Spraying options no.	Discount rates 2%	4%	6%	7%	8%	10%
	$	$	$	$	$	$
1	13 162 050	- 4 055 816	- 12 818 345	- 15 365 949	- 17 117 238	- 19 018 810
2	29 805 053	12 935 172	3 763 702	870 768	- 1 275 444	- 4 038 796
3	32 651 650	17 131 979	8 479 390	5 674 193	3 544 877	638 131
4	1 988 053	- 5 403 194	- 9 020 183	- 10 016 565	- 10 663 322	- 11 261 482
5	11 282 826	3 830 315	- 142 516	- 1 367 447	- 2 258 335	- 3 360 077
6	13 662 196	6 663 827	2 807 045	1 572 426	645 073	- 576 962
7	29 379 685	13 728 004	5 111 601	2 358 883	295 821	- 2 408 976
8	12 070 103	4 940 569	1 063 124	- 156 619	- 1 058 671	- 2 210 709

TABLE 8

Benefit-cost ratios considering only DIRECT values (stumpage values only) of options at various discount rates and stumpage values shown

Benefit-cost ratios

Rate of discount \ Options		1	2	3	4	5	6	7	8
Stumpage value: $3.64 and $5.88/cunit for sawlogs and pulpwood respectively*	2%	1.27	2.23	3.25	1.08	1.85	2.71	2.53	2.14
	4%	0.90	1.60	2.33	0.76	1.32	1.94	1.79	1.52
	6%	0.67	1.19	1.73	0.56	0.98	1.44	1.33	1.12
	7%	0.58	1.05	1.52	0.49	0.86	1.26	1.16	0.98
	8%	0.51	0.92	1.34	0.43	0.76	1.11	1.02	0.86
	10%	0.41	0.74	1.07	0.34	0.60	0.88	0.81	0.68

* *$1.28* and *$2.07/m^3 respectively*

TABLE 9

Benefit-cost ratios considering TOTAL values (stumpage value and indirect benefits included) of options at various discount rates and stumpage values shown

Benefit-cost ratios

Rate of discount \ Options		1	2	3	4	5	6	7	8
Stumpage value: $3.64 and $5.88/cunit for sawlogs and pulpwood respectively*	2%	14.80	25.97	37.82	12.52	21.50	31.56	29.39	24.91
	4%	10.53	18.62	27.07	8.90	15.39	22.55	20.86	17.67
	6%	7.80	13.90	20.17	6.59	11.46	16.77	15.44	13.06
	7%	6.81	12.18	17.66	5.75	10.03	14.67	13.47	11.40
	8%	6.00	10.76	15.60	5.06	8.86	12.94	11.86	10.03
	10%	4.77	8.62	12.47	4.02	7.07	10.31	9.43	7.97

* *$1.28* and *$2.07/m^3* respectively

TABLE 10

Internal rate of return on investment (DIRECT value only) options based on stumpage values of $3.64 and $5.88/cunit (*$1.28* and *$2.07/m³*) of sawtimber and pulpwood respectively

Options							
1	2	3	4	5	6	7	8
3.39%	7.37%	10.69%	2.26%	5.90%	8.91%	8.17%	6.85%

TABLE 11

Internal rate of return on investment (TOTAL benefits) options based on stumpage values of $3.64 and $5.88/cunit (*$1.28* and *$2.07/m³*) of sawtimber and pulpwood respectively

Options							
1	2	3	4	5	6	7	8
37.8%	64.4%	85.5%	31.1%	50.5%	63.3%	68.7%	58.5%

spraying options promise internal rates of return in excess of even the highest (10%) discount rate selected as an alternative rate of return (Table 11).

CONCLUSION

In terms of direct values, this study concludes that options 3, 6 and 7 are economically acceptable. But finally, option 7 is recommended because it is a compromise in terms of economic effectiveness and also of risk with respect to the success of the spraying operations themselves. Indeed, recent spraying operations show that spraying two years in a row (option 7) provides more protection than the same number of spraying operations with a time interval between them. Furthermore, according to options 3 and 6, there is too much risk if the spraying operations made every third year are not technically successful.

For the current program of aerial spraying against spruce budworm in the province of Quebec, it is recommended that option 7 be followed, which prescribes spraying specific areas for two successive years followed by two years with no treatment. The areas include all softwood and mixedwood stands that have been subjected to one year of severe defoliation prior to the first year of treatment. This option is economically and biologically acceptable since the point of no return is attained after three years of severe defoliation.

Even though this study considers only the value of timber saved, it constitutes a starting point to more detailed studies where other criteria including social and aesthetic aspects should be considered along with economic values.

LITERATURE CITED

DORION, P., 1958. *Aspects économiques de la prolongation des arrosages contre la tordeuse des bourgeons de l'épinette dans la forêt gaspésienne.* 81 pp. et cartes. Thèse de baccalauréat à la faculté de Foresterie et de Géodésie de l'université Laval, Québec, Canada.

LUSSIER, L.-J., et G. TARDIF, 1969. *Etude des problèmes liés à l'utilisation optimale des ressources des petites forêts privées du Québec.* Rapport soumis au ministère des Terres et Forêts du Québec. Québec, Canada.

MARTY, R., 1972. *Benefit-cost analysis in natural resource administration.* Material prepared at Michigan State University. U.S.A.

McLINTOCK, T.F., 1955. *How damage to balsam fir develops after a spruce budworm epidemy.* Northeastern Forest Experiment Station, U.S.D.A., Forest Service. Station paper 75.

NADEAU, J.-P., R. MARTINEAU, J.-L. BOIVIN et M. PELLETIER, 1972. *Etude de détermination d'une politique globale d'arrosage aérien contre la Tordeuse des bourgeons de l'épinette à partir de critères économiques, au Québec.* Rapport non publié. Service de la recherche du ministère des Terres et Forêts du Québec. 351 pp.

NADEAU, J.-P., 1973. *La Tordeuse des bourgeons de l'épinette: problème de décision économique.* Le Papetier, 10e année, no 2, avril. Conseil des Producteurs des Pâtes et Papiers du Québec.

WILSON, D.A., 1966. *Benefit-cost analysis, spruce budworm spraying program, New Brunswick 1960 outbreak.* Unpublished report. Canadian Department of Forestry. Ottawa, Canada.

Éditeur officiel du Québec
Imprimé au Québec