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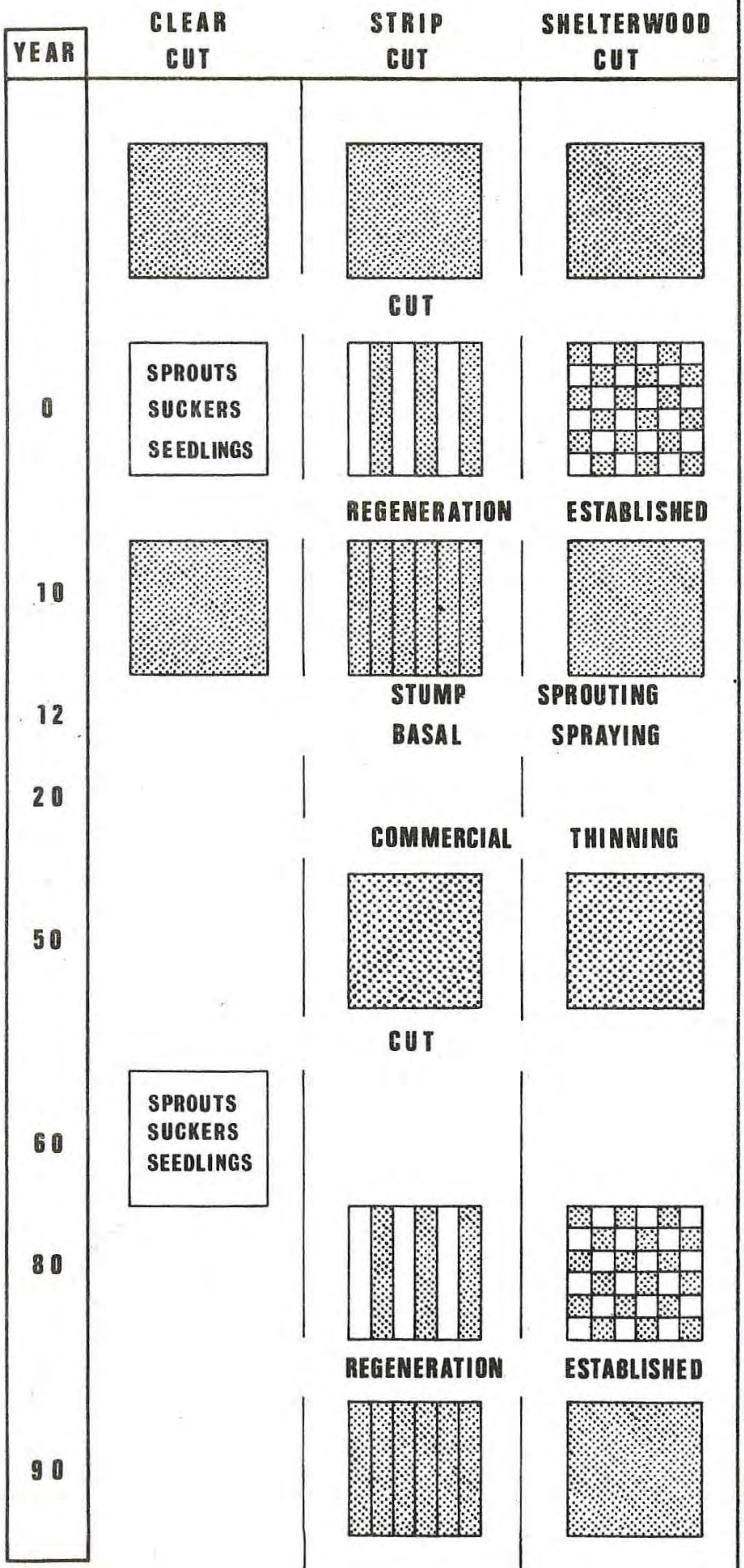

ECONOMIC ANALYSIS OF THREE SILVICULTURAL SYSTEMS USED IN THE MANAGEMENT OF TOLERANT HARDWOODS IN NOVA SCOTIA

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MARITIMES

CANADIAN FORESTRY SERVICE

MARITIMES FOREST RESEARCH CENTRE

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ABSTRACT

The purpose of this study was to evaluate costs and returns of three silvicultural systems for management of tolerant hardwoods in Nova Scotia. Two variations of clearcutting, stripcutting, and shelterwood cutting were compared. One clearcut variation included a noncommercial thinning while the other did not. Stripcutting alternatives included one with a 75% volume removal, (i.e., clearcut in alternate strips with a shelterwood cut in the leave strips); and one with a 50% volume removal. The shelterwood alternatives included one with 75% of volume cut and the other with 50%.

Yield, cost, and revenue data are mostly estimates, however, some information was available from recent cutting trials. The study includes sensitivity analyses of various assumptions. Discounting formulae and factors are included in the appendices to enable calculation of changes in results as new yield, cost, and revenue information becomes available.

Net present value (NPV) was used to compare results, however, nonfinancial impacts such as wildlife, water, and aesthetics are also identified for each system. On the basis of NPV, clearcutting without thinning was the best alternative followed by a shelterwood with 50% removal. The least desirable alternative was the stripcut with 50% of volume removed. However, clearcutting either with or without thinning, is expected to result in lower quality species, a smaller proportion of sawlog-size material, and possibly some erosion problems.

The sensitivity analyses show that results are influenced considerably by sawlog values and discount rates. Net present values were not very sensitive to assumptions about product mix i.e., proportion of sawlog yield to pulpwood or fuelwood.

RESUME

Le but de cette étude était d'évaluer les coûts et bénéfices de trois systèmes d'aménagement sylvicole des feuillus tolérants en Nouvelle-Ecosse. Deux variations de coupe rase, de coupe par bandes et de coupe progressive ont été comparées. Une variation de coupe rase comprenait une éclaircie non commerciale, contrairement à la deuxième. Les alternatives de coupe par bandes comprenaient une coupe prélevant 75% du volume, (c.à.d., coupe rase par bandes alternées avec coupe progressive dans les rideaux d'arbres et une autre prélevant 50% du volume). Les coupes progressives comportaient une coupe à 75% du volume et l'autre à 50%.

Les données sur le rendement, le coût et les bénéfices sont surtout des estimations; cependant, certains renseignements sur de récents essais de coupe étaient disponibles. L'étude inclut des analyses de sensibilité de diverses hypothèses. Des formules et facteurs d'escompte sont inclus en appendice pour aider à calculer les modifications dans les résultats, à mesure que des renseignements sur le rendement, le coût et le revenu nouveaux deviennent disponibles.

La valeur actuelle nette (VAN) a été utilisée pour comparer les résultats; cependant, les impacts non économiques comme la faune, l'eau et l'esthétique sont aussi identifiés dans chaque système. Sur la base de la VAN, la coupe rase sans éclaircie s'est avérée la meilleure alternative, suivie de la coupe progressive à 50% du volume. L'alternative la moins souhaitable a été la coupe par bandes, à 50% du volume. Cependant, la coupe rase, avec ou sans éclaircie, devrait résulter en des espèces de qualité inférieure, une proportion plus faible de grumes de sciage, et possiblement quelques problèmes d'érosion.

Les analyses de sensibilité montrent que les résultats sont influencés considérablement par la valeur des grumes de sciage et les taux d'escompte. Les valeurs actuelles nettes n'étaient pas très sensibles aux hypothèses concernant le mélange des produits, soit la proportion du rendement des billes de sciage au bois à pâte ou au bois de chauffage.

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I. INTRODUCTION

In the past few years there has been increasing interest in management of hardwoods in Nova Scotia. Inventory data and field observations reveal a decreasing proportion of high quality shade tolerant species such as yellow birch, (Betula alleghaniensis, Britton), white ash, (Fraxinus americana L.), and sugar maple, (Acer saccharum Marsh), and an increasing amount of low quality shade intolerant species such as red maple, (Acer rubrum L.), white birch, (Betula papyrifera Marsh.), and poplar (Populus sp.). This appears to be the result of clearcutting which encourages stump sprouting and root suckering of the aggressive pioneer species.

Results of work done elsewhere, particularly in the northeastern United States, indicate that partial cutting either in alternate strips or uniform and strip shelterwood can be used to encourage regeneration of the more valuable shade tolerant species. There are additional costs in partial cutting when compared to clearcutting. Strip and shelterwood systems are generally two-stage harvesting operations - the initial cut and a subsequent cut (maybe 10 years later) of the leave strips and residual trees. Because only some of the trees are removed initially, unit costs are high due to a smaller cut volume and the additional time required to select and skid trees to roadside. Unit product values are often higher. Emphasis of partial cutting is on higher quality species (yellow birch, ash, sugar maple) and improved quality within species through larger stem diameters, fewer branches, and straighter form.

Recently, the Hardwoods Working Group of the Nova Scotia Forest Research Committee identified the need for economic analysis of alternatives to present silvicultural practices. The Working Group was specifically concerned with a framework for analysis which would identify the sorts of data required and enable comparison of other alternatives. The problems were: What are the costs and benefits of silvicultural systems such as clearcutting, alternate stripcutting, and shelterwood cutting? And, what is a suitable approach or framework for comparing the alternatives? Because recent and valid empirical data are limited at present, a further question was - How could the analytical approach be designed to facilitate re-evaluation of alternatives as new data become available?

II. PROCEDURE

A. Stand Characteristics

To identify probable effects of various alternative systems and to draw meaningful conclusions, a typical hardwood stand was identified as having the following characteristics:- 30 acres in area; most trees are shade tolerant species such as yellow birch, sugar maple, and ash but mixed with red maple, white birch, and poplar; approximately 30 cords per acre (merchantable volume); average diameter of 7 inches; and average age of 70 years. Stands with these characteristics are common in the western part of the Province.

B. Alternative Systems and Treatments

Two variations of three silvicultural systems, clearcutting, alternate stripcutting, and shelterwood cutting were selected for comparison. The schedule of treatments is illustrated in Fig. 1, and is based on what was considered to be appropriate for each system.

1. Clearcut - The clearcut was used as a standard against which the effectiveness of the alternate treatments could be compared. It is the least costly logging system and will

yield the highest immediate harvest return. However, since a clearcut is favorable to shade intolerant species and to stump sprout regeneration it is unlikely that tolerant species will regenerate adequately.

The two variations of the clearcut are: Clearcut 1 (CC1) has an interim noncommercial thinning at year 20, while clearcut 2 (CC2) has no interim thinning (Fig. 1). Apart from this difference, the two clearcuts progress from an initial harvest of 100% at year 0, to a final rotation harvest of 100% at year 60.

2. Alternate Stripcut - The stripcut method is generally more costly than the clearcut and will yield a lower immediate harvest return. However, this method is likely to contribute substantially more to the desired regeneration. The stripcut treatment will provide intermittent returns as the leave strips are cut. With shade and a seed source provided by the leave strips during the regeneration period, the regeneration should have a higher proportion of intermediate and tolerant species of increased value, with a higher average dbh, a lower number of stems, and fewer sprouts than the clearcut.

Variations of this method include: Stripcut 1 (SC1) - 50% of the stand basal area is cut in alternate strips with an additional 50% shelterwood cut in the leave strips, for a total initial harvest of 75% of stand basal area at year 0. The cut and leave strips are assumed to be 66 ft wide.

Stripcut 2 (SC2) - 50% of stand basal area is cut in alternate strips but without a shelterwood harvest in the leave strips. The cut and leave strips are as in SC1. In both cases, the residual strips are cut in year 10 by which time regeneration should be established. Basal spraying for sprout management is applied in both treatments at year 12 and they are commercially thinned at the same intensity in year 50. At year 80, the sequence begins again (Fig. 1).

3. Shelterwood Cut - The shelterwood method, like the stripcut, is costlier than the clearcut, will yield a lower immediate harvest return, and also is likely to contribute substantially more to the desired regeneration. The two-cut shelterwood treatment will provide intermittent returns when the overstory is cut. With shade and a seed source provided by the overstory during the regeneration period, the regeneration should have a higher proportion of intermediate and shade tolerant species of increased value, with a higher average dbh, a lower number of stems, and fewer sprouts than is the case with repeated clearcutting.

Two intensities of shelterwood removal are compared. In year 0, 75% of the basal area in shelterwood 1 (SW1) and 50% of the basal area in shelterwood 2 (SW2) are cut, as the initial harvest. Thereafter, both treatments are the same. The residual overstory is removed in year 10, by which time regeneration should be established; a basal spray for stump sprouts control is applied at year 12; and, a commercial thinning at the same intensity as in the stripcuts in year 50. The sequence begins again at year 80.

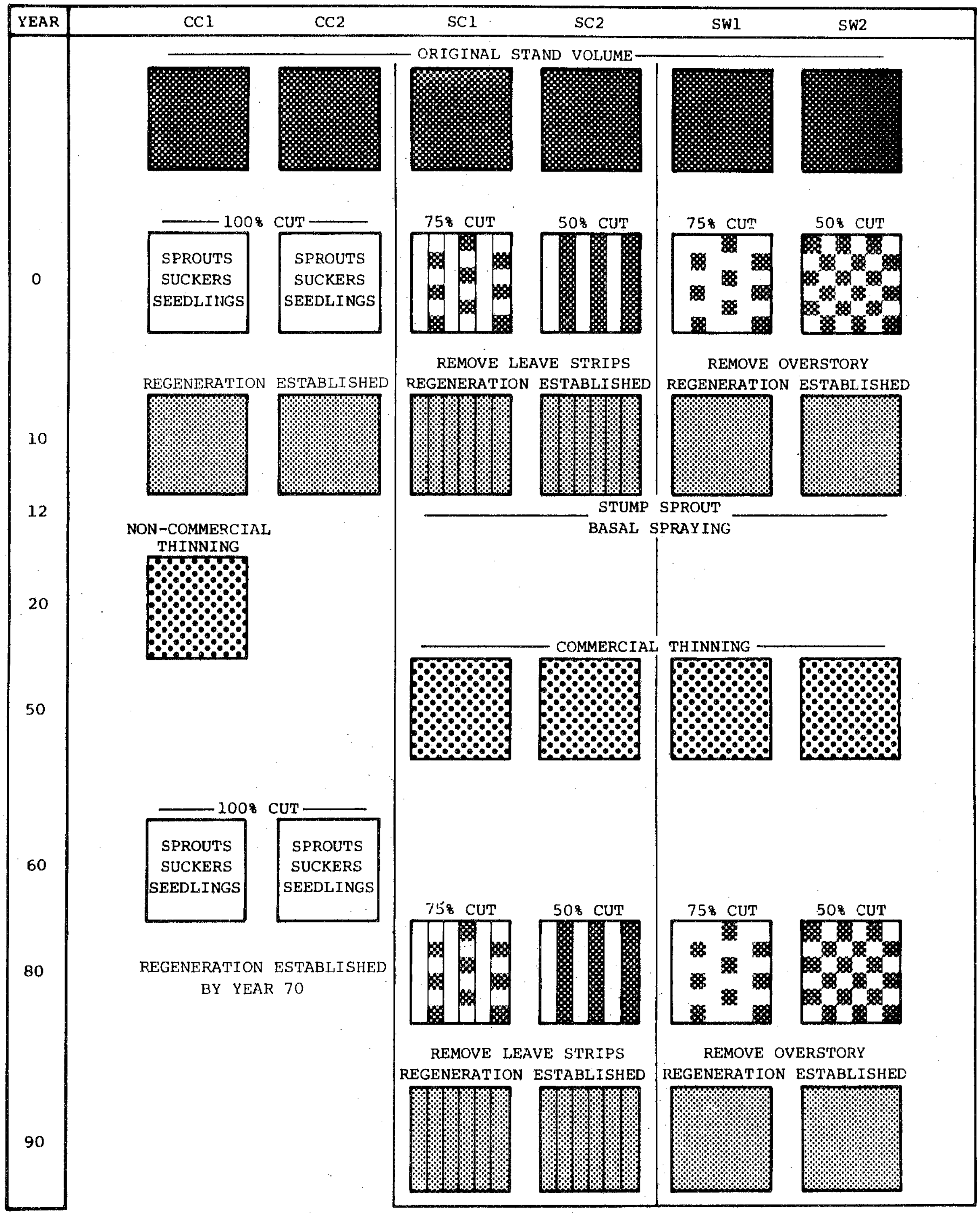
C. Assumptions

To keep the evaluation at a workable scale and to avoid complications arising from factors outside the present scope of this report, several assumptions are made to simplify the analysis.

1) The present evaluation is strictly a comparison of costs and returns from the identified alternate harvesting treatments; i.e., no attempt is being made to arrive at the optimal use of the land. For this reason, it is assumed that any forest stand to which the analysis is applied will remain in use as forest land. This precludes the necessity

FIGURE 1

SCHEDULE OF TREATMENTS



of relating the forest investment to an alternate rate of return on the land.

2) It is assumed that there will be a continuing demand for the product output from these forest stands, and that there is a commitment to provide this output. Accordingly, the relevant evaluation criteria for the prescriptions are the relative profitabilities among alternative treatments rather than the absolute profitability of each.

3) Because an extended time period is involved, many uncertainties arise over the life periods of the projects being evaluated. For example, forest management policies may change; demand for forest products may shift, both in terms of amount and product mix; the particular interest rate being applied may become irrelevant; and the relative real prices of forest products may change. For this reason, some sensitivity analysis is applied to the evaluation by assuming varying levels for the relevant parameters. Since, however, it is difficult to predict policy changes or demand over long periods this sensitivity analysis is directed only at the interest rate, physical output, (i.e., product), and price estimates.

4) It is assumed, in accordance with Federal Treasury Board guidelines for benefit-cost analysis, that inflation will affect revenues and costs, proportionately. Since shifts in relative prices are accounted for here explicitly, all values will be expressed in "real" terms, holding the general price level constant.

5) Three primary outputs are assumed to be generated from the forest stands: fibre, firewood, and sawlogs. Current local market conditions dictate that sawlogs command the highest price, followed by firewood, then fibre. There is, however, a commitment to provide all three outputs.

6) Because there are widespread opinions as to which discount rate is the "correct" one to apply in making forest investment decisions, a number of scenarios will be provided applying a low, most probable, and high rate to the calculations, and indicating any net changes in the results. For present purposes, a 10% interest rate has been chosen as the most probable rate.

7) The alternatives being evaluated have varying planning horizons; (e.g., the clearcut has a rotation period of 60 years, the others, 80-90 years). Evaluation among alternatives must be based on comparable time periods unless some assumption is made about the reinvestment of funds released at the end of the shorter investment. It is assumed that the rate applied to these reinvested funds will be the same as the discount rate used. The net result of the assumption, on present value calculations, will remain unaffected.

8) Labor costs are expressed in the form of estimated contract rates, so that the quality of inputs will be nearly homogeneous across alternatives. Also, the rates are cited "at roadside", to avoid complications arising from varying transportation rates. Variation in harvest costs is, however, recognized among treatments to reflect, i) the degree of difficulty according to the extent of partial cut, and ii) lower harvest costs in improved stands.

9) For the sake of simplicity, it is assumed that the fixed costs among the identified alternate treatments are comparable. This assumption may be relaxed at a later stage to identify the sensitivity of the results to different fixed costs; notably, the costs of road construction and maintenance.

10) There are various intangible costs and benefits involved in any investment in natural resources.

Although some of the relevant intangibles are identified, because of the complexity involved in their assessment, no attempt is being made to quantify these factors.

11) Risk and uncertainty play a significant role in any investment decision over an extended period, particularly for natural resures. While these factors are not explicitly accounted for here, they will be implicitly recognized by undertaking reiterations of the calculations with high and low estimates of values, thereby establishing a range of values within which some degree of risk and uncertainty can be allowed.

D. Criteria

As indicated earlier the criterion used for comparing alternatives is net present value (NPV). Because costs and revenues occur at different times, a discounting procedure is used to determine values at a common point in time - namely the present. Other criteria such as benefit-cost ratio, internal rate of return, or cost effectiveness could have been used but given the nature of alternatives and objectives, NPV was felt to the most applicable.

The data shown in Tables 1-3 are most probable values - that is, best estimates. It was recognized that actual yield, costs, and prices might be different. Therefore, a range of values was identified for some parameters. These include proportion of cordwood to sawlog quality material, sawlog prices, and discount rates. Results of these assumptions are shown in the sensitivity analysis.

Table 1. Estimated yield, costs, and prices: clearcut treatments. Present stand conditions: 30 cds/acre; 30 acres; $\bar{D}$ = 7 inches; age 70 years

Year	Variable	Clearcut 1 (CC1) (with thinning)	Clearcut 2 (CC2) (without thinning)
0	Yield (cds)[a]	30	30
	Roadside cost ($/cd)	19	19
	Roadside value (fuel - $/cd)	25	25
	Roadside value (fibre - $/cd)	20	20
20	Noncommercial thinning cost ($/ac)	140	-
60	Yield (cds)[a]	23	27
	Yield (Mfbm)	2	-
	Roadside cost ($/cd)	17	19
	Roadside cost ($/Mfbm)	50	-
	Roadside value (fuel - $/cd)	25	25
	Roadside value (fibre - $/cd)	20	20
	Roadside value ($/Mfbm)	150	-

[a] All values are on a per acre basis. It is assumed that 15% of the cord yield is sold as firewood and the remaining 85% for fibre products, e.g. hardboard.

Table 2. Estimated yield, costs, and prices: stripcut treatments. Present stand conditions: 30 cds/acre; 30 acres; $\bar{D}$ = 7 inches; age 70 years

Year	Variable	Stripcut 1 (SC1) (75% cut)	Stripcut 2 (SC2) (50% cut)
0	Yield (cds)[a]	22	15
	Roadside cost ($/cd)	22	21
	Roadside value (fuel - $/cd)	25	25
	Roadside value (fibre - $/cd)	20	20
10	Yield (cds)[a]	10	15
	Yield (Mfbm)	2	1
	Roadside cost ($/cd)	21	21
	Roadside cost ($/Mfbm)	50	50
	Roadside value (fuel - $/cd)	25	25
	Roadside value (fibre - $/cd)	20	20
	Roadside value ($/Mfbm)	150	150
12	Basal spraying ($/ac)	50	50
50	Yield (cds)[a]	12	12
	Roadside cost ($/cd)	25	25
	Roadside value (fuel - $/cd)	25	25
	Roadside value (fibre - $/cd)	20	20
80	Yield (cds)[a]	10	7
	Yield (Mfbm)	6	5
	Roadside cost ($/cd)	18	18
	Roadside cost ($/Mfbm)	50	50
	Roadside value (fuel - $/cd)	25	25
	Roadside value (fibre - $/cd)	20	20
	Roadside value ($/Mfbm)	150	150
90	Yield (cds)[a]	3	4
	Yield (Mfbm)	4	5
	Roadside cost ($/cd)	18	18
	Roadside cost ($/Mfbm)	50	50
	Roadside value (fuel - $/cd)	25	25
	Roadside value (fibre - $/cd)	20	20
	Roadside value ($/Mfbm)	150	150

[a] All values are on a per acre basis. It is assumed that 15% of the cord yield is sold as firewood and the remaining 85% for fibre products, e.g., hardboard.

Table 3. Estimated yield, costs, and prices: shelterwood treatments. Present stand conditions: 30 cds/acre; 30 acres; $\bar{D}$ = 7 inches; age 70 years

Year	Variable	Shelterwood 1 (SW1) (75% cut)	Shelterwood 2 (SW2) (50% cut)
0	Yield (cds)[a]	22	15
	Roadside cost ($/cd)	24	25
	Roadside value (fuel - $/cd)	25	25
	Roadside value (fibre - $/cd)	20	20
10	Yield (cds)[a]	10	20
	Yield (Mfbm)	3	3
	Roadside cost ($/cd)	22	20
	Roadside cost ($/Mfbm)	50	50
	Roadside value (fuel - $/cd)	25	25
	Roadside value (fibre - $/cd)	20	20
	Roadside value ($/Mfbm)	150	150
12	Basal spraying ($/ac)	50	50
50	Yield (cds)[a]	12	12
	Roadside cost ($/cd)	25	25
	Roadside value (fuel - $/cd)	25	25
	Roadside value (fibre - $/cd)	20	20
80	Yield (cds)[a]	10	7
	Yield (Mfbm)	6	5
	Roadside cost ($/cd)	20	21
	Roadside cost ($/Mfbm)	50	50
	Roadside value (fuel - $/cd)	25	25
	Roadside value (fibre - $/cd)	20	20
	Roadside value ($/Mfbm)	150	150
90	Yield (cds)[a]	3	6
	Yield (Mfbm)	4	8
	Roadside cost ($/cd)	19	17
	Roadside cost ($/Mfbm)	50	50
	Roadside value (fuel - $/cd)	25	25
	Roadside value (fibre - $/cd)	20	20
	Roadside value ($/Mfbm)	150	150

[a] All values are on a per acre basis. It is assumed that 15% of the cord yield is sold as firewood and the remaining 85% for fibre products, e.g., hardboard.

Finally, in most economic analyses there are a variety of costs and benefits that cannot be quantified and valued. These include effects on wildlife, aesthetics, and water. Benefits resulting from species diversification such as effects on soil fertility, decreased susceptibility to insects and disease, and increased options for manufacturing are difficult to determine and measure. These effects are considered in the section on nonmonetary impacts.

E. Data Collection

Some operational data were available from recent practical trials set up by the Department of Lands and Forests. This was limited to initial harvest yields, unit harvest costs, and product prices. Empirical data on subsequent yields, costs, and prices (years 10, 12, 50, 80) are not available. For the most part, information presented below are best estimates. The sensitivity analyses show how results are affected by changing estimates.

Probable values for the various systems and treatments are presented in Tables 1-3. Most data are relatively straightforward, however, some differences should be recognized and are described as follows. The distinction between CC1 and CC2 is the noncommercial thinning. In CC1, about 350-400 trees per acre were cut resulting in log volumes of 2 Mfbm/acre at rotation over and above the pulpwood cord yield; no sawlogs were expected from CC2. Reduced yields for both clearcuts are projected because it is felt that repeated clearcutting will result in considerably more stump-sprouting and a lower volume yield at the rotation age of 60. A lower unit roadside cost for cordwood is expected because of improved stand conditions resulting from the thinning. Also, at initial harvest, a lower unit cost is attached to the clearcuts than to either the stripcut or shelterwood treatments.

The two stripcut treatments are differentiated by attaching a slightly higher unit cost to SC1, in which a shelterwood cutting is applied in the residual strips (Table 2). The cost of basal spraying at year 12, and the costs and returns for the commercial thinnings at year 50 are common to both stripcut treatments and both shelterwood treatments. Unit harvest costs in years 80 and 90 are lower than at initial harvest in both cases, reflecting the lower costs of operating in an improved stand. In both cases, the yield of higher valued sawlogs is significantly greater at rotation than at initial harvest, reflecting a quality growth response to the stripcut treatment. As a result of the supplementary shelterwood cutting in SC1, a portion of the returns from SC1 is realized 10 years earlier than in SC2. Although unit costs at initial harvest for the stripcuts exceed those for the clearcuts, they are lower than those for either of the shelterwood treatments.

The shelterwood treatments differ in intensity of the harvest cut (Table 3). In SW1, 50% of the volume is removed and in SW2, 75%. Roadside costs for various harvests reflect differences in volume removed. Yield at year 10 for SW2 is considerably higher than for SW1 because of the lower initial harvest and expected response to that level of cut. Intermediate treatments and costs for both SW1 and SW2 are the same.

III. RESULTS AND DISCUSSION

A. Most Probable Values

Results of the analysis based on most probable estimates (data presented in Tables 1-3 and using a 10% discount rate) are shown in Table 4. As indicated in the table, CC2 (with-

Table 4. Net present values for alternative silvicultural systems and treatments - most probable estimates

System/treatment	Net present value $/acre (discount rate = 10%)
Clearcut	
CC1 - with thinning	33.13
CC2 - without thinning	53.15*
Alternate Stripcut	
SC1 - 75% cut	33.37
SC2 - 50% cut	17.00
Shelterwood	
SW1 - 75% cut	24.06
SW2 - 50% cut	41.49

* Indicates treatment with highest NPV.

out thinning) is the most financially attractive of the six options. This is followed in order of importance by SW2, SC1, CC1, SW1 and SC2.

The principal reasons for this ranking appear to be as follows. Returns from CC2 occur early in the rotation cycle and costs are minimal. NPV in CC1 is considerably lower than in CC2 because the results of noncommercial thinning are not sufficient to cover the $140/acre thinning cost at year 20. Although some sawlog quality material is produced in CC1 (and not in CC2), their higher value (which is not realized until year 60) is not sufficient to compensate for costs.

NPV for SC1 is about twice that for SC2. In this case, the additional cost per cord of the shelterwood removal in the leave strips is justified by the additional early yields. Also, an implicit assumption in this comparison is that competition among stems in the residual strips of SC2 will, to some extent, inhibit growth.

Of the two shelterwood treatments, SW2 results in a substantially higher NPV than SW1. The slightly higher per unit harvesting and skidding costs due to the lower intensity cut (50%) are offset by the increased yield at year 10.

In summary, the best alternative based strictly on NPV, is the clearcut without a thinning (CC2). This is closely followed by the shelterwood treatment with 50% of basal area removed (SW2). The least desirable alternative is the alternate stripcut (SC2) in which 50% of basal area is removed.

B. Sensitivity Analyses

It is apparent from the foregoing data and results that minor differences in values such as per unit cost, yields, and so on, have a considerable effect on NPV. Because empirical data are not available for many of these values a best estimate was given. To determine how critical some of these estimates were, a range of values was selected for several variables and the NPV's were recalculated. The variables considered for sensitivity analysis were the discount rate, sawlog-cordwood output mix, and sawlog values.

1. Sensitivity to Discount Rate - As stated in the assumptions, there is wide difference of opinion on what is the appropriate rate. The 10% rate was chosen for the initial calculation because this is the most probable rate and the one suggested by the Federal Treasury Board in benefit-cost analysis (Canada, Treasury Board Secretariat 1976). Ultimately, however, the appropriate rate depends on the decision maker because it reflects his tradeoff of present income for future benefits. A higher rate means that he is more interested in immediate or early benefits while a lower rate implies that he is more willing to sacrifice now for future benefits.

To determine sensitivity to different rates, NPV's were calculated using 8 and 12%. The results are shown in Table 5. For comparison, figures using the 10% rate are also shown. All yields, costs, and prices remained as given in Tables 1-3.

At the lower rate (8%) the stripcut and shelterwood treatments become more attractive. This is because lower rates do not "discount" future yields as much, rather, they favor longer rotations, while the higher rates make shorter rotations and earlier returns more attractive.

2. Sensitivity to Product Mix - A major reason for undertaking partial cutting is to improve quality of output - both species and size. It is expected that shelterwood treatments and to some extent stripcuts will increase the proportion of sawlog material. The amount is not known. NPV's were calculated for two additional estimates of the cordwood-sawlog output (Table 6). This was done only for the strip and shelterwood treatments and it was assumed that differences would occur only at year 80. In other words, a high estimate (high proportion of sawlogs relative to cordwood) and a low estimate were compared to the most probable value shown in Tables 2-3. Other unit cost and price information remained the same. The discount rate used is 10%.

Table 7 shows that NPV results are not very sensitive to assumptions about product yield over the long term. Even with a high proportion of sawlogs to cordwood, the CC2 alternative yields the highest NPV. Apparently, because benefits from a higher proportion of sawlogs are not realized until year 80, their discounted value is not significant. This can be seen by comparing NPV's for SW2. Though the sawlog volume for the high estimate is more than twice that for the low estimate (7 Mfbm compared to 3 Mfbm) the NPV difference is only $.19 ($41.59 compared to $41.40). This is partially offset by the differences in cordwood yield.

3. Sensitivity to Sawlog Value - The final sensitivity analysis was done on sawlog values. The most probable value used earlier was $150/Mfbm (roadside value). To compare effects on NPV, a high estimate of $200/Mfbm and a low estimate of $100/Mfbm were also compared (Table 8). Assuming the high estimate ($200/Mfbm roadside) the best treatment is SW2 followed by SW1 and SC1. If sawlog value is $150/Mfbm, the best treatment is CC2 followed by SW2. Using the low sawlog value of $100/Mfbm, CC2 is still the best but is followed by CC1. Negative NPV's simply indicate that investment in these treatments yields returns of less than 10%. Further analysis shows that a sawlog value of $160-165/Mfbm would make the CC2 and SW2 about equally attractive in terms of NPV.

Table 5. Sensitivity of net present value (NPV) to discount rate

System/treatment	Net present value - $/acre discount rate 8%	10%	12%
Clearcut			
CC1 - with thinning	25.97	33.13	38.81
CC2 - without thinning	53.46	53.15*	53.05*
Alternate Stripcut			
SC1 - 75% cut	45.49	33.37	23.84
SC2 - 50% cut	21.12	17.00	14.02
Shelterwood			
SW1 - 75% cut	43.13	24.06	8.83
SW2 - 50% cut	62.82*	41.49	24.50

* Indicates treatment with highest NPV.

Table 6. Alternate estimates for cordwood-sawlog mix for stripcut and shelterwood treatments

System/treatment	Yield at year 80 - per acre		
	High	Probable	Low
SC1 - 75% cut			
cordwood (cds)	6	10	14
sawlogs (Mfbm)	8	6	4
SC2 - 50% cut			
cordwood (cds)	3	7	11
sawlogs (Mfbm)	7	5	3
SW1 - 75% cut			
cordwood (cds)	6	10	14
sawlogs (Mfbm)	8	6	4
SW2 - 50% cut			
cordwood (cds)	3	7	11
sawlogs (Mfbm)	7	5	3

Table 7. Sensitivity of net present value to cordwood-sawlog mix for various systems and treatments

System/treatment	Net present value[a] $/acre Product yield estimate		
	High	Probable	Low
Clearcut[b]			
CC1 - with thinning	33.13	33.13	33.13
CC2 - without thinning	53.15*	53.15*	53.15*
Alternate stripcut			
SC1 - 75% cut	33.46	33.37	33.28
SC2 - 50% cut	17.10	17.00	16.85
Shelterwood cut			
SW1 - 75% cut	24.15	24.06	23.96
SW2 - 50% cut	41.59	41.49	41.40

[a] Discount rate = 10%.

[b] Values do not change since product yield estimate does not change.

* Indicates treatment with highest NPV.

Table 8. Sensitivity of net present value to sawlog value for alternative system and treatments

System/treatment	Net present value[a] $/acre sawlog value $/Mfbm		
	High ($200)	Probable ($150)	Low ($100)
Clearcut			
CC1 - with thinning	33.46	33.13	32.80
CC2 - without thinning	53.15	53.15*	53.15*
Alternate stripcut			
SC1 - 75% cut	72.11	33.37	-5.38
SC2 - 50% cut	36.45	17.00	-2.44
Shelterwood cut			
SW1 - 75% cut	82.07	24.06	-33.97
SW2 - 50% cut	99.52*	41.49	-16.55

[a] Discount rate = 10% and values for other variables are the most probable.

* Indicates treatment with highest NPV.

In summary, results are sensitive to the discount rates and sawlog values. At higher discount rates, the clearcut treatments are more attractive, while at lower rates, shelterwood and alternate strip-cutting become more feasible. Benefits from these latter treatments do not accrue for some time into the future. They are "discounted" more at higher rates, and become lower than benefits accruing in the short term. Sawlog values are critical. If roadside values are about $160-165/Mfbm, the shelterwood treatments become feasible. Results are not very sensitive to assumptions about product mix - at least over the range analysed here. Because benefits do not show up until year 80, the difference would have to be large to have any appreciable effect on NPV.

C. Nonmonetary Impacts

In addition to financial impacts, there are many effects resulting from the various treatments that are difficult to quantify or value. These effects are summarized in Table 9. Beneficial effects of the shelterwood system outweigh those of the stripcut and the clearcut. The forest manager must decide which of these impacts should be considered and their importance relative to monetary returns.

Table 9. Nonmonetary impacts of various systems

Area of impact	System		
	Clearcut	Stripcut	Shelterwood cut
Stand quality maintenance	Difficult, extensive planting required	Not difficult, some planting may be required	No planting required
Product utilization potential	Few options	Some options	Several options
Wildlife habitat	Good for big game and small birds	Excellent for wildlife	Good during regeneration but not too good later
Forest aesthetics	Generally not aesthetically pleasing - but depends on size and shape of cut	Limited adverse aesthetic effects depending on alignment and size of strip	No adverse aesthetic effect of cutting as stands remain uniform
Watershed management/erosion control	May have detrimental effects	May be but unlikely to have detrimental effects	No problems

IV. SUMMARY AND CONCLUSIONS

A framework was developed to compare the costs and returns associated with six silvicultural treatments for hardwood management. The alternatives were two variations, each, of clearcutting, alternate stripcutting, and two-cut shelterwood systems. The clearcut operations were used as a standard against which to measure the effectiveness of the additional time and expense required for the other silvicultural treatments. The analysis consisted of net present value comparisons. A sensitivity analysis was undertaken to determine the effects of several assumptions, including product price and discount rates, on net present value.

In most instances, the alternatives were found to yield positive net present values. On the basis of monetary costs and returns, the straight-forward clearcut (treatment CC2), and the 50% shelterwood cut (treatment SW2), were found to contribute the most to net present value. The clearcut treatment (CC2) was the most financially attractive option using the "most probable" values of yield and value estimates and a 10% interest rate. However, NPV for CC2 was not substantially higher than for SW2 (50% cut). Discount rates and sawlog values are quite critical; it was found that at an 8% rate or a sawlog value of $160-165/Mfbm roadside, SW2 was more attractive than the other assumptions. Consideration of other effects shows that there are several nonmonetary costs associated with clearcutting, i.e., costs of maintaining stand quality, aesthetics, product utilization potential which may favor the alternative treatments despite the higher financial outlay.

Several implicit assumptions have been made in this study which have not been discussed and which should be examined further. These include:

1) The present value determinations were initially conducted using a 10% discount rate as an approximation of the market rate. Subsequently, the calculations were reiterated using an 8% rate to reflect a "conservation weighting", and a 12% rate to reflect a "risk-aversion weighting". No decision was made, however, as to which rate is most appropriate. It is suggested that such a decision should be made at the policy-making level, and should be at a rate consistent with similar resource investments. Discussion of some of the advantages and disadvantages of high and low discount rates can be found in Price (1967) and Webster and Gordon (1975).

2) The cost estimations in this report are based on chainsaw felling operations. No examination was made of more capital intensive approaches. Ketcheson (1975), discusses some general economic implications of mechanization in silviculture. Mattice and Curtis (1978), investigated commercial strip thinning with a tree-length harvester, and Biltonen _et al_. (1976), discussed fully mechanized thinning.

3) A simplification was made in the analysis, citing no significant variation in fixed costs among the identified alternatives. In reality, this assumption may require modification, particularly with variations in the costs of road construction and maintenance. An analysis of such costs associated with stripcutting can be found in Ketcheson (1977).

4) The estimates of product values are cited as "typical" values, and include a common unit stumpage levy for each product. Over time or from place to place, variations in stumpage appraisal and variations in methods of levying stumpage value may yield values significantly different from these "typical" ones. Some

considerations in this regard are discussed in Nautiyal and Love (1971), and Worley (1962).

5) The harvest-silviculture treatments discussed here and the associated yield responses are based on natural regeneration. Artificial regeneration, planting, and seeding practices particularly regarding hardwoods, are still uncertain prospects which may or may not satisfy cost-effectiveness criterion. Studies that examine these areas include: von Althen (1969 and 1970), who discusses hardwood plantations and reforestation and some implications regarding utilization; Marquis (1973), who examines the effects of tree improvement, and Brett and Benskin (1968), who discuss fertilization and intensive management for softwoods, some principles of which may have applications in the management of hardwoods.

6) Some nonmonetary benefits and costs associated with the alternative harvest treatments were identified. No attempt was made, however, to quantify these factors. This does not imply that they are trivial or insignificant; rather, that the issue is complex and the assessment of these values requires subjective evaluations specific to each individual situation, as well as subjective weighting of their importance relative to the accompanying monetary costs and returns. Maniate and Carter (1973b) developed a general methodology for assessing these benefits and Smyth and Methven (1978) looked specifically at quantifying the aesthetic impact of an improvement cut in pine mixedwoods.

7) The framework used in this study is suitable for a small number of variables and iterations. To undertake the analysis for a larger number of variables and more rigorous sensitivity analysis, it is suggested that the framework provided here be adapted to a computerized methodology. Past efforts which may have applications in developing such a methodology, include those of Payendeh and Field (1978), Solomon (1977), and Chappelle (1969).

The final conclusions are:

a) Clearcut operations. In general, interim noncommercial thinning on clearcuts do not yield sufficient improvement in quality yield to warrant the cost.

b) Alternate stripcut. A supplementary shelterwood removal from the residual strips appears to be financially justified.

c) Shelterwood cuts. A lower intensity cut (50%) appears to be better than the higher intensity (75%).

d) Comparative effectiveness of alternatives. It is evident that high discount rates favor the clearcutting operations because of early returns. Lower discount rates favor operations which do not yield benefits for some time into the future, such as stripcut and shelterwood operations. These latter treatments offer considerably more options in that there is more variation in species and quality than in clearcut operations.

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VI. APPENDICES

A. Calculations of Net Present Values

In this study, net present value is used as the criterion to compare effectiveness of the various treatments or alternatives. The following examples and table are presented to show how the values are calculated and to enable the reader to determine the effects of other assumptions or of new data. For example, what is the effect of a higher cost of basal spraying or thinning? What if sawlog prices were higher?

Present values of costs and revenue are calculated from the formula:

$$PV_c \text{ or } PV_r = FV \left[\frac{1}{(1+i)^n}\right]$$

where: PV_c = present value of costs

PV_r = present value of revenues

FV = future value of costs or revenues

i = interest or discount rate

n = number of years the costs or revenues are discounted.

$\left[\frac{1}{(1+i)^n}\right]$ = multiplier = present value of $1.00 discounted for n years at interest rate i (values shown in table)

<u>Example 1</u>: The present value of noncommercial thinning cost (PV_c) of $100/acre occurring at year 20 discounted at 6%.

$$PV_c = FV \left[\frac{1}{(1+i)^n}\right] = 100 \left[\frac{1}{(1.06)^{20}}\right] = 100\ [.31180]$$

$$= \$31.18/\text{acre}$$

<u>Example 2</u>: The present value of harvest yield of $500 at year 60 discounted at 10%.

$$PV_r = FV \left[\frac{1}{(1+i)^n}\right] = 500 \left[\frac{1}{(1.10)^{60}}\right] = 500\ [.00328]$$

$$= \underline{\$1.64}$$

<u>Example 3</u>: Net present value of a treatment or alternative with revenues and costs as shown below using a discount rate of 6%.

Year	Costs ($)	Revenues
0	400	400
20	100	-
50	-	500
80	-	1000

$$PV_c = 400 \left[\frac{1}{(1.06)^0}\right] + 100 \left[\frac{1}{(1.06)^{20}}\right]$$

$$= 400\ [1] + 100\ [.31180]$$

$$= 400 + 31.18 = \underline{\$431.18}$$

$$PV_r = 400 \left[\frac{1}{(1.06)^0}\right] + 500 \left[\frac{1}{(1.06)^{50}}\right] + 1000 \left[\frac{1}{(1.06)^{80}}\right]$$

$$= 400\ [1] + 500\ [.05429] + 1000\ [.00945]$$

$$= 400 + 27.15 + 9.45 = \underline{\$436.60}$$

$$\text{Net present value} = PV_r - PV_c$$

$$= 436.60 - 431.18$$

$$= \underline{\$5.42}$$

Example 4: Net present value of a treatment with costs and revenues as shown in Example 3 but using a discount rate of 12%.

$$PV_c = 400 \left[\frac{1}{(1.12)^0}\right] + 100 \left[\frac{1}{(1.12)^{20}}\right]$$

$$= 400\ [1] + 100\ [.10367]$$

$$+ 400 + 10.37 = \underline{\$410.37}$$

$$PV_r = 400 \left[\frac{1}{(1.12)^0}\right] + 500 \left[\frac{1}{(1.12)^{50}}\right] + 1000 \left[\frac{1}{(1.12)^{80}}\right]$$

$$= 400\ [1] + 500\ [.00346] + 1000\ [.00012]$$

$$= 400 + 1.73 + .12 = \underline{\$401.85}$$

Net present Value = \$401.85 - 410.37

= \$ -8.52

Examples 3 and 4, show the sensitivity of net present values to discount rates. A negative value simply indicates that this treatment is not yielding a rate of return of 12% but something less. In this case, we know that NPV was positive at 10% but negative at 12%, the actual rate of return is between the two rates.

B. Table of Discounted Single Payment Multipliers

Discounted single payment multiplier - Value of one dollar discounted for n years for selected interest rates $\frac{1}{(1+i)^n}$

Year (n)	interest rate (i) .06	.08	.10	.12	.14
1	.94340	.92593	.90909	.89286	.87719
2	.89000	.85734	.82645	.79719	.76947
3	.83962	.79383	.75131	.71178	.67497
4	.79209	.73503	.68301	.63552	.59208
5	.74726	.68058	.62092	.56743	.51937
6	.70496	.63017	.56447	.50663	.45559
7	.66506	.58349	.51316	.45235	.39964
8	.62741	.54027	.46641	.40388	.35056
9	.59190	.50025	.42410	.36061	.30751
10	.55839	.46319	.38554	.32197	.26974
11	.52679	.42888	.35049	.28748	.23662
12	.49697	.39711	.31863	.25668	.20756
13	.46884	.36770	.28966	.22917	.18207
14	.44230	.34046	.26333	.20462	.15971
15	.41727	.31524	.23939	.18270	.14010
16	.39365	.29189	.21763	.16312	.12289
17	.37136	.27027	.19784	.14564	.10780
18	.35034	.25025	.17986	.13004	.09456
19	.33051	.23171	.16351	.11611	.0829
20	.31180	.21455	.14864	.10357	.0727
25	.23300	.14602	.09230	.05882	.03779
30	.17411	.09938	.05731	.03338	.01963
35	.13011	.06763	.03558	.01894	.01019
40	.09722	.04603	.02209	.01075	.00529
45	.07265	.03133	.01372	.00610	.00275
50	.05429	.02132	.00852	.00346	.00143
55	.04057	.01451	.00529	.00196	.00074
60	.03031	.00988	.00328	.00111	.00039
65	.02265	.00672	.00204	.00063	.00020
70	.01693	.00457	.00127	.00036	.00010
75	.01265	.00311	.00079	.00020	.00005
80	.00945	.00212	.00049	.00012	.00003
85	.00706	.00144	.00030	.00007	.00001
90	.00528	.00098	.00019	.00004	.00001
95	.00394	.00067	.00012	.00002	.00000
100	.00295	.00045	.00007	.00001	.00000

Source: Lundgren, A.L. 1971. Tables of compound - discount interest rate multipliers for evaluating forestry investments. USDA, For. Serv., North Central For. Exp. Sta., Res. Pap. NC-51.