Comparative Analysis of Harvesting and Siliviculture Costs Following Integrated Harvesting

P. Zundel, and L. Lebel[1]
Université de Moncton
Edmunston, Canada

ABSTRACT

This paper presents a hypothetical case in which the positive and negative impacts of intensive forest harvesting (using the full tree method rather than the shortwood method) are evaluated over the long term using financial criteria. The full tree harvesting system collects branch and top material for use as a fuel as well as the roundwood. The analysis shows that the silviculture cost savings and energy biomass value more than offset the loss in long term value due to slower growth of the stand following intensive harvest. This conclusion is robust to changes in discount rate, value of roundwood and volume growth loss. The price of energy biomass had a major effect.

Keywords: *Energy biomass, financial analysis, full-tree harvesting, growth reduction, short-wood harvesting.*

INTRODUCTION AND LITERATURE REVIEW

Harvesting of branch and top biomass along with conventional forest products can have important repercussions on the establishment and growth of subsequent stands. Until quite recently, concern over the removal of organic matter and nutrients has centered on growth effects [14]. Leijon [12] presented the results of Swedish field trials which showed significant differences in stand establishment success and early growth between areas harvested with the shortwood and full tree systems. This work showed that the effects of branch and top biomass removal could be positive or negative depending on the site and species.

It is also clear that the removal of branch and top biomass may have significant effects on the productivity of silvicultural activities (and hence their cost). Smith *et al.* [19] found significant differences in scarification productivity and success between areas logged with tree length or full tree systems. Haggblom and Kaila [9] found that the quantity of forest residues left on a cutover had a major effect on the productivity of planting. These findings are echoed by Hakkila [10]. In all these cases, the removal of biomass would result in lower silvicultural costs.

Forest management has as one of its primary objectives to produce the maximum quality and quantity of fiber at the lowest possible cost. Management activities aimed at fiber production include both the harvest of timber and subsequent reforestation and silvicultural tending activities. Traditionally, economic analysis and optimization has been undertaken for the harvesting phase (Arola and Miyata [3], Sturos [20], Cameron [4]). Stand establishment and tending activities have been analyzed individually with the objective of minimizing their cost. The economic optimization of rotation length has been a subject of discussion since Faustman developed his classic formula in the last century. The global economic effects of full tree harvesting have, however, not been evaluated.

In October of 1990, an International Energy Agency workshop was held in Garpenberg, Sweden, to attempt to identify the forest management practices that would have to be adopted as we move toward intensive forest harvesting. During this workshop it became clear that there was a considerable amount of data in Sweden on the effects intensive harvesting on both stand establishment and subsequent growth. It was at this point that a joint project was developed by Bo Leijon (Swedish Agricultural University, Umeå) and Pierre Zündel (Université de Moncton, Canada).

This project, funded by Canada's Energy from the Forest Program (ENFOR), is now underway and has as its aim the combination of Swedish expertise in stand growth and establishment modelling and Canadian expertise in economic modelling. The project compares the overall economics of full tree logging on a number of spruce and pine sites in Sweden. This paper will present a simplified hypothetical case to demonstrate the kind of analysis to be undertaken in the project.

METHOD

A hypothetical softwood stand is set up, in this case a black spruce (*Picea mariana* Mill. B.S.P.)/bal-

[1]*The authors are respectively: Professor of Forest Harvesting and Research Associate, School of Forest Science.*

sam fir (*Abies balsamea* L. Mill.) stand on a medium site class in Quebec [2]. This "stand" is then harvested by two systems, a shortwood system and a full tree system. In the full tree system, branch and top biomass left at roadside after delimbing is chipped and recovered. The stand is then scarified, hand planted and thinned at age 40 when it will contain 70 m^3 per hectare. The stand is clearfelled at age 65 with a volume of 150 m^3/ha. To simplify the analysis, the commercial thinning is performed using conventional shortwood methods in both cases. The scenarios differ in the following ways:

1) the full tree system has revenues from the sale of branch and top biomass for energy;

2) the regeneration costs are different, reflecting the effect of the removal of logging debris from the cutover site.

3) growth is reduced in the stand where intensive harvesting is carried out. This affects revenues by reducing the volume of wood available for harvest at both the commercial thinning stage and at the final harvest. The lower volume at rotation age also increases costs (which are a function of stand volume per hectare).

Tables 1-4 show the costs and revenues used in the evaluation of each scenario. Table 1 shows the breakdown of harvesting costs by phase for the initial harvest. Table 2 shows a breakdown of reforestation costs for two harvesting systems. Table 3 contains a breakdown of the energy biomass harvesting costs and revenues. Table 4 shows the logging costs and revenues in the second and subsequent rotations. As is the common practice in forest economics the analysis for subsequent rotations has been taken to infinity. It should be noted that the data presented here are hypothetical and are used for illustrative purposes only. Sources consulted to obtain financial data included [1], [5], [6], [7], [8], [11], [13], [15], [16], [17] and [18].

To ease the financial analysis, cost data on each scenario are included in a LOTUS 1-2-3 spreadsheet. The spreadsheet calculates the net present worth of the harvest of the initial stand as well as the subsequent reforestation activities and harvests to infinity. The difference between the present worth of the stand when harvested by the full tree system rather than the shortwood system are also calculated. There exists considerable uncertainty about wood and energy value and the magnitude of the cumulative growth reductions. As with all discounted cash flow analyses, there exists uncertainty about the discount rate to use in the analysis. Sensitivity analyses for the following variables have, therefore, been prepared:

1) discount rate (base case value = 4%);

2) energy biomass value (base case value = \$21.37/m^3);

3) wood value (base case value = \$34.19/m^3);

4) percentage reduction in the cumulative volume growth (base case value = 3%).

These analyses measure the effect of changes in these variables on the difference in present net worth (PNW) of the two systems (i.e., How much more or less attractive is the full tree system when we change the values of these input variables). The PNW variable is calculated as follows:

$$PNW = (R_{ft} - C_{ft}) - (R_{sw} - C_{sw})$$

Where:

R_{ft} = the sum of discounted revenues for the full tree harvesting system;

C_{ft} = the sum of discounted costs for the full tree harvesting system;

R_{sw} = the sum of discounted revenues for the shortwood harvesting system;

C_{sw} = the sum of the discounted costs for the shortwood harvesting system.

The analysis takes for granted that intensive logging could take place over time without cumulative effects of nutrient and organic matter removals.

RESULTS

In the base case, it is clear that the full tree harvesting system has the highest present net worth, in spite of a higher harvesting cost. The difference is attributable to the energy revenues and lower reforestation costs (see Tables 2 and 4).

Figure 1 shows the effect of wood price on the PNW of the full tree system. A 20% change in the price yields a 1% change in PNW. As might be expected in an analysis stretching over a long period, the discount rate had a more significant impact (Figure 2). A reduction of 20% in the discount rate yields a 1.5% reduction in the PNW while a 20%

Table 1. Breakdown of harvesting costs by phase for the intial harvest (at time = 0) for both systems.

SHORT-WOOD $/M³		FULL-TREE $/m³	
Harvester	8.38	Feller-B.	4.26
Forwarder	4.32	Skidder	2.57
		Slasher	2.99
Total	12.70	Delimber	3.42
		Total	13.24

Table 2. Reforestation costs by harvesting system.

	SHORT-WOOD $/ha	FULL-TREE $/ha
Scarification Cost	69.91	60.25
Planting Cost	399.57	384.62
Total	469.48	444.87

Table 3. Energy biomass recovery data.

Chip Harvesting Unit Productivity (Gt/PMH)	9.33
Harvesting Cost ($/PMH)	94.02
Chip Transport Cost for a Known Distance ($/Gt)	3.80
Green Weight Recovered per Unit of Gross Merchantable Volume (Gt/m³)	0.23

Table 4. Costs and revenues for harvesting activities in subsequent rotations.

		SHORT-WOOD $/ha	FULL-TREE $/ha
THINNING	Cost	258.46	245.54
	Revenue	744.00	706.80
	Benefit	485.54	461.26
HARVESTING	Cost	1905.13	1998.29
	Revenue	5166.67	5011.67
	Benefit	3261.54	3013.38
BIOMASS	Cost	-	458.44
	Revenue	-	705.74
	Benefit	-	247.30

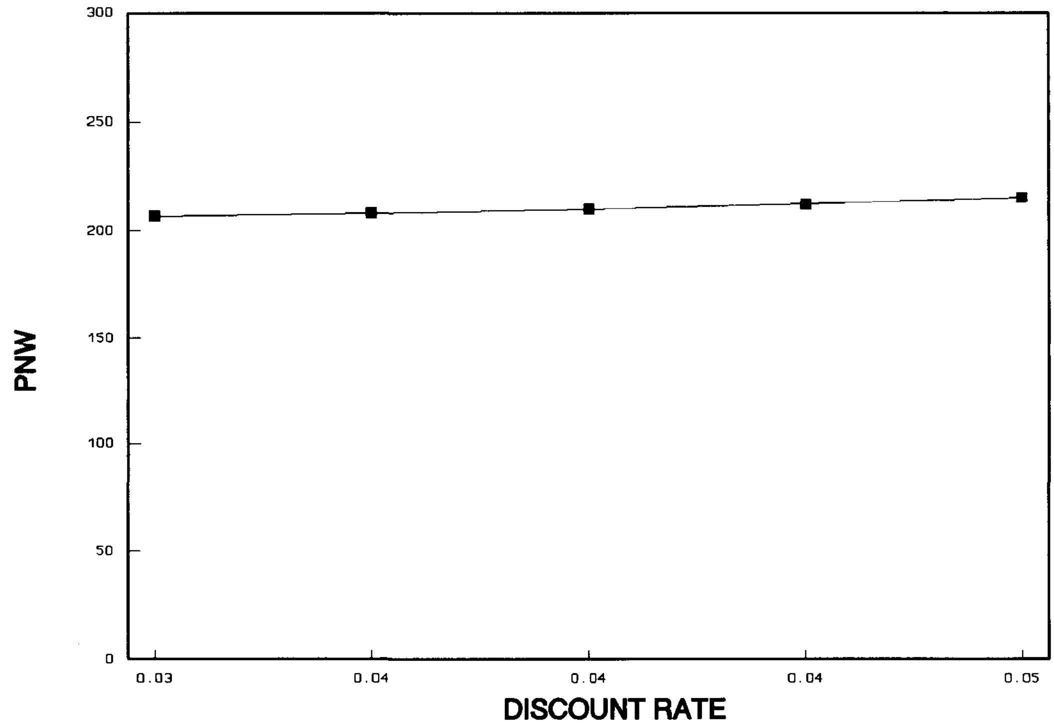

Figure 1. Present net worth ($/ha) of the intensive harvesting system as a function of roundwood price.

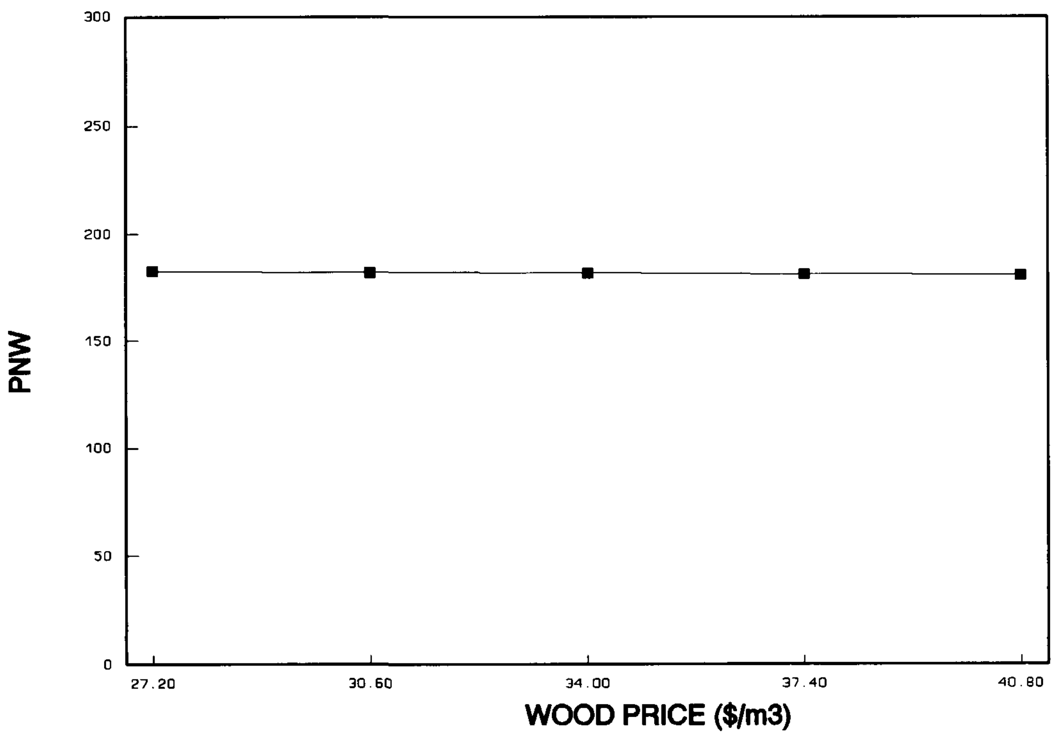

Figure 2. Present net worth of the intensive harvesting system ($/ha) as a function of discount rate.

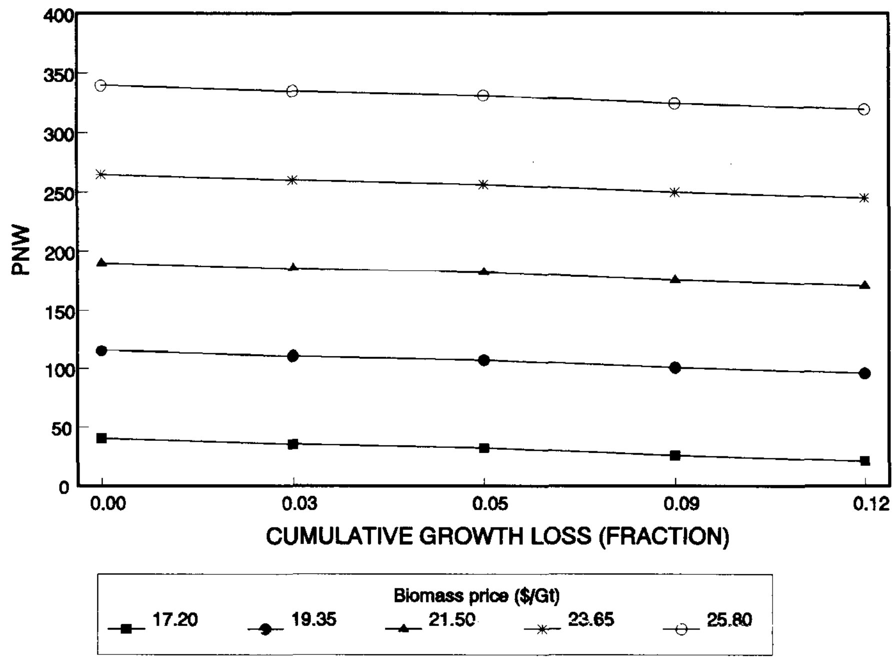

Figure 3. Present net worth of the intensive harvesting system ($/ha) as a function of the cumulative loss of growth in stand volume (m^3/ha) and of the price of biomass ($/green tonne).

increase in the discount rate leads to a 2.5% increase in the PNW.

Figure 3 shows the simultaneous effect of cumulative volume reduction and energy biomass price. Each curve on the graph represents the effect of wood cumulative growth reduction on PNW for a given biomass energy price. The assumed biomass price is indicated in the legend at the bottom of the graph. A 100% change in the cumulative volume reduction yields a 5.1% change in PNW. On the other hand, a 20% change in energy biomass price causes a 72.6% change in PNW. The large variation in growth rate loss was used to demonstrate that even large changes in the volume reduction have negligible effects on the PNW.

DISCUSSION

It is interesting that the negative impact which has been most often discussed with regard to the effect of intensive harvesting, reductions in forest production, has a very small effect financially. This is understandable since reductions in forest production affect only thinning and harvest revenues in subsequent rotations. The discounted value of those revenues is small due to their timing. This is also true with regard to wood price. Since the volumes harvested at time zero are identical, the only influence of wood price occurs at the time of thinning and final harvest during subsequent rotations.

Conversely the additional revenues of biomass harvesting and the lower costs for silvicultural activities occur at or close to time zero. This gives them a much higher discounted value. It is therefore not surprising that the net worth of full tree harvesting system is affected most by energy biomass value.

The long time horizons involved in forestry activities make the choice of discount rate important. The net worth of the full tree system increases as interest rates increase. The reason for this trend is that a higher discount rate reduces the effect of the greater harvest volume by the shortwood system. This leads to an increasing difference between the full tree system (whose revenues are less affected by discount rate since they come earlier) and the shortwood system.

The financial analysis performed here depends on the legality and ethics of allowing ourselves to reduce the long-term growth potential of the forest by mining nutrients. If we do not accept this premise, it is necessary to factor in the cost of the replacement of the mined nutrients (this fertilization activity is not included in the calculations above). Another alternative is to exclude the use of full tree harvesting on the grounds of reduced productivity. The latter approach calls into question the notion of benefit cost analysis where significant externalities exist (such as the reduction in cumulative stand growth). Nearly all human activity has an impact on the natural environment. It is preferable to evaluate this impact for a wide variety of proposed actions and to take the least harmful one or the one with the highest total benefit. An example of the danger of arbitrary limitations might be choosing to use coal rather than wood in a district heating plant to "protect" the forest. In this case the externalities resulting from the use of coal (e.g., acid rain, loss of forest from strip mining) are not taken into account.

One effect of reduced volume growth in the forest which was not evaluated here, but which may be of significant importance, is related to the calculation of the sustainable yield "annual allowable cut" (AAC). When stand growth is reduced, there may be an effect on the AAC immediately. This is the opposite of the "allowable cut effect" (ACE) which accrues to a forest manager who intensifies silvicultural activities. The ACE normally is positive and allows a forest manager to liquidate his mature and overmature stands more quickly because of expected gains in productivity from intensive silviculture. With anticipated growth reductions, it is necessary to reduce the AAC now to conserve growing stock. This means a reduced supply of wood and thereby lower profits if the supply and demand of timber are in equilibrium.

CONCLUSION

The use of hypothetical data in this analysis precludes making conclusions with regard to the net benefit/cost of intensive harvesting. The analysis does, however, show that taking a more holistic approach and using economic criteria can lead to a different perspective on the impacts of intensive harvesting than a consideration of physical effects alone.

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