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COMPUTER SIMULATION COMPARISONS BETWEEN AN ECOSYSTEM MANAGEMENT STRATEGY AND CLEAR-CUTTING WITH ARTIFICIAL REGENERATION FOR A FOREST IN NORTHWESTERN ONTARIO

T. Gooding[1] and L. Van Damme[2]

INTRODUCTION

In recent years, the resource management paradigm called "ecosystem management" has become the focus of considerable attention (*see* Ontario Forest Policy Panel 1993, Salwasser et al. 1993, Grumbine 1994, Jensen and Bourgeron 1994, Alberta Pacific Forest Industries Inc. 1995). Ecosystem management embraces goals that are much broader than simply providing a sustainable flow of wood products from a forest. The goals of ecosystem management mirror society's evolving expectations of how the stewardship of forests should be conducted, and of the benefits their forests should provide. These goals often include: maintaining representative ecosystems at all spatial scales, conserving biodiversity, and maintaining evolutionary and ecological processes. Key mechanisms for achieving these goals include: recognizing and managing within the hierarchical structure of forest ecosystems (Grumbine 1994), using adaptive management techniques (Lee 1993), and mimicking natural disturbance patterns through the application of a variety of silvicultural systems (O'Hara et al. 1994).

In Ontario's boreal forest the adoption of ecosystem management can manifest itself in many ways. To better emulate nature, one can expect that some large cuts and some small cuts will be added to the current range of cut sizes (Hunter 1990, Hunter 1993). Cut boundaries can be modified to follow landforms and existing stand boundaries. Green tree, snag, and wood debris retention within cut boundaries provide important biological legacies for successional communities (Franklin 1992). Some ecosystem management strategies in Ontario schedule harvests in a way that creates age–class distributions thought to emulate wildfire.

In addition, there is an expectation that clear-cuts and plantations will give way, in some measure, to an increase in the use of alternative silvicultural systems such as shelterwood or selection cutting (Matthews 1989). All of these systems were traditionally designed to encourage natural regeneration and can be modified to imitate natural processes, such as fire, that do not consume all the standing trees. These systems can also create openings that emulate insect attacks and other biotic and abiotic forest disturbances. The creative application of silvicultural systems manipulates both the horizontal (patch size) and vertical structure of stands to achieve a multitude of forest management objectives.

One potentially troublesome aspect of ecosystem management, as with many new ill-defined philosophies, is that it may be viewed as a panacea. Can ecosystem management maintain the supply of wood flowing from boreal forests in addition to providing expected ecological benefits? Many think not (Miller 1995, Rauber 1995).

[1]Senior resource analyst, Pearson Timberline Forestry Consultants, Suite 315, 10357–109th St., Edmonton, Alberta. Phone (403) 425-8826. FAX: (403) 428-6782. E-mail: elg@tfic.bc.ca

[2]Consulting forester, KBM Forestry Consultants Inc., 349 Mooney Ave., Thunder Bay, Ontario. Phone: (807) 345-5445. FAX: (807) 345-5858. E-mail: laird.vandamme@lakeheadu.ca

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A recent review of the literature (Wedeles et al. 1995), and personal observations of forest conditions in northwestern Ontario, indicate that the adaptability of boreal tree species allows for the application of a wide array of silvicultural systems despite the shade tolerance rules of thumb to which most foresters subscribe (i.e., shade-intolerant species can only be grown under clear-cutting systems). However, the economic consequences of applying alternative silvicultural systems that rely on natural regeneration have not been studied in northwestern Ontario.

ECONOMICS OF SILVICULTURAL SYSTEMS

The authors have chosen to generalize those management strategies governing forestry activity in the boreal forests of Canada over the last half century as sustained yield strategies. Sustained yield strategies rely to a large degree upon clear-cutting in a way that normalizes the forests age–class structure over time. Therefore, few forest types exist that are older than a predetermined rotation age. These strategies are considered to be the most economically efficient in even-aged forests under classical economic theory (Davis and Johnson 1987).

Today, clear-cutting is essentially the only silvicultural system used in the boreal forest as part of sustained yield management. It features low harvest and operating costs and is compatible with the largely even-aged forests. However, maintaining the level of conifer growing stock in upland, conifer-dominated ecosystems usually requires expensive inputs of site preparation, planting or seeding, and tending. Until rather recently, responsibilities for forest management expenses in Ontario were separated from harvesting operations. Thus, the total costs of the clear-cutting silvicultural system remained obscure.

Studies have shown that under certain conditions the total cost of planning, cutting, road maintenance, and stand tending of alternative silvicultural systems can be less than conventional clear-cutting systems (Haight and Monserud 1990, Jeglum and Kennington 1993). The cost of harvesting can be 2–15 percent greater for alternative silvicultural systems (Kramer and Conan 1985, Kellog et al. 1991, Keegan et al. 1995). However, these costs can be offset by savings in silvicultural expenditures even when the costs of discounted revenues from delayed regeneration and harvests are taken into account.

Unfortunately, these stand-level studies have not examined the cumulative effects (e.g., larger road networks) of expanding the harvest to areas beyond those required to meet wood volume targets under a clear-cut regime. For example, natural regeneration may delay commercial harvest by 10–20 years because crop trees take longer to establish compared to planted seedlings. Wood supply is then reduced in one locality and alternative sources must be discovered. This results in increased haul costs and can interfere with harvest schedules that seek to recover volumes prior to natural decay and decline processes. Stand level studies also ignore the long-term consequences of the resulting forest structure. This is particularly relevant given the Ontario Ministry of Natural Resources' (OMNR) recent silvicultural direction to place greater reliance upon natural regeneration.[3] Hearnden et al. (1993) demonstrated that a reliance upon natural regeneration or planting, without proper maintenance, leads to a shift from upland conifers to mixedwoods that can be poorly stocked following clear-cutting. This may lead to more costly future harvests and a reduction in the allowable cut.

This report looks at the economic consequences of expanding the use of alternative silvicultural systems using computer simulation techniques. These alternative systems feature natural regeneration as but one component of an ecosystem management strategy. The strategy is considered in contrast to a sustained yield management strategy similar to that practised during the last decade on the Seine River Forest.

METHODS

A digital map and forest inventory were acquired for the 270 000-ha Seine River Forest (SRF) in northwestern Ontario. Managed by Stone Consolidated Corp. of Fort Frances, Ontario, the site lies along the central southern margin of Canada's boreal forest and is dominated by older jack pine (*Pinus banksiana* Lamb.) stands typical of the region.

Modifications were made to computer simulation software called HSG[4] (Harvest Scheduled Generator). HSG was developed by Moore and Lockwood (1990) to schedule stands for clear-cutting in even-aged forests. These modifications allowed the depiction and reporting of the biological effects of alternative silvicultural systems. In addition, new algorithms allowed stands to be scheduled for harvest using economic criteria in addition to biological criteria related to stand age.[5]

Stand growth estimated from regionally corrected yield tables was linked to a geographic information system (GIS) so that maps, graphs, and tables depicting forest inventory projections could be produced. Harvest, transportation, and silvicultural cost estimates were also assigned to match stand conditions for any point in time. Wood product prices were assigned to stands in a similar fashion. Species and stand structure changes due to succession and the application of silvicultural systems were also modeled and assessed for both economic and biological criteria. These forest inventory projections were then subjected to an economic analysis.

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[3]Ontario Ministry of Natural Resources. 1993. Provincial silvicultural directions. Sault Ste. Marie, ON. Unpub. Rep. 5 p.

[4]HSG is distributed by Dendron Resource Surveys Inc., 880 Lady Ellen Place, Suite 206, Ottawa, ON. K1Z 5L9.

[5]Gooding, T. The economics of alternate silvicultural systems in northwestern Ontario. M.Sc.F. Thesis, Lakehead University, Thunder Bay, ON. (In prep.)

Two general strategies were explored: sustained yield management and ecosystem management. The sustained yield management strategy used the clear-cutting system exclusively. The pattern of harvest and silvicultural activity was considered to be similar to patterns followed in the 1980s. Sustained yield management tends to create a relatively young even-aged forest.

The ecosystem management strategy used a mixture of clear-cutting and alternative silvicultural systems. These alternative silvicultural systems featured some type of intermediate harvest, a reliance upon natural regeneration, and a specific leave time following the intermediate harvest before a final cut is permitted.

RESULTS

Forest inventory projections showed that ecosystem management developed a greater diversity of forest stand ages and structures compared to a sustained yield management strategy. The authors were satisfied that the computer simulation depicted realistic biological conditions associated with both strategies.

The ecosystem management strategy resulted in a significant decrease in the allowable cut[6] from 313 000 m^3/yr to 235 000 m^3/yr (Table 1). This dramatic reduction reflects the cumulative effects of regeneration delays, constraints to harvest scheduling, shifts in species composition, and increased stand ages that resulted from the ecosystem management strategy.

Harvest levels under the maximum sustained yield strategy were reduced to equal the allowable cut under ecosystem management. This moderate sustained yield strategy allowed a better cost comparison with the ecosystem management strategy. Ecosystem management resulted in a 15 percent increase in total timber operating costs compared to the moderate sustained yield management strategy (\$43.30/m^3 vs \$49.46/m^3).

Figure 1 shows that total wood procurement costs were approximately equal during the first 40-year period. However, they began diverging by as much as 30 percent as the forest structure changed. The average hauling and regeneration cost differences between the three strategies were not as large as had been anticipated at the start of the study (Table 1). Access requirements (i.e., road infrastructure) associated with different silvicultural systems were similar at the forest scale over the long run. Whether a road is extended to acquire more timber from stands undergoing partial cutting, or to access new stands that become ready for clear-cutting seems to balance out in the larger scheme of things.

Despite the relatively small cost differentials, the general pattern is consistent with most foresters' expectations, i.e., hauling costs go up and regeneration costs go down when alternative silvicultural systems are relied upon more than clear-cutting.

Average residual timber values (RTV) were calculated for harvested wood volumes at each time period (Table 1). Residual timber value is a nonmarket estimate of stumpage or value of the growing stock (Nautiyal et al. 1995). The large residual timber value of the moderate sustained yield strategy is a result of a harvest strategy that has a greater timber value compared to the other system. This is not a result of "high grading" profitable stands because high RTVs are maintained over the long run. The lower harvest level allowed the model to cut stands and create plantations

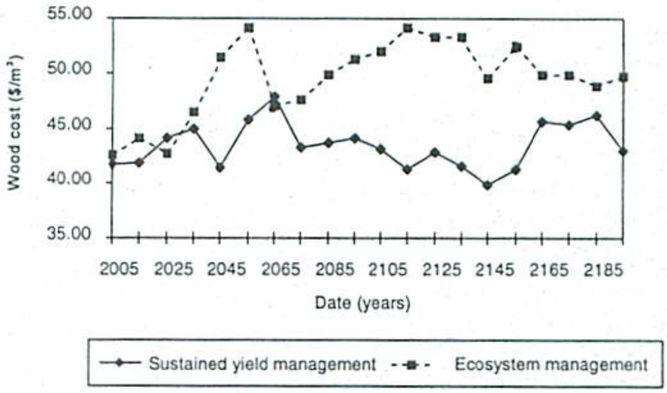

Figure 1. Graph showing total timber production costs from the year 2005 to 2195.

Table 1. Economic indicators averaged over a simulated 200-year period for the Seine River Forest.

Management strategy	Volume cut (m^3/yr)	Area cut (ha/yr)	Hauling cost (\$/m^3)	Regeneration cost (\$/m^3)	All costs[a] (\$/m^3)	RTV[b] (\$/m^3)
Maximum sustained yield	313 000	2 300	18.72	3.45	47.75	13.33
Moderate sustained yield	235 000	1 500	18.15	3.18	43.30	27.82
Ecosystem management	235 000	3 600	19.25	2.28	49.46	16.13

[a]All costs = total timber operating costs of harvest, renewal, maintenance, haul costs, road maintenance, crown dues, taxes, and overhead. These costs represent an average over the 200-year forecast period.
[b]RTV = Residual timber value. Refer to text.

[6]Allowable cut in this study refers to the even flow of wood that can occur throughout the 200-year simulation and yet not exceed the growing stock of merchantable wood in any 5-year time period.

near main roads rather than searching further afield (similar to prime site strategies). More analysis is required to verify the forest structure characteristics that are responsible for the high residual timber value associated with this strategy.

To maintain a wood flow of 235 000 m^3/yr, the area cut annually in the simulation study averaged 3 600 ha under ecosystem management compared to 1 500 ha under the moderate sustained yield management strategy (Table 1). Computer generated maps showed that patch sizes were smaller and cutting locations were more dispersed compared to moderate sustained yield management. Although this did not seem to result in large increases in hauling costs, this dispersion of forestry activities across the landscape may create land use conflicts. For example, tourist outfitters in the area may appreciate the aesthetic appearance of alternative silvicultural systems but may not like the dispersion of logging. Dispersed logging may result in frequent industrial activity in areas that might otherwise enjoy extended quiet periods between harvests.

Both dispersion of operations and the reduction in allowable cut leading to job losses suggests that the social costs associated with ecosystem management may be a more important consideration than the increased timber production costs. These socioeconomic costs of ecosystem management, as defined in this note, might be mitigated by more intensive management (e.g., planting and thinning operations that could be concentrated in strategic areas). The technology and operating skill acquired from intermediate harvests as part of ecosystem management can be applied to thin stands commercially. The volume recovered from thinnings could then help to avoid the reduction in allowable cut forecasted to result from ecosystem management. Thinned stands will also develop windfirm characteristics, thus increasing the range of areas eligible for the later application of alternative silvicultural systems. This should improve the flexibility of future operations and may increase the allowable cut.

Undoubtedly, a greater reliance upon thinning to supply wood from small diameter trees will increase wood costs (Mellgren 1990). Furthermore, the age–class distribution of forests like the case study one may not have enough stands eligible for thinnings in the right time period to have the desired effect upon long-term wood supply.

The sustained yield management scenarios allowed clear-cutting to occur without any constraints. This is a fairly unrealistic assumption. Numerous guidelines/regulations have recently been enforced to exclude clear-cutting from riparian zones and other forest stands in an effort to protect wildlife and other forest values (Koven and Martell 1994). As a consequence, the allowable cut will go down and the operating costs will rise above those shown from the sustained yield scenario. For example, it can be inferred that the introduction of moose habitat management guidelines and other spatial constraints to harvesting increases operating costs and reduces the allowable cut to levels in a pattern similar to, but somewhat below, current forecasts for ecosystem management.

There is a move to introduce partial cutting and alternative silvicultural systems using new harvesting equipment to draw wood from shoreline and wildlife reserves in an environmentally sensitive way. One can assume that changes in technology, such as cut to length harvesting systems (Jewiss 1992) and increased planning sophistication, will reduce the cost of alternative silvicultural systems. In this sense, ecosystem management strategies will become more closely aligned to sustained yield management costs over time. After all, early attempts at establishing conifer plantations as part of sustained yield management were twice as costly as they are today.[7]

CONCLUSIONS

Computer simulation of an ecosystem management strategy consisting of an expanded use of alternative silvicultural systems in Canada's boreal forest resulted in more expensive wood. Higher costs of operating in older forest types and dispersed operating areas were incurred as the forest changed in response to this management strategy. These higher costs may become less significant over the long run as new harvest technology and more sophisticated planning systems are developed.

Of greater concern is the reduction in allowable cut that resulted from a reliance upon natural regeneration and a forest structure with older, less productive (in a timber sense) stands that were conserved to provide amenities other than timber. Reduced allowable cuts can carry significant social costs from job losses. However, if the public and regulatory agencies continue to impose restrictions upon clear-cutting, the current socioeconomic advantage of the sustained yield management strategy used in this study is questionable.

On sites like the Seine River Forest, intensive management with clear-cutting, planting, and thinning activities will likely be required on significant portions of the estate to maintain timber harvests at the current level, particularly if other parts of the forest are allowed to develop to serve other purposes. The results of this study supports the idea of a triad of intensively managed forest, forest managed in a natural state, and protected forest as part of a rational ecosystem management strategy covering large geographic areas (Seymour and Hunter 1992).

The study results are tied to the assumptions related to the generalized forest management strategies and the forest structure used in the simulation exercise. Other forest management areas could be examined for economic impacts of various forest management strategies using the methods developed in this study.

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[7]Mac Squires, Divisional Forester, Abitibi Price Inc. Personal comm.

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