ECONOMIC WOOD SUPPLY FROM ALTERNATIVE SILVICULTURAL SYSTEMS: A CASE STUDY IN ONTARIO'S BOREAL FOREST

by

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ABSTRACT

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Key Words: alternative silvicultural systems, forest modelling, economic wood supply, residual timber value, HSG, harvest scheduling.

A modified version of the Harvest Schedule Generator model (HSG) was used to predict the economic wood supply from alternative silvicultural systems on a case study forest (Seine River Forest) in northwestern Ontario's boreal forest. Alternative silvicultural systems were compared with traditional clearcut harvesting to determine the impacts on sustainable harvest levels, wood costs and residual timber value. Results show large reductions in harvest volumes, increased harvest area and decreased profit for alternative silvicultural systems. Alternative silvicultural systems' savings in regeneration costs did not offset the increased harvest and delivery costs nor the reduced volume productivity from the forest as a whole. The different silvicultural systems resulted in little variation in the residual forest age-class structure after 200 years when harvest levels were equal. Based on the assumptions used in this study, the use of alternative silvicultural systems as a replacement for clearcutting in northwestern Ontario's boreal forest would produce undesirable socio-economic impacts.

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1 INTRODUCTION

In this decade, the practice of forestry is evolving towards a phase of greater social responsibility. This socially responsible forestry has been referred to as "new forestry" (Kimmins 1992). In new forestry, forest management activities are tempered by and adapt to society's evolving perception of what constitutes proper stewardship. Consequently, forest management approaches such as ecosystem management and objectives such as maintenance of biological diversity (biodiversity) (Sampson and Knof 1982; Hunter 1990; Kimmins 1992) are now mandated in many jurisdictions. Part of new forestry is an increased reliance upon alternative silvicultural systems at the expense of traditional systems based on clearcutting and artificial regeneration (Kimmins 1992).

Over the previous two decades there has been a tremendous emphasis upon clearcut silvicultural systems that rely upon tree planting to assure successful conifer regeneration (Anon. 1993; Hearnden *et al.* 1993; Koven and Martel 1994). The high cost of tree planting, coupled with perceptions over the ecological consequences of large-scale clearcutting and planting, has become a public concern (Kimmins 1992; Dodds 1994; Carleton 1995; Reed 1995; Ulley 1995). For example, international attention upon clearcutting in British Columbia's Clayoquot Sound resulted in significant reductions in the area scheduled for harvesting and the introduction of alternatives to clearcutting such as green tree retention (Beese and Dunsworth 1994; Reed 1995; Lewis 1995). In Ontario, international pressure has been less intense, but recent government initiatives aimed at reducing the traditional level of clearcutting and artificial regeneration have been introduced (OMNR 1993b; Koven and Martel 1994; Boast 1995). As a result, alternatives to clearcut silvicultural systems are now receiving greater levels of interest across Canada (Koven and Martel 1994; Alberta Pacific Forest Industries 1995). Recently, studies have been initiated to determine the impacts of alternative silvicultural systems (see Jeglum and Kennington 1993; Yang and Bella 1994; Arnott *et al.* 1995; Navratil *et al.* 1995; Rollins *et al.*1995; Alberta Pacific Forest Products 1996; Lieffers 1996). However, these are all stand-level studies that fail to take forest-level dynamics into account.

In new forestry, it is not a matter of whether alternatives to traditional silvicultural systems will be applied, but rather to what degree. Integrating these alternative silvicultural systems into forest management practices will have effects upon the forest that differ from those of clearcutting. Faced with public pressure for change, there is a requirement to make reasonable predictions about the effects of alternative silvicultural systems upon both the forest structure and the goods derived from them (Ontario Forestry Policy Panel 1993; Dodds 1994). Due to the long time required to demonstrate the pros and cons of new forestry, the probable consequences should be explored in the interim by using computer simulation models (Kimmins 1992).

The objective of this study is to examine the long-term, forest-level consequences of applying alternative silvicultural systems in forest management strategies for boreal forests of northwestern Ontario. This was accomplished by comparing the predicted results from a range of forest management strategies. The predicted results were generated from a modified forest planning computer model, the Harvest Schedule Generator (HSG) developed by Moore and Lockwood (1990). Using the modified model, 200-year forecasts were developed for both a case-study northwestern Ontario forest and some hypothetical forest structures.

Three forest management strategies were developed. One follows a traditional sustained-yield forest management philosophy using clearcut harvesting followed by artificial regeneration. The second strategy follows a philosophy of harvesting with only alternative silvicultural systems. The third is a combination of all silvicultural systems representing one possible interpretation of an ecosystem management philosophy.

The data files which were used to drive the simulations are included in the Appendices. Appendix II is a technical reference of the changes made to the HSG model. A glossary of the technical terms is included. Throughout this report HSG commands are in CAPITAL letters and HSG terms are in *italics*. Actual model syntax is printed in **Times New Roman** type face.

2 CONCEPTS IN FOREST PLANNING AND ECONOMICS

2.1 Silvicultural Systems

Natural boreal forest ecosystems are driven by catastrophic disturbances such as fire. The species which make up these ecosystems have adapted to such disturbances (Fowells 1965; Koven and Martel 1994). Clearcut harvesting, the traditional method used in the boreal forest (Anon. 1993), produces different conditions than those that follow natural catastrophic disturbances (Koven and Martel 1994; Wedeles *et al.* 1995). Natural regeneration following clearcut harvesting tends to favour the regeneration of hardwood species which are capable of vegetative reproduction, resulting in a different forest structure after harvest than that produced by natural conditions (Hearnden *et al.* 1993). This situation applies to Ontario's boreal forest, where the primary method used during the 1980's to regenerate the commercially preferable conifer species following harvesting was planting or seeding on a prepared site possibly followed by tending (Koven and Martel 1994).

Other methods can be used to maintain the conifer component in the boreal forest (Wedeles *et al.* 1995). These methods involve changing not only the method of regeneration, but the entire approach to harvesting, regeneration and stand renewal, which taken together comprise a silvicultural system. For this study, the term "alternative silvicultural system" refers to all silvicultural systems other than those using clearcutting. These systems are considered alternative only because clearcutting has been the dominant and traditional silvicultural system employed in the boreal forests of Ontario since the beginning of this century (Wedeles *et al.* 1995).

"Silvicultural Terms in Canada" (Canadian Forest Service 1995) defines silviculture as the theory and practice of controlling the establishment, composition, growth and quality of forest stands to achieve the objectives of management. It also defines a silvicultural system as a process that applies silvicultural practices, including tending (thinning, pruning, etc.), harvesting and replacement of a stand in order to produce a crop of timber and forest products.

According to Wedeles *et al.* (1995) and the Canadian Forest Service (1995), silvicultural systems are named by the cutting method with which the regeneration is established. The names used to classify silvicultural systems are not consistent in the literature. This study will follow the convention used by Wedeles *et al.* (1995). For this study, silvicultural systems are divided into the following categories:

- Clearcutting System
- Modified Clearcutting System
    - Strip Clearcutting System
    - Seed Tree System
    - Multi-pass Harvesting System
- Shelterwood System
- Selection System

There is also confusion in the definition of each term in the literature. For the purposes of this study, the definitions used in Silvicultural Terms of Canada (Canadian Forest Service 1995) will be followed. The clearcutting system removes all economically merchantable trees from a site in one pass. Any appropriate method of regeneration may be applied after harvest, but the system remains clearcut.

The modified clearcutting systems are departures from the normal clearcut harvest. In the strip clearcutting system, the harvest pattern is defined spatially within each harvest area. Alternating strips of residual unharvested and clearcut harvested strips are applied to the harvest areas. In the clearcut strips all economically merchantable trees are harvested. A modification on this theme is block cutting where the harvest zone is broken into clearcut and leave blocks.

The seed tree system resembles the clearcutting system as all merchantable trees are removed except for a small number of trees which are left as a seed source. The intent is to establish an even-aged stand, as with clearcut harvesting.

Multi-pass harvesting includes two and three-pass harvesting. Multi-pass harvesting is usually a combination of other silvicultural systems and therefore not a true silvicultural system. However, its growing application in even-aged forests has increased the use of the term, hence its listing here as a silvicultural system. In this study, at least one of the cuts must include a regeneration cut. This should not be confused with the block clearcutting system used in western Canada, which is also called two-pass harvesting.

The shelterwood system consists of any regeneration cutting in a more or less regular and mature crop, designed to establish a new crop under the protection of the original stand, or where the resulting crop will be more or less regular. This application can be spatially applied in a uniform, irregular or strip manner.

The selection harvest should not be confused with the selective harvest. The selection system is defined as a method of regenerating a forest stand and maintaining an uneven-aged structure by removing some trees in all size classes either singly or in small groups or strips (Canadian Forest Service 1995). A selective harvest is used to remove trees from only certain species, quality and/or size class (i.e. high-grading).

Different silvicultural systems can be combined in a single application which reduces the distinction between them. In this situation, there are no well-defined lines where one system ends and another begins.

Other than strip clearcutting, there is little experience with the application of alternative silvicultural systems in northwestern Ontario's boreal forest (Wedeles *et al.* 1995). Therefore, potential impacts of alternative silvicultural systems must be derived from a combination of the limited local data with results achieved in other areas. Potential prescriptions for alternative silvicultural systems in Ontario's boreal forest can be developed from prescriptions of similar techniques to similar ecosystems, tempered with assumptions from local experience.

Thinning, both commercial and non-commercial, is a silvicultural technique or treatment. It is not in itself a silvicultural system because it does not establish regeneration. Instead, it recovers wood volume that would be lost through tree mortality from self-thinning and often improves the value of the remaining trees by altering stand structure and increasing diameter growth. For the purposes of this study, only silvicultural treatments establishing regeneration are considered. For this reason thinning has not been included in this study.

2.1.1 Stand-level Application of Silviculture Systems

There are many differences between the application of alternative and clearcut silvicultural systems at the stand-level. These differences include both the criteria under which they can be applied and the effect on the developing stand after their application.

There is a difference in the range of stand conditions to which silvicultural systems can be successfully applied. In northwestern Ontario's boreal forest, regeneration is possible on almost any clearcut site (Hearnden *et al.* 1993). Therefore, clearcut systems can be successfully applied to almost any stand condition while alternative silvicultural systems have greater limitations to the range of biophysical conditions under which they can be successfully applied (Wedeles *et al.* 1995).

Clearcutting followed by artificial regeneration is an equaliser of sites. The crop to be established does not depend upon the previous stand composition. Following clearcutting, the decisions on the future stand's composition are mainly economic or policy related. By contrast, stand compositions that can be produced from the application of alternative silvicultural systems depend heavily upon the existing stand structure. In northwestern Ontario, modifying the harvesting system will not produce a spruce stand from a pure poplar stand in any realistic time frame. Some form of artificial regeneration is required.

Alternative silvicultural systems require a greater knowledge of stand conditions for successful application than does clearcutting. Foresters in Ontario use the Forest Resources Inventory (FRI) as the standard forest management inventory (OMNR 1986, 1995). The information in the inventory is that which can be derived from aerial photography. Forest floor and substrata information is only available when collected by a supplemental ground survey. This means that for Ontario, the information required for accurate and correct prescriptions of alternative silvicultural systems is limited.

Foresters have traditionally supported the concept that maximum yield is produced in the boreal forest from even-aged management (Smith 1986; Davis and Johnson 1987). In the boreal forest, foresters have assumed that alternative silvicultural systems will produce a lower yield from regeneration lag, inferior stocking, reduced growth from shading and the establishment of lower-yield species (Smith 1986; Davis and Johnson 1987; Koven and Martel 1994). This assumption has never been tested in a rigorous manner in Ontario.

Using the Prognosis stand growth simulator (Wykoff *et al.* 1982), Haight and Monserud's (1990) study in mixed-conifer stands in the US Northern Rocky Mountains showed that the use of alternative silvicultural systems to produce an uneven-aged stand could increase yield and economic efficiency compared to even-aged stands. They concluded that converting a white pine plantation to a naturally regenerated, mixed-conifer stand using shelterwood harvests produced a slightly higher yield than a series of plantations. They also concluded that their uneven-aged shelterwood system could be just as efficient as plantation management as long as the stand is initially well stocked and adequate natural regeneration is available.

Haight and Monserud (1990) accomplished these gains by changing the species composition and encouraging natural regeneration. They further noted that species composition and initial stand structure is important.

The natural species required to conduct uneven-aged management in northwestern Ontario (i.e. shade-tolerant species) will likely not show the same increase in yields as the species used by Haight and Monserud (1990) in the US Northern Rock Mountains. When natural regeneration is encouraged in a shelterwood system on many sites in northwestern Ontario, a mixture of balsam fir and white and black spruce will develop. These species compositions will increase the chance of spruce budworm infestations resulting in yield losses and mortality. This concern is strong enough that some management plans in northwestern Ontario (e.g., Canadian Pacific Forest Products 1991) call for a reduction in the balsam fir component through an aggressive stand conversion program.

One of the reasons Haight and Monserud (1990) achieved economic gains is the reduction in forest management costs through a reduction in regeneration costs. This reduction in regeneration costs and perceived benefits of “natural regeneration” is one of the reasons the Ontario Ministry of Natural Resources (OMNR) is starting to increase the use of alternative silvicultural systems (OMNR 1993b; Koven and Martel 1994). What is not clear is the degree to which potential savings in regeneration costs might be offset by the higher harvesting costs.

2.2 Forest Management

There are important differences between the management of forests and of forest stands. Within a forest stand is a community of trees possessing sufficient uniformity in composition, age, arrangement or condition to make it distinguishable from adjacent forest or non-forest areas, thus forming a silvicultural or management entity (Davis and Johnson 1987; Canadian Forest Service 1995). In Ontario's boreal forests, stands are usually greater than 8 hectares and less than 200 hectares in size. By contrast, a forest is a large tract of predominantly forested land managed under a single administrative control (Canadian Forest Service 1995). It is made up of forest stands, often tens of thousands in the boreal forest, as well as other non-forested areas such as water, grasslands and wetlands (Canadian Forest Service 1995).

Forest-level management encompasses a wider range of objectives and a broader spatial scale than stand-level management. As a result, management objectives can be complex and often conflict. A large part of forest management entails resolving these conflicts (Ontario Forest Policy Panel 1993; Koven and Martel 1994; OMNR 1995).

In Ontario, the Crown Forest Sustainability Act (Legislative Assembly of Ontario 1994) requires that Crown forests be managed to meet the social, economic and environmental needs of present and future generations. This is accomplished in part by setting sustainable forest-level objectives (OMNR 1995). Sustainable forest-level objectives specify the even-flow or maintenance of consumptive goods (e.g. timber) and non-consumptive goods and services, (e.g. recreation, future forest structure) over a long-term planning period (OMNR 1995). Quantitative targets are then determined for the forest-level objectives. The chosen target levels are influenced in part by economic demand, productive capacity of the land, public perception and forest structure. It is the impact of alternative silvicultural systems upon the harvest target level that is the objective of this study.

Stand-level objectives are often developed for individual stands in isolation of other stands. Stand-level silviculture deals with how to produce the desired goods and services at the least possible cost from an individual stand. In Ontario, goals for a stand are often expressed in terms of the stand age at harvest (referred to as rotation or harvest interval) and any subsequent regeneration activities that will maximise the value from the stand.

Silvicultural treatments, and the auditing of their success or failure, are usually developed and prescribed at the stand level (Hearnden *et al.* 1993). For forest management in Ontario, permissible silvicultural treatments (referred to as silvicultural ground rules) are identified in each forest management plan (OMNR 1995). Silvicultural ground rules describe the range of treatments to be applied to groups of similar stand types and the resulting stand structure. These prescriptions are based upon stand-level biological growth criteria and economic demand. As a result, silvicultural ground rules consider the biological capacity of the site mostly in reference to producing timber (Koven and Martel 1994).

At the stand-level, the fibre-maximizing harvest age is the stand age where the current annual increment (CAI) equals the mean annual increment (MAI) (Smith 1986; Davis and Johnson 1987). However, at the forest-level, objectives such as even-flow will usually require deviations from the optimum harvest age. As a result, it is necessary either to alter the age at which some of the stands are harvested and perhaps, to engage in non-optimal silvicultural treatments, or to relax the forest-level objectives. This clearly shows the forest manager's dilemma - which objectives should be relaxed and which sub-optimal treatments should be applied to produce the best possible combination of activities resulting in the most desirable outcome for the whole forest? A desirable solution cannot be determined until the forest manager can predict the outcome of different management regimes upon the whole forest (Baskerville 1986; Willcocks *et al.* 1990). Forest-level models were developed specifically as a decision support tool to aid the forest manager in solving this dilemma (Moore *et al.* 1994).

2.3 Forest Planning Models

Testing forest management alternatives with forest planning models is gaining wider acceptance. The Forest Management Planning Manual for Ontario's Forests (ONMR 1995) requires the use of a forest-level planning model in the planning process. Furthermore, the manual stipulates that the model must be used in an adaptive management framework to predict the outcome of a range of management alternatives. These legislative requirements move forest planning models from theory to practical application.

Forestry computer models can be classified in many ways. One way they can be classified is by either intended use or method of operation. For example, forest-level models are those that operate and predict results for a whole forest. Stand-level models operate and produce results for individual stands.

Models can also be classified by the temporal period involved as either strategic or operational planning models. Strategic models such as HSG (Moore and Lockwood 1990), FORMAN+1 (Timberline Forestry Consultants 1995), SFMM (Davis 1994) and FORPLAN (Schuster *et al.* 1993) are used for long-term planning. By comparison, operational models such as Logplan II (Newham 1991) and SNAP II (Sessions and Sessions 1992) provide a plan for a combination of operation activities such as harvesting, hauling and regeneration for periods of less than 5 years.

The forest planning models considered for use in this study were: FORMAN (Wang *et al.* 1987) or one of its derivatives such as FORMAN+1, Ontario's Strategic Forest Management Model (SFMM) and HSG (Moore *et al.* 1994).

A common simulation based forest planning model used in Ontario is FORMAN+1 (Timberline Forestry Consultants 1995). It is a non-spatial, sequential forest inventory projection model, operating with aggregated forest classes derived from a forest inventory. FORMAN+1 is an updated version of its predecessors, viz., FORMAN (Wang *et al.*. 1987) and OWSFOP (Hall 1977; 1978). The version available in 1994 was limited to a maximum of twenty, five-year iterations, resulting in a maximum simulation length of 100 years. FORMAN+1 does, however, permit a form of multi-pass harvesting. This is accomplished by subtracting the difference between the existing yield curve and the new specified yield curve. Partial harvesting is also supported but limited to a default of thirty percent removal of existing volume. FORMAN+1 is equipped with a wide selection of forest class priority rules for both harvest and silviculture assignment. Economic priority rules exist for the allocation of forest classes for harvest, using a cost-to-roadside curve, and the allocation of silvicultural treatments by treatment cost and yield.

The Strategic Forest Management Model (SFMM) (Davis 1994) is a forest-level, linear programming model developed by the OMNR to replace the Maximum Allowable Depletion (MAD) spreadsheet model. Like FORMAN+1, SFMM is a non-spatial model utilising an aggregated forest strata structure to describe the forest. SFMM is a optimisation model, running in a PC environment (Windows 3.1), using the AIMS software package to solve the objective function (Davis 1994, pers. comm., October 1994). SFMM develops the forest management activities and user-specified outcomes, or future forest condition, into an equation and a set of constraints. It then solves these equations by determining the optimal solution, if one exists, and reports the results. For use in this study, SFMM's primary problems are its lack of spatial detail, higher cost resulting in greater RAM requirements and the cost of the AIMS software. In addition, SFMM was still undergoing development and testing as of the fall/winter of 1994.

2.4 HSG Version 2.0: Overview

The HSG forest modelling system was the forest planning model chosen for this study because of its spatially referenced capacity, readily available source code, and operating environment. In addition, HSG tracks the individual species components for each stand which could be manipulated to simulate the application of alternative silvicultural systems. The HSG forest modelling system is the PC (DOS) version of the UNIX based Harvest Schedule Generator (HSG) (Moore and Lockwood 1990; Moore *et al.* 1994).

HSG is a forest inventory projection simulation model that maintains each and every forest stand's unique identity, and thus its area, throughout the simulation (Moore and Lockwood 1990). This tracking of each individual forest stand through time separates HSG from the aggregated forest-class models, (such as FORMAN+1 and SFMM). Since the stand boundary remains fixed throughout the simulation, the results can be linked to a Geographic Information System (GIS) to produce maps. There is no real-time interactive computer linkage between the GIS software and HSG (each operates completely independently), but files produced from one program can be used by the other.

The HSG forest modelling system is linked and packaged with components of the IDRISI GIS software (Eastman 1992a , 1992b). IDRISI was designed as a low-cost system for use on PC's. It is a raster-based system with fewer demands upon computer resources and is thus well suited to PC's. (A raster-based system uses a grid made up of individual cells to represent the image compared to a vector-based system which is made up of vectors and points.) IDRISI's primary purpose in the HSG package is the display of results (only the display module is included with HSG; the complete set of IDRISI utilities must be purchased separately). IDRISI can be used to construct some of the data sets used by HSG. However, the manipulation of spatial information is usually better accomplished with a full-function GIS such as ARC/INFO (Environmental Systems Research Institute 1994).

HSG's basic method of operation is demonstrated in Figure 2.4a. The existing forest inventory is converted into HSG format and loaded into the model. The *STEP* command updates the inventory using the *state table* and yield curves. Harvesting is scheduled and applied to selected stands using the *eligibility constraints*, *mandatory harvest list* and harvest priority rules. Regeneration activities are scheduled and applied to selected stands using the *treatment priority list*. The simulation continues until the last *STEP* command is executed. New updated forest inventories can be produced at any period. In addition, the *schedule* and *summary files* containing the simulation results can be produced. These data base files allow for detailed analysis of both forest conditions and management activities.

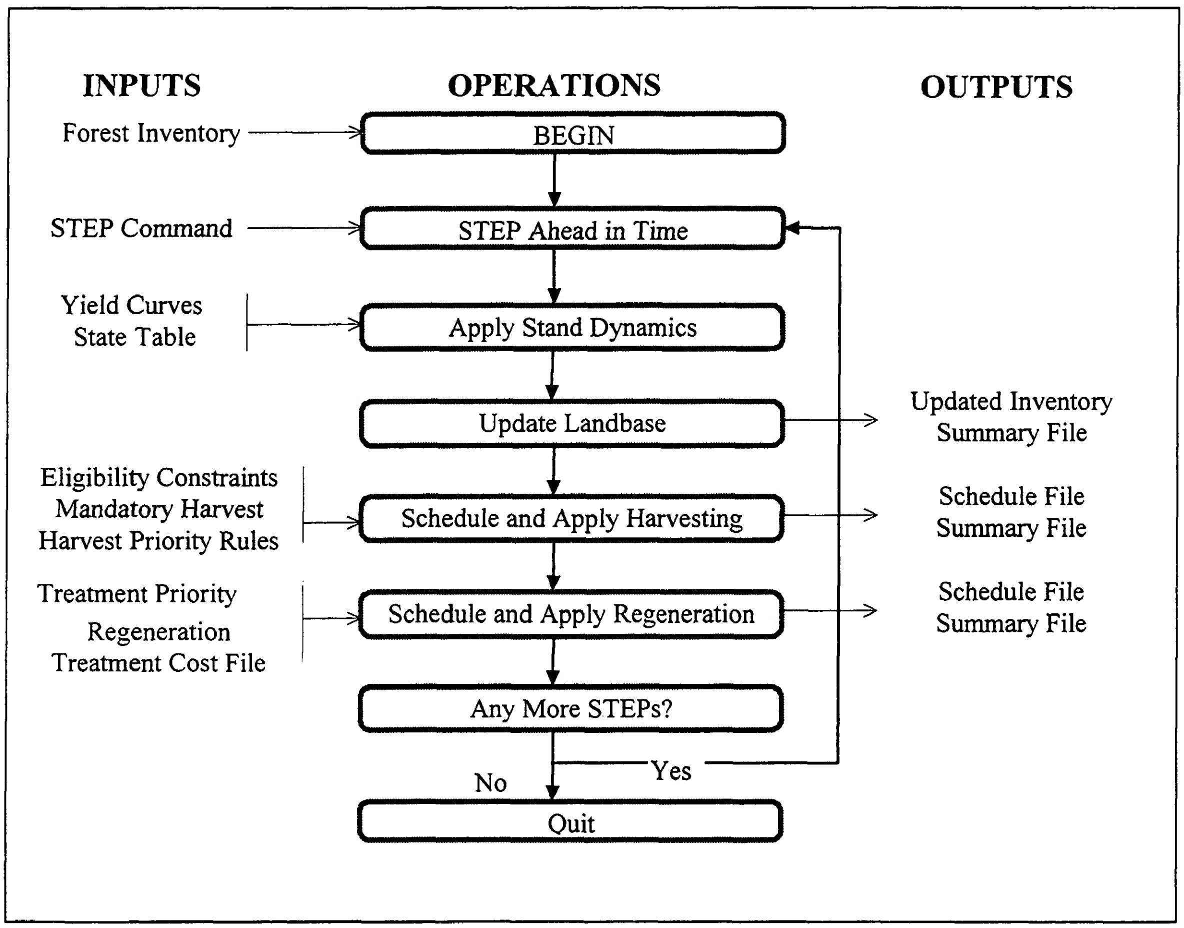

Figure 2.4a Flow chart of HSG operations, inputs and outputs.

Like FORMAN and SFMM, HSG projects the forest through time by using time-dependent yield curves. These curves describe the development of stand volume over a prescribed time period. Unlike aggregate models, HSG uses pure-species yield curves, which describe the development for a single species on a single site. Stand volume is calculated as the sum of the total individual species volumes present within the stand (Figure 2.4b).

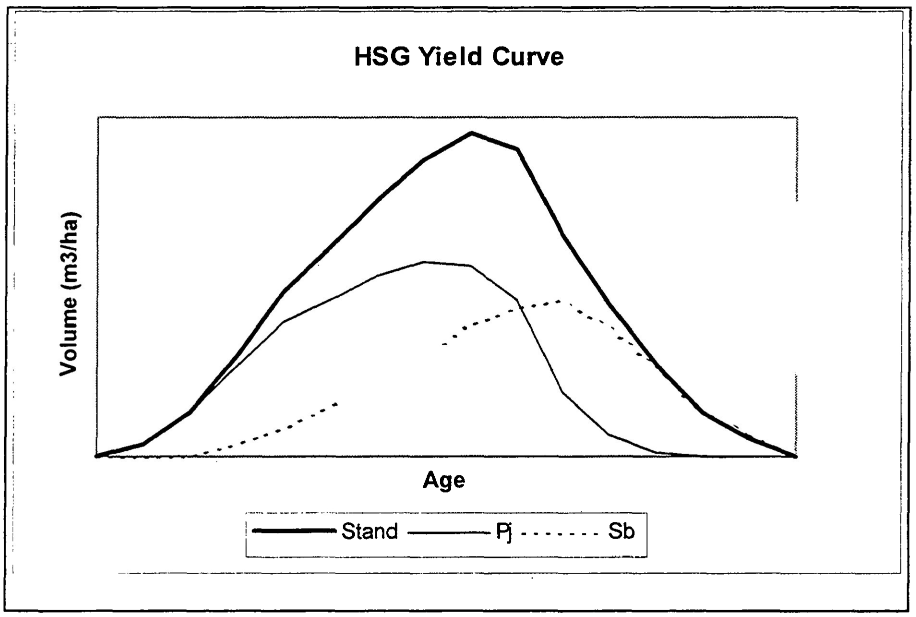

Figure 2.4b Typical HSG yield curve format showing the relationship between two individual species components (Pj = jack pine, Sb = black spruce) and total stand yield.

The forest inventory used by HSG is a modified FRI stand listing where each record represents a forest stand. In an HSG inventory, each record comprises a maximum of five species, each with its own site code, age, stocking, and volume. In addition, fields are included for the stand working group (species, site code, and age class), total volume and area (Figure 2.4c).

<Code>	<Site>	<Age>	<Stocking>	<Volume>
PJ	1	67	0.46	106.4

Figure 2.4c Format and example of the individual species information present for each stand in a HSG inventory file.

The individual species volume present in a stand is calculated by looking up the species site/code volume from the appropriate yield curve, at the desired age, then multiplying this result by the species' stocking in the inventory to produce a scaled volume from the normal, pure-species 100% stocked yield curve. The underlying assumption is that species stocking is directly related to volume, and that this relationship holds true for all species and stocking combinations. HSG uses the species composition and stocking within a stand to determine stand volume, but it is also used to describe a biological stand condition.

Due to the detailed information contained within the inventory file, HSG is well suited to model alternative silvicultural systems: such as selection, seed tree, multi-pass, and shelterwood. The results of these systems' activities upon the stand's biophysical structure can be represented by changes in the stand's components listed within the inventory. Aggregate models do not contain, to the same degree, this information on an individual stand's species components and are thus unable to track the change in species composition that result from alternative silvicultural activities.

HSG controls changes in stand composition through a file referred to as a *state table*. This table applies changes in stand composition (species, site class, age and stocking) resulting from natural succession and management (harvest and regeneration) activities. The *state table* does not contain a mechanism to account for random natural events such as fire or insect infestations. Proper construction of this table is a key factor when using HSG. The *state table* operates by matching and then replacing the existing stand components with user-defined new stand components. This mechanism requires that assumptions regarding changes in stand structure are explicitly described in the *state table*. The user must be able to state explicitly the resulting stand structure taking into account the effect from all the possible site, age and species combinations that could occur within this stand. Some of the factors to be considered are: what are the effects of different levels of overall stand stocking on future stand composition; would a 50% stocked stand result in the same future composition as a fully-stocked stand? The possible combinations of future stand structures are too numerous to describe individually in the *state table* and as a result only a few general stand structures are typically described. Results produced with HSG, which contain detailed descriptive stand information, can produce a false level of detail when only a few working groups are actually described in the *state table*.

The information in the inventory is used not only to calculate yields from the forest, but also to describe the forest's structure in biological terms. There is real danger in over-simplification and misuse of the *state table*. For example, while reducing stocking by half may produce the correct volume results for a 50% strip-cut application, the resulting physical structure of the stand is poorly described by a 50% stocking reduction of the original stand. A 50% strip cut would actually result in the creation of two new stands. One new stand would have the same conditions as the original stand, but only half the area, while the other new stand would be a clearcut stand. Use of a descriptive inventory resulting from an improperly constructed *state table* that poorly describes the physical stand structure in a case where stocking is a critical factor (such as with a wildlife modelling exercise) may produce erroneous results.

In modelling exercises where clearcut harvesting is used exclusively, along with a high harvest level intended to regulate the forest, stand break-up has little impact because most stands are harvested before natural break-up takes place. When dealing with alternative silvicultural systems, however, the processes of succession and break-up become more important because these systems manipulate the natural process of stand development and succession to obtain a desired result. If the break-up and succession processes are not understood, and therefore not explicitly described, confidence in the results is weakened. Attempts should be made to describe these processes even in the absence of data because, as Ward Thomas (1979) has written: "To say we don't know enough is to take refugee behind a half-truth and ignore the fact that decisions will be made regardless of the amount of information available."

The main HSG command used to control HSG operations is the *STEP* command. This command controls the number of years in the iteration, ages the forest, sets the harvest targets, describes the rules to ranks stands for harvest, and sets the harvest method (Figure 2.4d).

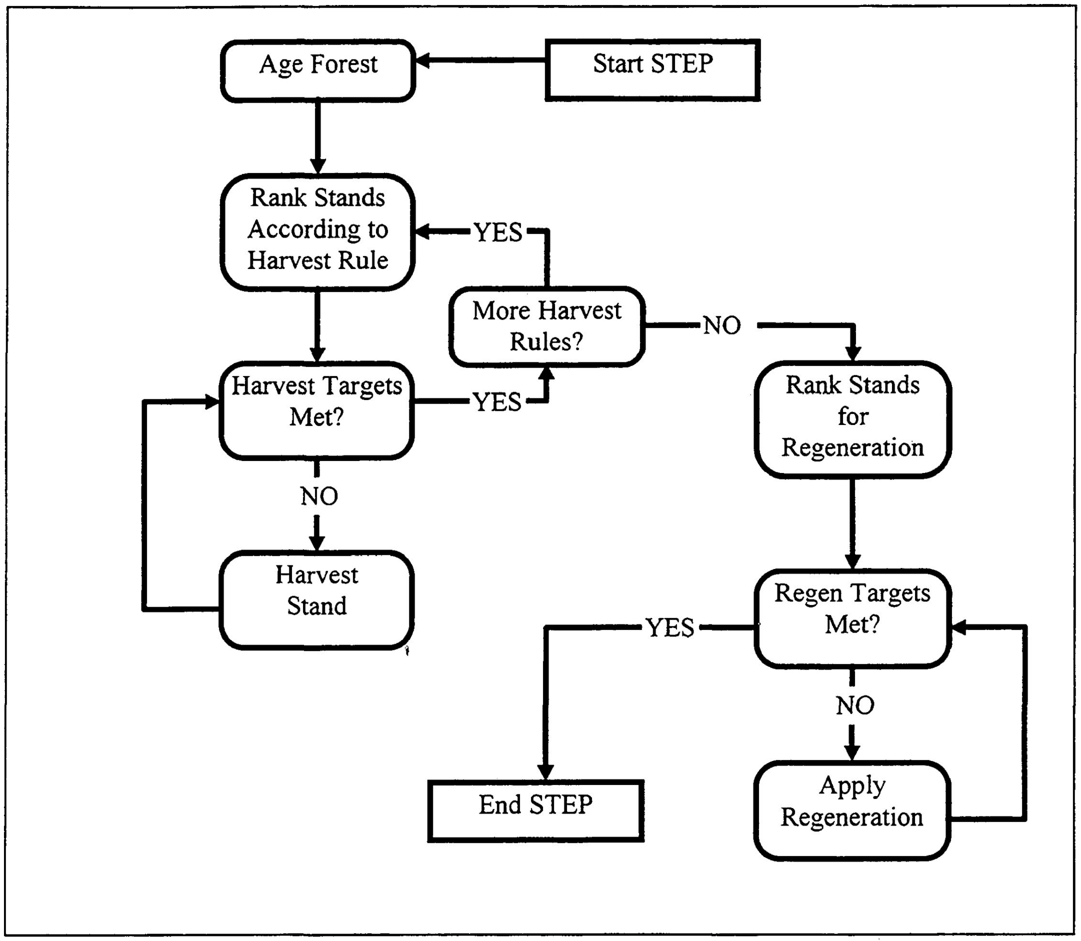

Figure 2.4d. General flow of HSG *STEP* function with multiple harvest rules to prioritise stands for harvest regeneration application.

Each *STEP* command establishes a global harvest target for the entire user-defined period. Any number of harvest rules, each with its own sub-target, can be used to control the harvest. The capacity of multiple harvest rules, each with its own harvest target and prioritisation method, is a useful feature when different harvesting methods are employed at the same time.

The model operates by first aging the forest. A base list of eligible stands is created by checking the forest stands against the user-defined global minimum stand volume operability limit (*OPMIN*). The *OPMIN* command is a constant applied throughout the simulation, used to set the minimum volume of all species that must be present in a stand to be economically operable (typically stands less than 40-50 m^3/ha are never harvested).

The first harvest rule in the *STEP* command is applied. A list of eligible stands is generated from the base list and ranked for harvest according to the harvest criteria of the current harvest rule. Individual stands are harvested until either the current harvest rule's target or the global target is satisfied, or there are no more eligible stands to harvest.

If the global harvest target is not satisfied by the first rule, the model continues harvesting according to the instructions in the second harvest rule. This process continues until either the global harvest target is met, there are no more harvest rules, or the list of eligible stands is exhausted.

As shown in Figure 2.4d, HSG splits the application of harvesting and regeneration treatments into two distinct functions within each step. First, all of the harvesting for the step is completed. The list of harvested stands is then ranked for regeneration treatments. These treatments are applied until the silvicultural treatment target is satisfied or the list of stands is exhausted. Separation of harvest and regeneration functions allows the ranking for regeneration treatments of the entire list of harvested stands for each *STEP* command. This permits regeneration treatments to be applied to best meet the regeneration goals. Unfortunately, when using this process the regeneration treatment is unknown when harvesting is conducted, so the potential effects of the regeneration treatment cannot be taken into account when harvesting.

HSG 2.0 was designed for biological scheduling but lacked the economic dimension required for this study. The following sections provide a background in economic theory in the context of harvest scheduling and forest management planning.

2.5 Forest Economic Theory

The competitive globalization of the world's economies, government fiscal restraint and changing public perceptions have forced change upon the management of Ontario's forests. As a result, the level of attention paid to economics, business principles and requests for economically based information is increasing. In the preface to his book, Nautiyal (1988) wrote:

> It must be conceded, however, that what most of these people [foresters and forest managers] seem to mean by knowledge of economics is, more correctly, a familiarity with business principles or financial analysis. It is rarely realised that economics does not merely mean dealing with dollars and cents but confronting larger issues of private and public choice involving human behaviour.

This statement contains two important but often misunderstood principles for forest management. First, economics is often confused with financial analysis and accounting; secondly, forest economics is a social science. It deals with the allocation of limited resources according to society's values expressed through human behaviour. As will be shown in the following pages, applying some economic principles to derive information for use in forest management is not difficult and it provides a framework to incorporate important information that until recently has been largely ignored.

In forest management, many of the management constraints, although expressed in biological terms, are economic, not biological. In Ontario, although annual silviculture level restrictions have been expressed in area, the constraining factor is usually available funds, not area. In addition, for variables that appear to be restricted by only biological factors, it is often an economic restraint which is actually the limiting factor.

For example, stand volume can be expressed as total gross volume or net merchantable volume. Total gross volume is not a useful measurement when considering forest products. Net merchantable volume, which is the appropriate measurement, is a function of gross volume and represents the amount of wood that can be economically recovered from the stand. Therefore, recovered volume depends upon an economic utilisation standard, which is a function of harvest systems, end use and demand.

Many different types of variables must be considered in forest management planning. The Annual Allowable Cut (AAC) is limited by biological variables (e.g. growth rate, species diversity, species requirements), economic variables (e.g. distance, road development, product requirements), physical variables (e.g. terrain, weather), and political variables (other uses, public perceptions, level of impacts, existing laws and regulations). In addition, many of these variables are affected by temporal and spatial dimensions. Incorporating all of these variables simultaneous into forest management is a daunting task. One impediment to utilising all of these variables is the type of measurement units associated with each. Standardising the expression of these variables into economic terms is one method of approaching this problem (Lockwood

1995). Although only a few of the many potential variables have been chosen for this study, the procedure could be expanded to include others.

The economic wood supply is that portion of the timber supply that is both physically suitable for commercial use and profitable to harvest (Nautiyal 1988). Some authors view the economic wood supply as a stock of timber (Williams 1994) but in this study it will be considered as a periodic flow of wood over an extended period of time. To understand how the economic wood supply is determined and how economic principles are used to prioritise forest management activities, some definitions and economic theory are discussed in the following sections.

2.5.1 Timber Valuation

The value of timber is often referred to as “stumpage” (Nautiyal 1988; Duerr 1993). This term is confusing because it has many different meanings. In an internal OMNR report on stumpage in Ontario (OMNR 1993a), “stumpage price” is defined, in broad terms, as the price per unit volume of harvested timber, and “stumpage value” the value of harvested timber (i.e., volume multiplied by stumpage price). Duerr (1993) defines “stumpage” as standing timber destined soon for harvest, and its value is derived from the value of the serviceable goods that will be made from the harvest. Nautiyal (1988) defines “stumpage” as the volume of standing timber and defines “stumpage value” as the price of timber standing on the stump. The term and definition used throughout this thesis is that supported by forest economists; “stumpage value” is defined as the value of timber standing on the stump (Nautiyal 1988).

Determining the stumpage value can be difficult. Stumpage value can be appraised by either prospective buyers or sellers. The result is that different values can be derived for the same timber depending upon the accounting stance of the appraiser (Duerr 1993). In competitive markets, stumpage value is estimated by what the highest bidder will pay. In imperfect (non-competitive) markets, such as is the case in northern Ontario, stumpage value can be determined using the residual timber value (RTV) technique (Nautiyal 1980; Nautiyal *et al.* 1995). This method, also known as the Rothery reduction technique, is determined by:

$$\text{RTV} = \text{finished product price} - \text{all processing costs} \qquad \textbf{[1]}$$

where the finished product price is the sum of the selling price of the optimum finished product mix produced from the timber, and processing costs are the sum of all costs incurred to produce that product mix, including investor return (profit), allowances for risk, manufacturing costs, taxes, transportation and harvest costs.

In Ontario, where the government controls Crown land and there is imperfect competition, RTV's can only be estimated in a manner similar to that used by Nautiyal *et al.* (1995). Nautiyal's approach is followed for this thesis.

In Ontario, RTV can be taxed by the Crown in the form of stumpage dues under the Crown Forest Sustainability Act of 1994 or retained by the industry as economic profit. A decision on how the RTV should be allocated as either tax, value to landowners, or profit to the conversion industries is beyond the scope of this thesis. However, the concept is useful as it represents either potential profit or tax revenue depending upon the accounting stance.

A rational forest manager seeking profit would only harvest timber from stands which are profitable to harvest; in other words, timber that has a positive RTV. Since RTV is a function of revenues and expenses, its value changes with different stand characteristics, distances to market and market prices. Determining the value of these components is therefore, of interest to the forest manager.

Greater value is derived in the ability to predict a stand's RTV under different management alternatives. With this information, the respective costs and benefits from a number of management alternatives can be judged by comparing the RTV's produced from each management alternative. This permits rational decision-making based upon predicted quantitative results derived from computer simulation instead of qualitative judgements. Not only can alternatives be compared to each other, but established numerical targets can be compared against actual results (Lee 1993). This information is useful not only to buyers and sellers of timber, but to managers of other forest resources.

2.5.2 Present Net Value

Discounting is applied in Present Net Value (PNV) calculations, sometimes referred to as Present Net Worth (PNW). The PNV calculation provides a mechanism to compare streams of revenues and expenses over time periods of varying length. This is accomplished by discounting the revenues and expenses back to a common date. The comparison of different time periods is important to this study.

Discount rate measures can be either real or nominal. The nominal discount rate is the rate charged by banks. The real discount rate is the nominal rate less the inflation rate. The real discount rate is often lower than perceived due to inflation. Nautiyal (1988) calculated Canada's real discount rate for the twenty-five year period 1961-1985 as just less than 3 percent.

2.5.3 Marginal and Average Costs

The distinction between the concepts of marginal and average costs is central to economic theory. Average cost is determined by total cost divided by quantity produced. Each unit of quantity produced has an equal average cost. Marginal cost is the cost to produce the last unit of output (Nautiyal 1988). Marginal cost varies with each unit produced unless there are constant returns to scale. Marginal and average production rates are well known to foresters in the form of annual tree growth increments. Knowledge of a tree's Mean (average) Annual Increment (MAI) is useful when analysing growth. Useful, too, is the tree's Current (marginal) Annual Increment (CAI) which is the growth of the last increment. Most useful, though, is the combination of both values, with the optimum volume-based rotation age occurring when the MAI equals the CAI (Smith 1986). The same concept holds true in economics. Optimal economic production is found when average production cost equals marginal production cost. This concept is used in the development of the opportunity cost of harvest delay scheduling methods (Armstrong *et al.* 1992).

2.5.4 Opportunity Cost

Opportunity cost is defined as the value of the highest foregone alternative (West and Miller 1978). Duerr (1960) identified three different types of opportunity costs in forest management. Type (a) opportunity cost is the cost of waiting out the rotation or the cost incurred by not harvesting the current crop now. This cost is simply the interest cost of the current crop less the value added during the same time period. Type (b) opportunity cost is the cost of postponing the yields from subsequent rotations. This cost can also be thought of as the cost of holding land. Since land usually has other uses, there is an opportunity cost of using the land for timber production unless it is the optimum land use. Even if there is no other land use, the opportunity cost is not zero. There is always the opportunity to harvest the existing crop and using the land to start a new crop. The type (b) opportunity cost can also be thought of as the indirect cost of waiting not just one rotation, but all the subsequent rotations before a new crop is begun (Nautiyal 1988). Therefore, it can be viewed as the cost of delaying future rotations and is calculated by multiplying the interest rate by the present net worth of the stand. Type (c) opportunity cost is the cost of regulating the timber growing stock in such a fashion that yields can be harvested annually (Duerr 1960). Put another way, this cost arises from the cost of waiting to harvest stands in order to even out the flow of timber.

2.5.5 Soil Expectation Value

Much of forest economic theory is based upon the work of Martin Faustmann. He developed a formula designed to calculate the present value of bare forest land, from which an infinite series of harvests are expected (Pearse 1967). This value is often referred to as the land or Soil Expectation Value (SEV). The SEV (equation [2]) can also be thought of as the Present Net Worth (PNW) of bare land which will receive an infinite series of silviculture treatments producing forest products (Nautiyal 1988).

$$F(t) = \frac{H(t)e^{-rt} - S}{1 - e^{-rt}} \qquad [2]$$

Where:

F(t) = the SEV (in $/ha)
H(t) = a function of the value of timber at time (t), (in $/ha)
t = time (years)
r = discount rate (decimal)
S = the PNV of the total silvicultural costs including regeneration and all tending costs (in $/ha)
e = ~ 2.7182 (base of the natural logarithm)

Equation [2] requires a function (H) of the value of timber at rotation (t). For any given rotation period (t), the function for the value of timber can be substituted for the RTV at that time. Making this substitution and rearranging equation [2] produces equation [3].

$$F(t) = \frac{V(t) \times \left[P(t) - C(t) - M(t)\right] - S \times e^{[r \times (t)]}}{e^{[r \times (t)]} - 1} \qquad [3]$$

Where:

F(t) : SEV of a single hectare stand at time (t) with treatment S (in $/ha)
(t) : the expected harvest age of the stand with regeneration treatment S (in years)
V(t) : stand volume at time (t) (in m^3/ha)
P(t) : value of the stand's products at time (t) (in $/$m^3$)
C(t) : cost of harvesting the stand's products to roadside at time (t) (in $/$m^3$)
M(t): total transportation cost of stand's products to mill (in $/m3)
S : present value of all regeneration costs for the stand (in $/ha)
e : ~2.71828 (base of the natural logarithm)
r : discount rate expressed as a decimal

The SEV result pertains only to the silvicultural regime and rotation age (t) specified. Thus, equation [3] will produce an optimum SEV only when the optimum rotation age (t*) and the optimum silvicultural regime are used. This permits an economic stand-level comparison between different silvicultural treatments. If there are no other constraints, the profit-maximising manager would choose the treatment with the greatest SEV. In contrast, if the SEV is negative, the manager would choose not to grow a forest crop (based solely on economic principles).

2.6 Applying Economic Theory to Forest Planning Models

Commercially available forest-level models have permitted financial analysis in their allocation of forest resources. FORMAN 2.1 (Wang *et al.* 1978) selects forest classes for harvest based upon cost to roadside. Economic studies using derivatives of this model (Willcocks *et al.* 1990; Williams 1990b) use economic principles such as present net worth and benefit cost analysis to select among alternative management strategies. However, in these studies, stand volume was used to schedule the treatments. An economic analysis of the treatment schedules was used to rank the management strategies. The result is an economic analysis of volume-based forest management decisions. The assumptions used in this process is that decisions based upon volume parameters are the "best" decisions, economic or otherwise, or that there is no significant difference between economic or volume-based scheduling.

In studies to determine the value of timber in northern Ontario (OMNR 1993c; Nautiyal *et al.* 1995) it was found that distance and piece size were the primary variables for determining timber value. An economic analysis should contain at least these variables. Models have been developed that contain some of these variables (Iverson and Alston 1986; Zundel 1993; Lockwood 1995). However, these models are often difficult to apply to other cases, or not technically supported and thus not widely used (Lougheed 1988; Koven and Martel 1994; Rouck and Nelson 1995).

Forest management involves both the selection of activities and the timing of their application over extended periods of time. In many cases, in order to maximise forest-level returns, stand-level treatments must be applied that appear inefficient when using stand-level criteria. The forest manager must decide which inefficient treatments will be applied to which stands and when in order to meet the forest-level objectives (e.g. even-flow, adjacency, minimum cover types, other uses). Stand-level economic models cannot provide the optimum forest-level treatment since they fail to consider the forest-level implications. However, stand-level projections of management options can be used within a forest planning model to predict how individual stands will respond to different treatments.

Economic principles such as opportunity cost can be used to set priorities on stands for harvest (Armstrong *et al.* 1992; Lockwood 1995). Opportunity cost allows for a greater range of inputs such as haul cost and product values to be included in the scheduling rule, when compared to strictly volume-based harvest rules. The difference between stand-level and forest-level applications is that, at the forest level, harvesting would not necessarily take place at the optimum stand-level rotation age. Instead, stands would be ranked according to their opportunity cost and the number of stands treated would be determined according to forest-level constraints. Opportunity cost is a useful measure for forest management planning because it can provide the cost of delaying an activity at each time period. This ability to predict the opportunity costs of delay until the next period at each iteration makes opportunity cost useful in simulations which operate with distinct time periods.

Soil expectation value is another method that can be used to set priorities to stands for silvicultural treatments. Calculating SEV will permit the forest manager to determine the relative return of a number of treatment alternatives and stand conditions, thus providing a means to rank and select among silvicultural treatments. Like opportunity cost, SEV brings a greater range of inputs into the selection of silvicultural treatments.

2.6.1 Potential Harvest Priority Methods

Forest-level simulation models that apply treatments to individual units (e.g. FORMAN, HSG) use harvest priority rules which arrange the eligible stands for harvest in a manner which represents a management strategy or mimics an operational approach. The operation of these rules is quite simple. First, all the stands eligible for harvest within a period are determined. A list of stands meeting these requirements, and thus eligible for harvest, is prepared. Stands in this list are then ranked for harvest according to the specific priority rule employed. Harvesting begins at the top of the list and continues until either the harvest volume target is obtained, or the list of stands is exhausted. In this way, stands that best fit the requirements of the harvest priority rule (thus the management strategy) are harvested first.

Rule-based control over the harvest pattern is limited to the variables considered by the harvest priority rule. Volume-based priority rules can only control volume attributes; similarly, age-based harvest priority rules only consider age. For example, HSG 2.0 has three harvest priority rules:

- Rule_0: harvest oldest stands first;
- Rule_1: maximise harvested volume; and
- Rule_2: minimise non-harvested volume loss.

The best rule to use will harvest stands according to the real-world conditions and the management strategy planned for the forest being modelled.

The choice of harvest priority rule depends upon the objectives of the modelling exercise and the structure of the forest (Moore *et al.* 1994). The Present Net Value and Opportunity Cost priority rules are the only ones which consider the three main economic factors in determining the value of forest products removed from a stand: the selling price of the individual products produced in the stand, the cost to produce those products at roadside, and the cost of transportation (Table 2.6.1). The major problem with the PNV rule is the large negative values often associated with the boreal forest (OMNR 1993c; Nautiyal *et al.* 1995). Under these situations PNV (harvest the most profitable stands first) would harvest the youngest eligible stands first. Most forest managers would not want to harvest the youngest stands first. If the PNW is negative, a profit-maximising forest manager would not harvest any stands. Under the same conditions, the "opportunity cost of harvest delay" rule would select those stands that are costing the most not to harvest. Since the loss would be greater, older stands would be harvested first. In this way, opportunity cost of harvest delay operates in a manner similar to a rule of minimise non-harvested volume loss, except that economic variables are used instead of volume variables.

Table 2.6.1. The advantages and disadvantages of several potential harvest priority ranking rules.

Priority Method	Advantages	Disadvantages
Volume (m^3/ha)	-traditional format -easy to understand -no modifications required to run model -simple methodology	-only considers volume -no spatial input into rule
Harvest Cost ($/$m^3$)	-easy to calculate -works well if harvest costs only are to be considered -easy to comprehend - average harvest costs are available	-value of the products produced from the stand are not considered -does not directly consider other biophysical properties
Present Net Value (PNV) (current forest value) ($ or $/$m^3$)	-can be used to maximise/ forest value -permits the addition of economic variables in the harvest queue	-often produces values in the negative range -may select the youngest stands for harvest in forests with slow growth rates
Opportunity Cost of Harvest Delay ($/$m^3$ or $/ha)	-can control the loss/increase in product value -does not depend upon "optimum economic rotation"- fits well with forest level goals (even-flow) -selects stands across a wide range of biological variables similar to current allocation process in Ontario	-does not optimise stand or forest level yields -provides an opportunity cost for the current time period only, not for total simulation - difficult to determine

Few forest management planning models applied to the boreal forest account for opportunity costs associated with management activities. However, Armstrong *et al.* (1992) compared two opportunity cost of harvest delay scheduling functions on a study area in Saskatchewan. One scheduling function expressed the opportunity cost of harvest delay as a function of stand area, while the other, expressed the opportunity cost of harvest delay as a function of stand volume. Linear programming formulation was used to compare the difference in harvest scheduling between the two functions on the case study forest. Their objective function minimised the net opportunity cost of delayed harvest by first scheduling those stands which cost the most if the harvest is delayed.

Most firms in the boreal forest operate under government-imposed harvest constraints which include policies constraining periodic harvest volume. Armstrong *et al.'s* (1992) study is applicable to firms operating under such constraints. The results of their study showed that when volume-based opportunity cost ranking criteria are used, there is an economic net gain and that a much wider variety of species associations and site classes are scheduled for harvest. They concluded that this mix of harvested species and sites is consistent with the observed behaviour of firms which tend to harvest from a wide range of species and site associations.

This behaviour of harvesting from a wider range of stand conditions seems to contradict economic theory which suggests that the best natural resources should be extracted first (Pearse 1990). This does not mean that the "extract the best first" principle is inapplicable here. It simply means that the forester's idea of best (high volume and site index) is inappropriate. In this context, the best timber type is the one that will reduce the opportunity costs of harvest delay the most (Armstrong *et al.* 1992).

2.6.2 Developing An Opportunity Cost of Harvest Delay Rule

Harvest scheduling by opportunity cost has been used in forest-level models (e.g. Armstrong *et al.* (1992); Clarkson (1993); Lockwood (1995) and Mussell and Fox (1995)). The concept behind this approach is relatively simple. Consider the case of a one-hectare forest stand which will be used to produce forest products for the foreseeable future. A profit-maximising manager will harvest the stand when the cost of maintaining the stand in a forested state equals the marginal value (loss) of the products produced from the stand. Thus, the stand will be harvested when the interest cost of the stand's current value over the next year (including the value of the land) just equals the increase in value of the stand's products for the same time period. The stand should be harvested when it is still adding volume (and value) at the optimum point. Following this, if the marginal benefit of delayed harvest is less than the marginal cost, a stand should be harvested as it is increasing in value at a rate less than the cost to keep it. Similarly, when the marginal benefit of delayed harvest is greater than the marginal cost, the current crop should be left to increase in value. This provides a decision rule of when best to harvest a one-hectare forest stand.

How can the opportunity cost of harvest delay be used to determine the allocation and the timing of stands for harvest at the forest level, where the decision of when to harvest is complicated by additional forest-level constraints and the best forest-level decision could be a poor stand-level decision? Opportunity cost scheduling will first harvest those stands that are loosing the most value (greatest opportunity cost of harvest delay). Harvest priority setting will continue selecting the stand with the greatest opportunity cost each time until the harvest targets are reached, not necessarily when the opportunity cost of harvest equals zero. In this way, opportunity cost is used to rank the stands for harvest based upon the stand's current condition at each period in time and the harvest target achieved is a forest-level target.

Following the method suggested by Armstrong *et al.* (1992), a formula to determine the opportunity cost of delay in harvesting a stand can be developed. The development of this formula is based upon the land valuation method of Faustmann, and the optimum forest rotation model explained by Pearse (1967). The following assumptions pertain:

- there are no accessibility, harvest volume, or area constraints;
- the optimum silvicultural regime is known;
- the firm has secure tenure; and
- prices, costs and the discount rate are all known and constant.

Starting with the general SEV equation [2] and given a strictly concave function for bare land value (where **F"(t)<0**) the optimal harvest age **(t*)** can be determined as the age where the first-order condition for maximisation, (i.e. where **F'(t*)** = 0) is satisfied. Thus:

$$F'(t^*) = H'(t^*) - \left[rH(t^*) + r\frac{H(t^*)e^{-rt^*} - S}{1 - e^{-rt^*}} \right] \qquad \textbf{[4]}$$

From equation [4], there is a point where the rate of change in the optimum land value (**F'(t*)**) equals the rate in change in the timber value less the interest cost in the value of timber plus the interest cost of the optimum land value. This occurs at a point where the rate in change in the optimum land value equals 0. Therefore, setting **F'(t*)** equal to 0, produces equation [5]:

$$0 = H'(t^*) - \left[rH(t^*) + r\frac{H(t^*)e^{-rt^*} - S}{1 - e^{-rt^*}} \right] \qquad \textbf{[5]}$$

which can be rewritten as:

$$H'(t^*) - r[H(t^*) + F(t^*)] = 0 \qquad [6]$$

Recall that the optimal harvest age is the age where the marginal value growth is just offset by the interest costs incurred by not liquidating the existing forest inventory and starting a new timber stand. The decision rule is then to choose t^* (the optimum rotation age) such that:

$$H'(t^*) = r[H(t^*) + F(t^*)] \qquad [7]$$

The opportunity cost of delay in the harvest of a hectare of forest land ($D_a(t)$) is:

$$D_a(t) = rH(t) + rF(t^*) - H'(t) \qquad [8]$$

Where $rH(t)$ is the interest cost of holding the forest inventory at any given age (t); $rF(t^*)$ is the interest cost of holding land; and $H'(t)$ is the marginal value growth of the timber. This is the opportunity cost calculated at any age (t) not just at the optimum rotation age (t^*). The opportunity cost of delay in harvest per cubic metre (m^3) of timber from the same hectare $D_V(t)$ is:

$$D_V(t) = \frac{rH(t) + rF(t^*) - H'(t)}{V(t)} \qquad [9]$$

3 MATERIALS AND METHODS

HSG (Moore and Lockwood 1990) was the forest planning model chosen for this study. Modifications were made to the model to incorporate both partial stand harvesting and economic criteria. Data sets were prepared for both a test case forest (Seine River Forest) and a set of theoretical forests. Scenarios were developed that represented either the traditional 1980's FMA sustained-yield management philosophy of clearcutting followed by artificial regeneration, or a management philosophy of partial harvesting and natural regeneration which utilised alternative silvicultural systems.

3.1.1 Case Study Area: The Seine River Forest

The Seine River Forest (SRF) is located approximately 200 kilometres north-west of Thunder Bay and 100 kilometres east of Fort Frances, Ontario. This forest is Crown land managed by Stone Consolidated under a Forest Resource License (Legislative Assembly of Ontario 1994). The forest falls within the Great Lakes-St. Lawrence Forest Region (Rowe 1972) but is largely within the transition zone between the boreal and Great Lakes-St. Lawrence forests.

An existing digital FRI of the Seine River Forest (SRF), updated to 1991, was supplied by Stone Consolidated and converted into HSG format. The spatial inventory used in this study originated on Stone Consolidated's ARC/INFO system. The inventory was converted to a grid format (200 X 200 m cells) required by IDRISI (Eastman 1992b). This conversion resulted in the loss of almost 1000 of the 8000 polygons in the inventory; resulting in a loss of less than 4% of area. This reduced forest inventory consisting of 7093 polygons was the inventory used in the simulations. The polygon structure is composed of both forest and non-forest types. Like many boreal forests in Ontario, the distribution of age classes in the SRF is unbalanced. The majority of the productive forest area falls in the 60-to-90 year range (Figure 3.1.1a).

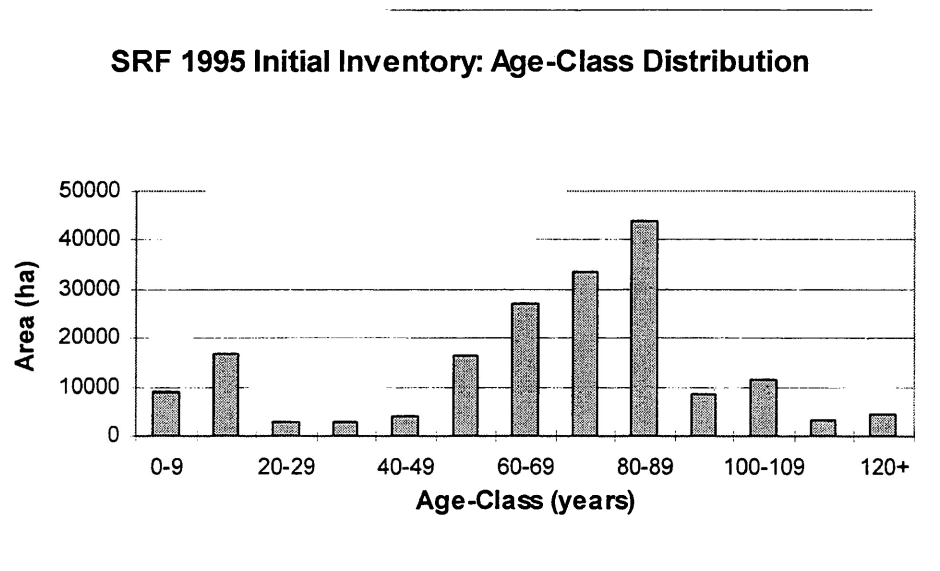

Figure 3.1.1a. Ten-year age-class distributions of the initial SRF inventory advanced to 1995 as used for the HSG simulations.

To capture the volume present in the older ages and to produce a forest structure that will provide a steady stream of forest products in the future, some degree of accelerated harvest level will be required in the short term. This is a common situation which most forest simulation models are designed to accommodate.

The growing stock volume in the SRF is composed primarily of three species: jack pine ((Pj) *Pinus banksiana* Lamb.), black spruce ((Sb) *Picea mariana* (Mill.) B.S.P.) and poplar ((Po) *Populus tremuloides* Michx.) (Figure 3.1.1b). The volume of the six remaining species make up only a small percentage of the total volume.

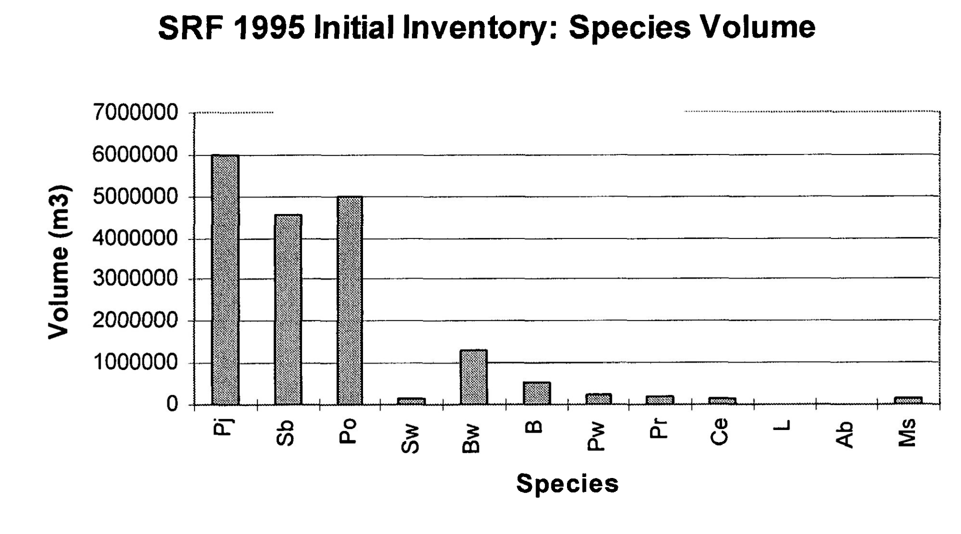

Figure 3.1.1b. Total merchantable growing stock volumes of the species present in the SRF initial inventory advanced to 1995 as modified for the HSG simulations[1].

Jack pine, black spruce, poplar and white birch ((Bw) *Betula papyrifera* Marsh.) are usually associated with fire-dominated stands as they are pioneer species that prefer open sunlight and rapidly colonise a site following disturbance (Fowells 1965). The combination of pioneer species and the dominance of the 60-to-90 year age class defines this forest as a disturbance-driven ecosystem.

3.1.2 Hypothetical Forests

Computer-generated hypothetical forests utilising the SRF polygon structure, consisting of a limited range of species and site-class combinations, were constructed. Ages were assigned to create a normal, young and old-age forest. The hypothetical forests were constructed for two reasons. One was to test and debug model behaviour on a

[1] Species follow OMNR FRI naming convention: jack pine (Pj), black spruce (Sb), trembling aspen (Po), white spruce ((Sw) *Picea glauca* (Moench) Voss), white birch (Bw), balsam fir ((B) *Abies balsamea* (L.) Mill.), white pine ((Pw) *Pinus strobus* L.), red pine ((Pr) *Pinus resinosa* Alt.), white cedar ((Ce) *Thuja occidentalis* L.), larch ((L) *Larix laricina* (Du Roi) K. Koch), black ash ((Ab) *Fraxinus nigra* Marsh.), soft maple((Ms) *Acer rubrum* L.).

simple forest structure. Second, based upon previous studies, it was hypothesised that forest age-class structure would have a large impact on the biological and economic indicators of a management strategy (Willcocks *et al.* 1990; Clarkson 1993; Whitmore, 1995). The hypothetical forests were generated to test this hypothesis.

In generating the hypothetical forests, the existing polygon structure (7093 polygons) remained constant, but the fields for stand date of origin, site class, stand stocking and species composition were altered for those records containing merchantable forest stands. The first step was to prepare a list of suitable species compositions representative of stands in northwestern Ontario's boreal forest (Appendix I). This species list was randomly assigned to stands using the random number generator in FoxPro 2.6 (Microsoft 1993). The range of site classes was reduced from five in the original SRF inventory, to three (1,2 and 3), and forest stands were assigned randomly to a class. Stand stocking was changed to fully stocked (100%) for all stands to further simplify the forest structure.

Using this resulting forest structure as a constant base, three age-class structures (normal, young and old age) were prepared to test the impact of changing the initial age class structure. The normal forest was prepared by assigning ages between 1 and 100 to all forest stands randomly. The young forest was developed by assigning the same range of ages but the random number generated was squared to create an exponential distribution. The old forest was prepared by rerunning the young and subtracting the result from 100. The actual formulae used were:

Normal Distribution: New_org = [Yr_upd - (100*RAND())]

Young Distribution : New_org = [Yr_upd - (100*RAND()^2)]

Old Distribution : New_org = [Yr_upd - (100 - (100*RAND()^2))]

The variation in age-class structure between these forests is slight compared to some natural forests since there are no empty age classes (Figures 3.1.2a, 3.1.2b, 3.1.2c).

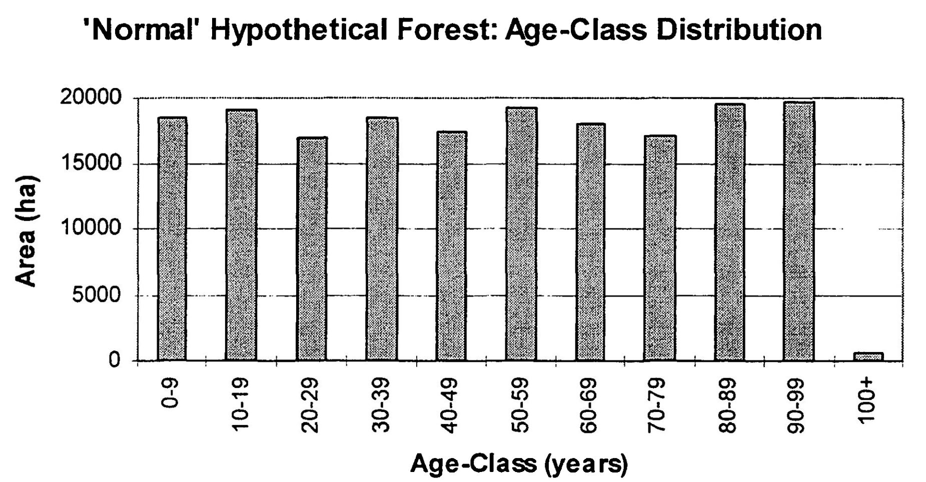

Figure 3.1.2a. Ten-year age-class distributions of productive forest area updated to 1995 for the "Normal" hypothetical forest.

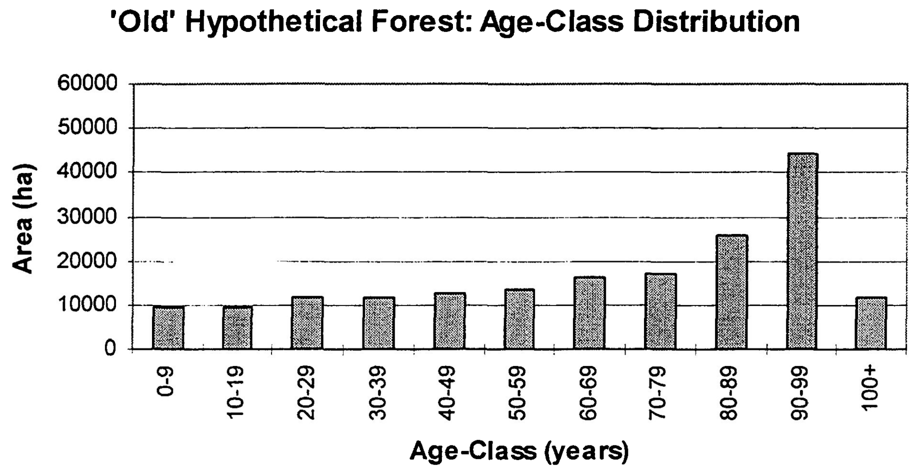

Figure 3.1.2b. Ten-year age-class distributions of productive forest area updated to 1995 for the "Old" hypothetical forest.

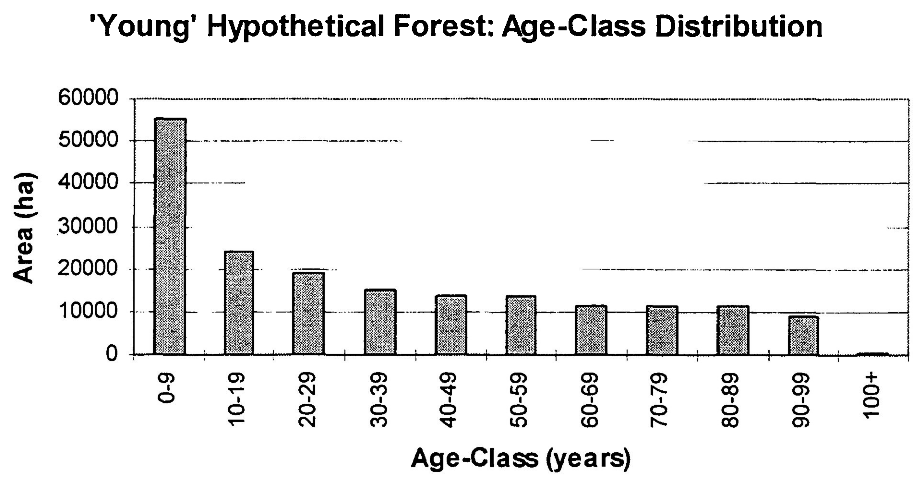

Figure 3.1.2c. Ten-year age-class distributions of productive forest area updated to 1995 for the "Young" hypothetical forest.

3.2 HSG Modifications: Version 3.0

Three major changes were made to the HSG source code for this study. First, a method was developed to permit partial harvesting. Second, a new harvest priority rule using economic harvest and regeneration parameters was added. Third, changes were made to the output files to track the previous changes. The modified version is referred to as HSG 3.0.

HSG is written in standard C. There is no difference in the HSG source code between the UNIX and DOS versions. Other than the operating environment, the primary difference lies in the package of utilities included with the DOS version of the HSG Modelling System. The modifications made to the model were confined to the HSG source code which was used to produce new versions of the HSG executable file. The DOS version was compiled on the DJGPP compiler (Delorie 1995), permitting large inventories to be run.

3.2.1 Harvest Modifications

The modifications made to the HSG model were accomplished through changes in the source code. A copy of the Version 2.0 source code was supplied by Tom Moore of The Canadian Forest Service at Petawawa, Ontario. A computer science graduate student (Sandy Gordon) was hired to make the actual program source code changes under my guidance. The first step in the process was to determine how the HSG model operated and what information was tracked internally. Using this information, proposed modifications were developed and the source code modified. The modified version was tested and debugged with specially designed data sets.

HSG was initially designed to support the clearcutting of whole stands. Although it contained information on individual stand components, it had no mechanism of harvesting these components individually. The HSG model was modified to allow the harvest of portions of individual stand components, to simulate the impact of the partial harvesting used in alternative silvicultural systems.

HSG 3.0 retains most of the operating features and structure of version 2.0. All of the harvesting changes were made within the *STEP* command. The creation of a base list and aging of the forest remains unchanged. The harvest changes consist of two new partial harvest functions and the addition of modifiers to apply additional control over stands eligible for harvest. The modification process is described in the following text.

The harvesting process begins with the creation of a base list of eligible stands for harvest (Figure 3.2.1a). The base list is a subsection of the inventory containing only those stands with volumes greater than that specified in the *OPMIN* command and which are flagged as "available" when the optional *CONSTRAINTS* command is included.

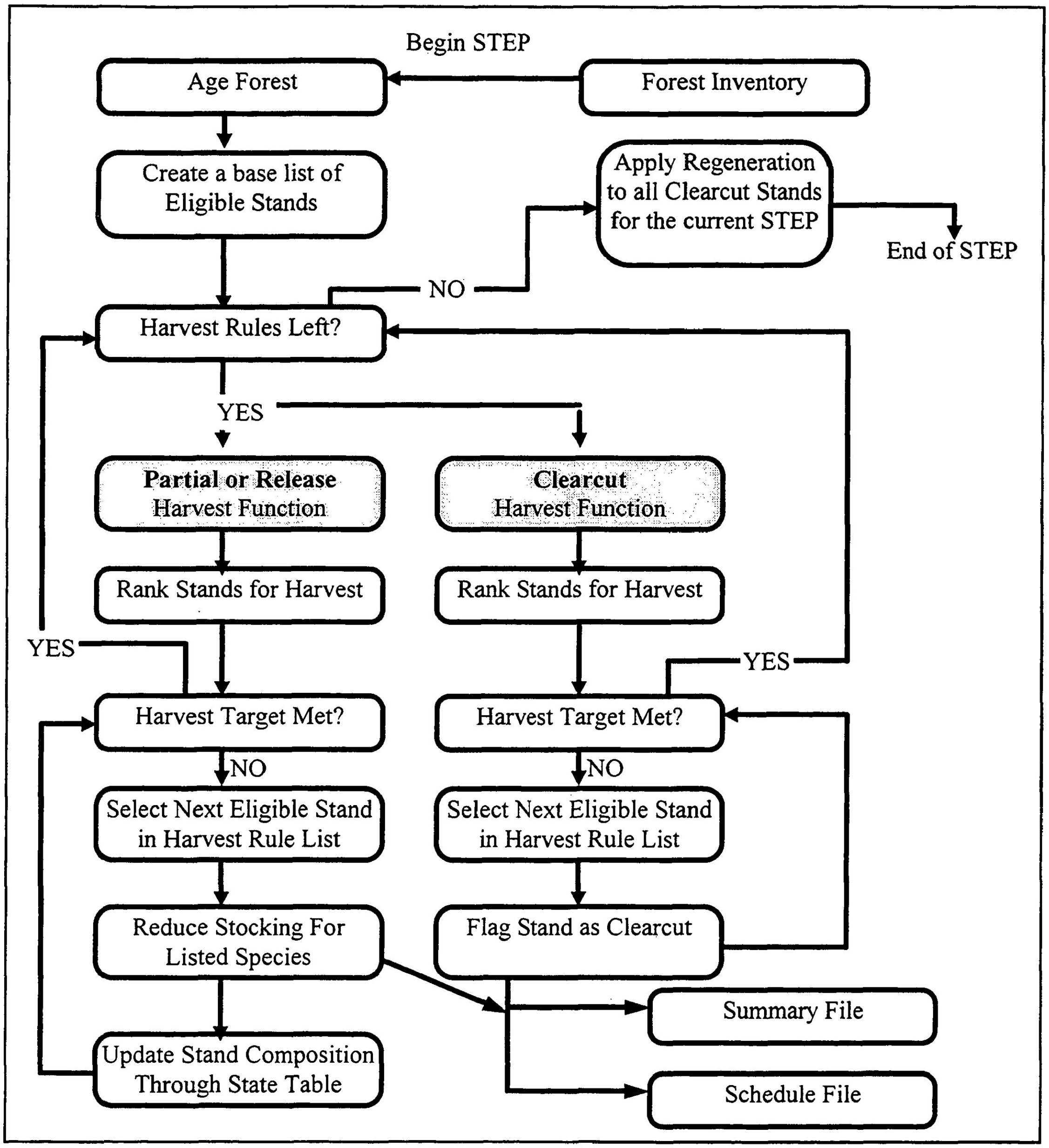

Figure 3.2.1a. HSG 3.0 *STEP* command detailing the differences between the clearcut harvest function and the modified harvest functions: Release and Partial.

The planner specifies the harvest targets, harvest priority ranking rule to be used, the modifiers to be applied to the priority rule, and the species to be harvested. The model then determines if the global harvest targets for the step have been satisfied. If not, the model selects and applies the first harvest priority rule. From the stands in the base list, a new list of stands eligible for harvest is generated. These stands are ranked based upon the criteria described in the current priority rule. If the harvest targets for the current priority rule have not been met, the model harvests the first eligible stand. If there are no priority rule modifiers, the model clearcuts the first stand following the same process used in version 2.0 (Figure 3.2.1a).

If the harvest function is modified as either "*Partial*" or "*Release*", the model applies the listed harvest function. The *Partial* and *Release* harvest functions are constructed in a similar fashion. The only difference between them is their names. This was done to permit the tracking of two different treatment types within a simulation.

The *Partial* and *Release* functions were designed to follow the same general format as the clearcut function. The stands in the base list are checked for eligibility and ranked for harvest following the criteria described in the current harvest priority rule. The result is a harvest priority rule eligibility list. Next, the harvest target for the current priority rule is checked to determine if it is satisfied. If not, the modified harvest rule is applied to the first stand in the harvest priority rule eligibility list. In this function a harvest volume is calculated for each species in the stand which is also present in the current priority rule. The harvest volumes by species are then reduced by the percent value listed in the modifier for the current priority rule. The resulting reduced harvest volume is reported in the summary database file as either *Partial* or *Release* using the same format as the clearcut function.

The modified harvest priority rules also reduce the stocking component for each harvested species in the stand by the specified percent. Only after these changes are made is the stand description written to the schedule database file. Therefore, the stand description in the schedule file from either *Partial* or *Release* harvest is the stand structure as modified immediately after harvest. In the clearcut function the stand description in the schedule file is the stand condition before harvest.

After the harvest, the modified harvest functions attempt to match the stand to the *state table*. If no match is found, the stand remains as modified and a message is sent to the screen to notify the user that no match was found. If a match is found the stand is updated to the condition described in the *state table*.

This application of the *state table* is the silvicultural treatment for partial harvest stands. It is applied to the stand during the harvest function, not with a separate regeneration function used for clearcut stands. No further regeneration treatment (i.e. elite, intensive, basic or extensive) can be applied to partially harvested stands. In this way, the *Partial* and *Release* functions assume that the harvest technique must be followed by a specific regeneration treatment.

Harvesting continues until either the harvest target is satisfied or there are no more eligible stands in the harvest priority rule eligibility list. When this is complete the model checks for more harvest rules in the *STEP* to begin the process again. As with HSG 2.0, any number of harvest rules can be applied in a single *STEP*.

The partial harvesting algorithm was designed to mimic the harvesting patterns resulting from selective cutting techniques such as multi-pass harvesting. These techniques remove a portion of a stand and are usually fairly evenly distributed throughout the stand. Block or strip harvesting is not well represented by the new partial harvesting algorithm. The following is an example of how the modified harvest rule can be applied.

Consider a poplar and spruce stand to which a two-pass silvicultural strategy will be applied. The stand is composed of two distinct vertical layers of one species each. The poplar component is 70 years old and the spruce 20 years old. The first harvest pass would remove the overstory of poplar and leave the spruce understory to form the next crop. In this case the user would instruct the model to harvest 100% of the poplar from the stand and leave the other stand components untouched. The result would be a 20-year-old spruce stand stocked to the level which existed before harvesting. Therefore, the stand in the model would closely represent the actual stand in the forest. However, the stocking of the spruce component in the model would not likely represent the actual stand stocking several years after harvest. Through time the stand stocking would move closer towards a fully-stocked stand. Specifically, stocking of the spruce would likely increase through seeding and some poplar would regenerate through coppice growth. A mechanism was required in the model to account for this ingrowth. This was accomplished in HSG 3.0 by calling the *state table* immediately after partial harvest. The user is provided with the option to either define the new stand structure to reflect the changing stand composition or to leave the stand structure as modified by the partial harvesting function.

The shelterwood system is another silvicultural system that was considered when developing the partial harvesting algorithm. This system removes a portion of the species components from the stand. The user would accomplish this by specifying the percent of the target species to be removed from the stand. HSG would then reduce the target species stocking in the inventory by the specified amount. The stand would then be matched to the *state table* to alter the stand's components to represent the new stand development path.

Alternative silvicultural systems are applicable to a narrower range of biophysical conditions than clearcutting. Therefore, HSG 3.0 was designed to permit the use of two harvest priority rule modifiers with any of the three harvest functions described above. One modifier is the *Harvest Allocation List* (HAL) used to restrict harvesting to a user-defined range of working group conditions. A HAL file was created to describe the range of stand working group variables (species code, site and age) that a potential stand must match to be eligible for harvest by the current harvest priority rule. In this manner, a harvest priority rule can be restricted to specific working groups. The second modifier created was the *harvest protection period* (HPP) (Figure 3.2.1b).

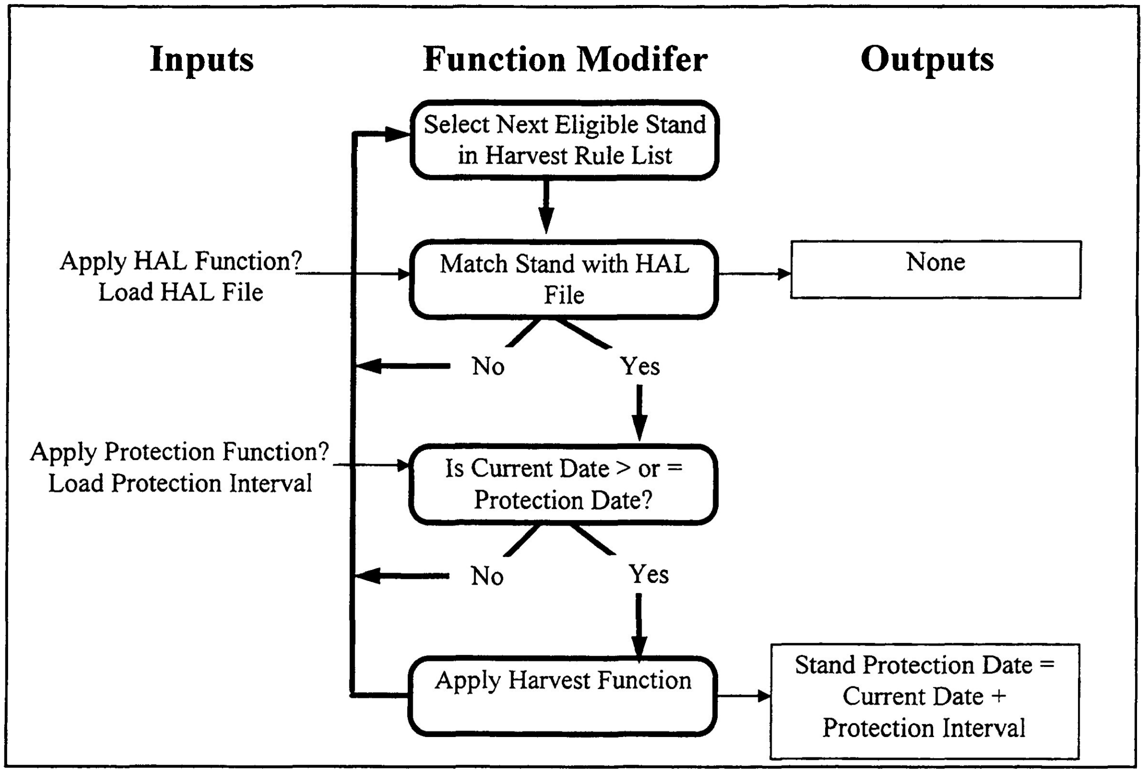

Figure 3.2.1b. Flow chart for HSG optional harvest function modifiers.

When a stand is selected for potential harvest and a HAL file is included in the harvest rule, the stand is tested against the list of working groups in the specified HAL file before harvest. If a match is found, harvesting of the stand continues. If no match is found, the stand is by-passed and the next stand in the harvest priority rule eligibility list is selected and tested against the HAL file. A stand will be harvested if, and only if, it matches at least one record in the designated HAL file. A stand matches a record if, and only if, both of the following are true:

- the working group species and site codes match exactly, and
- the stand age is greater than or equal to the lower bound and less than or equal to the upper bound.

This feature provides the user with the ability to restrict the range of eligible stands by working group for each harvest priority rule. Eligible stands are defined by working group species, site class and a range of years. There is no limit on the number of records in a HAL file, and any possible working group combination can be specified.

Often when an alternative silvicultural treatment, such as shelterwood, is applied to a stand, merchantable volume is still present. However, the stand should not be harvested until it has developed to a desirable condition. For this reason the *harvest protection period* function was created in HSG 3.0. This new capacity should not be confused with the separate “reserve” and “available” feature applied through the *CONSTRAINTS* command which was retained from HSG 2.0. The *harvest protection period* is an optional user-defined value that may be applied to each harvest priority rule to protect stands from harvest for a specified time period. This function operates by adding the number specified in the harvest priority rule to the current date in the simulation, to obtain a harvest protection period date. This date is stored in the inventory for each stand harvested by the rule. After a potential stand is checked for a match in the HAL file, its harvest protection period date is compared against the current date in the simulation. If the current date is greater than or equal to the harvest protection period date, the stand is eligible for harvest. The *harvest protection period* is checked before all stands are harvested, irrespective of whether a *harvest protection period* is specified in the priority rule.

The *harvest protection period* can be used to protect a stand from harvest until desirable stand conditions are established. Alternatively it can be used in conjunction with the *state table* and harvest rules to “hold” a stand within a range of conditions while partial harvesting is conducted upon the stand at regular intervals.

As mentioned earlier, HSG 2.0 permits multiple harvest priority rules in a single *STEP* command. Each rule is applied in the order in which it is encountered, until either the harvest targets are satisfied or the list of eligible stands is exhausted. In HSG 3.0, this presents a potential problem in that stands may be partially harvested by one rule and subsequently clearcut by the next rule in the same *STEP* command. A default of one year was added to the *harvest protection period* function to prevent this. Therefore a stand cannot be harvested by more than one rule in a single *STEP* command.

3.2.2 Economic Modifications : Rule_3

Four economic modifications were made in HSG 3.0. First, modifications were made to permit the input and utilisation of economic data. Second, a new harvest priority rule (Rule_3) which allocates stands for harvest by minimising the loss of the opportunity cost of delaying the harvest for each stand by one year was added. Third, Rule_3 was designed to apply regeneration to clearcut stands based upon the projected SEV for each stand and treatment combination. Fourth, modifications were made to the output functions to report economic results.

Although Rule_3 ranked and assigned treatments by SEV, in this study site conversion was not permitted and no constraint was placed on any silvicultural treatment level. As a result, the application of silvicultural treatments by SEV had no effect in the allocation of regeneration treatments in this study. Therefore, the information on regeneration assignment by SEV is described only in Appendix II.

The source code for HSG was expanded to input, utilise and produce economic output information for HSG 3.0. It was modified to recognise three independent economic variables: the value produced when the stand's products are sold (referred to as Price (P)); the cost at roadside to produce those products (referred to as Cost (C)); and the cost to transport those products to the mill (referred to as Transport (T)).

The price used can represent different values. In this study, price is the maximum value a mill would be willing to pay for the timber in a stand delivered to the mill gate in a perfectly competitive market.

Both price and cost are entered in $\$/m^3$ as a function of age for each species/site combination in the same manner as volume. Price for each species in the stand is calculated by multiplying the species volume in the stand by the appropriate price for that species, site and age combination. The equation for stand price is:

$$\sum_{i=1}^{n}\left[P_i(t) * S_i * V_i(t)\right] \qquad \textbf{[10]}$$

Where:

P(t) = Price of the species and site combination at time (t) in $\$/m^3$
S = stocking of the species present in the stand as decimal percent
V(t) = volume of the species and site combination at time (t) in m^3/ha
i = the list of species in the stand
n = number of species in the stand

To use this method, a separate price curve (expressed as a table) is required for each pure species and site combination used in the model (Appendix III).

Cost is handled in the same manner as price. The only difference is that a separate cost is permitted for each of the three harvest treatments (clearcut, release and partial). Cost data must be supplied for each pure species and site combination, and harvest treatments employed in the model. The equation for stand cost is:

$$\sum_{i=1}^{n}\left[C_i(t) * S_i * V_i(t)\right] \qquad \textbf{[11]}$$

where:
C(t) = harvest cost of the species, site and harvest system combination at time (t) in m^3/ha
S = stocking of the species present in the stand as decimal percent
V(t) = volume of the species and site combination at time (t) in m^3/ha
i = the list of species in the stand
n = number of species in the stand

Transportation cost is a constant value for each stand independent of species and site. It was designed to represent the cost of transporting the stand's products to the mill and is entered in $/m^3. The total transportation cost for each stand is calculated by multiplying the total stand volume by the stand's entered transport cost. The equation for stand transport cost is:

$$\sum_{i=1}^{n} V_i(t) * M \qquad \textbf{[12]}$$

where:
V(t) = net volume of each species at time (t) in m^3/ha
M = transportation cost for the stand in $/m^3
i = the list of species in the stand
n = number of species in the stand

The harvest portion of Rule_3 uses the same operating process as the existing Rule_2 (minimise the unharvested volume loss). For harvest allocation, its purpose is to provide a criterion on which stands can be ranked for harvest. Rule_3 ranks stands for harvest by calculating an annual average 10-year opportunity cost of harvest delay for each stand. Stands with the highest opportunity cost are ranked at the top of the queue. Harvesting commences from the top of the list and continues until the targets are satisfied or the list of eligible stands is exhausted. All of the features present in the harvest rules in HSG 2.0 were retained in Rule_3. Rule_3 calculates the opportunity cost of harvest delay using equation [13] which is an expanded version of equation [9].

$$D_v(t) = \frac{r \times V(t) \times [P(t) - C(t) - M(t)] - [V'(t)(P(t) - C(t) - M(t)) + V(t)(P' - C' - M')]}{V(t)} \quad \textbf{[13]}$$

Where:

$D_v(t)$= opportunity cost of delay in harvest at time (t) (in $\$/m^3$)
r = discount rate expressed as a decimal
V(t)= stand volume at time (t) (in m^3/ha)
V'(t)= rate of change in stand volume at time (t) (in m^3/yr)
P(t)= value of the stand's products at time (t) (in $\$/m^3$)
P' = rate of change in value of the stand's products at time (t) (in $\$/m^3/yr$)
C(t)= cost of harvesting the stand's products to roadside at time (t) (in $\$/m^3$)
C' = rate of change in cost of harvesting the stand's products to roadside at time (t) (in $\$/m^3/yr$)
M(t)= cost of transporting the stand's products to the mill at time (t)(in $\$/m^3$)
M' = rate of change in the transportation cost (in $\$/m^3/yr$)

Since economic variables are now present in the harvest rule, a new optional *economic operability minimum* was included. A rational profit-maximising forest manager would not harvest stands with a negative economic return[2] (i.e. stands that cost more to harvest than the total value of their products). Rule_3 was designed to give the user the option to set an *economic operability minimum*, for which the stand's RTV (P-C-T) must be greater than or equal to the minimum for it to be eligible for harvest. This function is applied globally and loaded through the *ECONOMIC* command. Like the *OPMIN* command (which sets a volume-based operability limit), the *economic operability minimum* applies to all Rule_3 harvest priority rules used in the simulation.

[2] There are exceptions. Harvesting stands with a negative economic return would be considered for stand conversions, or harvesting poor quality or damaged stands (e.g. fire, insect damage) in order to replace with a higher quality stand.

3.2.3 Output Modifications

The results from an HSG run are written to three different files: updated forest inventories, the *schedule file*, and the *summary file*. Depending upon the complexity of the simulation and the size of the initial forest inventory, the files produced from a run can be large. For the runs used in this study, the *inventory* and *summary files* were approximately one megabyte each, and each *schedule file* up to 5 megabytes. Clearly, files of this size require processing to extract meaningful information. The HSG forest modelling system is packaged with a set of programs that assist in the development of queries and viewing of query results to extract meaningful information. These programs are simple database query and display programs (Moore *et al.* 1994).

The output files contain fields that describe the various biological attributes of the forest and the treatments applied to the forest. Three new fields were added to the HSG 3.0 *summary* and *schedule files*. These fields were:

1. Residual Timber Value (RTV), which is calculated as P-C-M;
2. Delivered wood cost (Wood_cost), which is calculated as C+M; and
3. Transportation cost (Tran_cost), which is simply M.

where: P= price, C= cost and M= transportation cost.

In the *summary file*, output is stored in an grouped format. This permits queries for such things as delivered wood cost by harvest activity and date, or residual timber value by date for the growing stock in the forest.

The *schedule file* is a stand-by-stand record of all the activities undertaken on the forest for an entire simulation run. Each record in this file includes all the stand components tracked in the inventory. The types of activities included in the *schedule file* are: updated stand composition for each step, stands clearcut, partially or release harvested, and the regeneration treatments applied to each stand. Results from queries made on this file can be used in two ways. First, since the records in the file relate to individual stands in the inventory, the file can be linked with a GIS and maps produced. Second, results from this file can be displayed as charts or tables.

In addition to the inclusion of the three new economic fields in the *schedule file*, modifications were made to the reporting of harvesting functions (*Partial* and *Release*). For both *Partial* and *Release* harvest, the stand structure as modified by the harvesting function, before the application of the *state table*, is the structure reported in the *schedule file*. For clearcut, the stand components in the *schedule file* are those present in the inventory before the application of harvest. The data in the economic fields are calculated for only the volume actually harvested in the stand. The result is that RTV is the value of the percent of the species removed from the stand, except for clearcuts where RTV is calculated for all species.

The separate costs developed for analysis in the HSG model were tracked and reported. When economic data are input into the activity file, economic parameters are added to the *summary* and *schedule files* even if the harvest was scheduled with biological harvest priority rules. This permitted the reporting of activities in economic terms. The regeneration costs were not included in the harvest scheduling rule and were not reported in the *summary* and *schedule files*. These costs were determined by developing a regeneration cost suitability matrix and combining this with a *summary file* (refer to Moore *et al.* 1994). Total costs were then determined by adding the actual regeneration costs to the harvest and transportation costs from the *summary file*.

3.3 Management Alternatives and Scenario Development

The implications of applying alternative silvicultural systems to the SRF were explored through comparisons of results from computer-simulated management scenarios. The individual scenarios represented forest management strategies which in turn were derived from the two broad management philosophies of harvest exclusively by clearcut and harvest by alternative silvicultural systems.

Three forest management strategies were explored: 1) clearcut management; 2) no-clearcut management; and 3) combination management. Each of these forest management strategies were described by defining the permissible silvicultural treatments. The permissible silvicultural treatments were assembled into a set of silvicultural ground rules for each strategy. The silvicultural ground rules were used to describe the silvicultural treatments and the conditions under which these treatments may be applied (OMNR 1986, 1995). The silvicultural ground rules along with the management strategy goals were then used to develop the necessary HSG files which constitute a scenario. The maximum long-term sustained yield was determined for each management strategy through a binary search process of HSG runs and modifications in the scenarios' harvest targets.

3.3.1 Clearcut Management Strategy

The clearcut management strategy represents the forest management strategy which was applied in northwestern Ontario FMA's during the mid-to-late 1980's. This strategy was included in this study as a benchmark of traditional forest management activities, to which comparisons with other strategies could be made. The clearcut management strategy has been referred to as sustained yield management (OMNR 1986); however, in this study the more descriptive "clearcut management" term is used.

The clearcut management strategy harvested the maximum long-term sustained-yield through a silvicultural regime of clearcut followed by artificial regeneration. There was no attempt to produce maximum economic volume through an intensive silvicultural program of site conversion or thinnings. The aim of this management strategy was to harvest wood only by clearcutting and to regenerate harvested stands to an acceptable species stocking level at a free-to-grow status (OMNR 1986). No site conversions were permitted in this strategy. Conifer species were planted or seeded following site preparation on preharvest conifer sites. Natural regeneration was used to regenerate preharvest deciduous sites.

Table 3.3.1 details the silvicultural ground rules and the treatments which were applied (defined by working groups). For this scenario, all harvesting was done by clearcutting except for the site class III black spruce stands, for which a sacrificial seed source was retained for regeneration. There was no limit placed on the maximum level of artificial regeneration treatments. Therefore, the most intensive regeneration treatment (basic treatment) was applied to each eligible stand.

Table 3.3.1. Silvicultural ground rules for the clearcut management strategy.

Original WG	Future WG	Harvest	Site Prep	Regeneration	Tending	Treatment	Cost($/ha)
Pj X,1,2	Pj	clearcut	mechanical	plant Pj	if required	Basic	600
Pj 3,4	Pj/Po	clearcut	mechanical	aerial seed Pj	if required	Basic	300
Sb X,1,2	Sb	clearcut	mechanical	plant Sb	if required	Basic	600
Sb 3,4	Sb	group seed tree	none	natural	none	Extensive	none
Sw X,1,2,3	Sb	clearcut	mechanical	plant Sb	if required	Basic	600
Sw 4	Sb	clearcut	none	natural	none	Extensive	none
B X,1,2	Sb	clearcut	mechanical	plant Sb	yes	Basic	700
B 3,4	B/Sb/Po	clearcut	none	natural	none	Extensive	none
Po all sites	Po	clearcut	none	natural	none	Extensive	none
Bw X,1,2	Sb	clearcut	mechanical	plant Sb	yes	Basic	650
Bw 3,4	Bw/Po/Sb	clearcut	none	natural	none	Extensive	none
Pw all sites	Pw/Po	clearcut	none	natural	none	Extensive	none
Pr X,1,2	Pr	clearcut	mechanical	plant Pr	if required	Basic	600
Pr 3,4	Pr/Po	clearcut	none	natural	none	Extensive	none
Ce all	Ce/Sb/Po	clearcut	none	natural	none	Extensive	none
L X,1,2	Sb	clearcut	mechanical	plant Sb	if required	Basic	600
L 3,4	Sb/Po	clearcut	none	natural	none	Extensive	none
other hardwood X-4	Po/Ab/Ms/Bw	clearcut	none	natural	none	Extensive	none

Activity File of the Clearcut Management Strategy

The activities simulated in each HSG scenario are controlled in the *activity file* (Appendix IV). Within the *activity file,* the *STEP* command controls most of the actions applied to the forest. Each *STEP* command sets the advancement age, harvest targets, and controls treatment application. The actual *STEP* command used for the clearcut management strategy was:

```
#
STEP 5 : Pj/Sb/Sw/Po/B/Bw=375000: Rule_2-Pj/Sb/Sw/Po/B/Bw=375000(50)
#
```

This command aged the forest 5 years. Then a global harvest target of 375,000 m^3/yr of any combination of jack pine, black spruce, white spruce, poplar, balsam fir, or white birch was established. One harvest priority rule was used to control all the harvest. The harvest target was specified to equal the global target, with the additional constraint that only stands with a minimum volume of 50 m^3/ha of the target species could be harvested. Stands were selected for harvest, then clearcut using the "minimise the unharvested volume loss" priority harvest rule (Rule_2). This was a simplified sustained-yield management strategy, since there were no constraints on the species mix harvested, nor were there any additional biologically defined minimum stand criteria such as minimum eligibility age. The only stand eligibility criterion required for harvest was a minimum target species volume of 50 m^3/ha. The harvest targets were increased until the maximum long-term (200 years) even-flow sustained yield was determined to the nearest 5,000 m^3/yr.

Regeneration was applied by working groups, according to the order listed in the *silvicultural treatment file* <basic_80.trt> (Appendix V).

3.3.2 No-Clearcut Management Strategy

The no-clearcut management strategy used alternative silvicultural systems and natural regeneration to obtain wood volume. This management strategy represents one application of alternative silvicultural systems in the boreal forest. It was included to examine the impact of a clearcut harvesting ban.

The no-clearcut management strategy attempts to harvest the maximum long-term (200 year) sustained yield from the forest through a silvicultural regime of alternative silvicultural systems and a reliance upon natural regeneration. The aim of this management strategy was to harvest wood without clearcutting while maintaining a suitable forest cover of merchantable species. Unlike the clearcut management strategy, stand conversion between species composition was permitted.

Two alternative silvicultural treatments were developed for this strategy: a release treatment for spruce growing in young (40 to 60-year old) jack pine stands, and a "hold volume on the stump" treatment for mature stands. These two treatments were chosen because they were felt to have practical application in northwestern Ontario boreal forests.

The release treatment is applicable to young jack pine stands which have a suitably stocked component of understory spruce. The key to a successful treatment is the spruce understory. A two-day field tour of the SRF revealed no jack pine stands with a suitable understory. However, I have encountered many suitable stands in other northwestern Ontario forests. There are two problems with this treatment. First, the information required on understory stocking is not present in the inventory and thus not available to the model. Second, some of the stands that receive this treatment will require some fill-in planting. For this study, the first problem was ignored (all eligible stands are assumed to have suitable understories and are treated) and the second problem was addressed by assigning one third the normal planting costs ($200) to fill-in-plant the stands that require it. Jack pine stands which receive this treatment were converted into black spruce stands after the removal of the pine canopy.

The second alternative silvicultural treatment was based upon the concept of holding wood volumes on the stump. This treatment is a partial harvesting treatment since most of the merchantable volume remained in the stand following harvest. There were secondary benefits to this treatment such as harvest wood volume that would be lost to mortality and maintenance of continuous forest cover for other ecosystem functions. However, in this study, its primary function was to help determine the types of effects expected from a program of multi-pass harvesting and modified clearcutting.

The partial harvest treatment was applied to a stand as it begins to lose volume and break-up. At this point, gaps form in the canopy and an understory becomes established. The stand begins to convert to a new structure (stand break-up and succession). The concept used is that 30% of the stand volume can be harvested by individual tree selection and the remaining stand will regenerate and fill in over time. The partial harvest will release the understory and increase the stand conversion rate. By controlling which trees are harvested, the species composition and future stand structure can be controlled. Thus, through intermediate harvests the stand break-up and renewal phases of stand development can be accelerated. Clearcutting also accelerates these phases but at a much faster rate and will produce a stand at a different developmental phase. This partial harvest treatment would result in an uneven-aged stand comprised of a mixture of species and ages. In this study, stands treated through this system were harvested every 30 years and the cycle was assumed to be sustainable for 200 years.

One problem with any partial harvest treatment is windthrow damage. Mitchell (1995) and Ruel (1995) recommend the harvesting of shorter, younger-aged stands. They also recommend that less than 40% be removed and that leave trees be selected for windthrow resistance characteristics to reduce windthrow loss. The impact of windthrow on the partial harvesting method used in this study was unknown and no direct allowance was made for windthrow loss. It was assumed that harvest methods would allow for success in identification and retention of wind-firm trees so that windthrow loss would be acceptably low.

Long-lived white pine and red pine make up a minor component of the SRF but are not true boreal species. Despite information that alternative systems work well with these species (Chapeskie *et al.* 1989), they were not included in the partial harvesting treatment because they do not cover significant area in boreal forests. These species and several other minor ones are included in the inventory only because they were present on the SRF but were ignored by the harvest rules.

The silvicultural ground rules of the alternative silvicultural treatments used in this strategy are identical to those used in the combined management strategy.

Activity File of the No-Clearcut Management Strategy

The no-clearcut management strategy was simulated through the <sr_alt2.act> *activity files*. The actual *STEP* command from a scenario shown below:

```
#
STEP 5 : Pj/Sb/Sw/Po/B/Bw=150000: Rule_2-{Release-100}[pj_rel.hal]-
Pj/Sb/Sw/Po/B/Bw=150000(50), Rule_2-{Partial-30}[bas_hold.hal;30]-
Pj/Sb/Sw/Po/B/Bw=150000(50)
#
```

This *STEP* command is more complex than that used in the clearcut scenarios due to the two harvest priority rules used. In addition, harvest rule modifiers were used to define the harvest treatment. The aging of the forest 5 years and the setting of the global harvest target were the same, as was the harvest priority rule (Rule_2).

The first harvest rule in the *STEP* command applied a black spruce release treatment to jack pine stands (referred to as jack pine release in this study). Since this rule was first, it had first choice of eligible stands from which to harvest. This rule harvested 100% of the jack pine volume from young jack pine stands, specified in the HAL file <pj_rel.hal> (Appendix VI). The black spruce in the understory was released and some fill-in planting was applied to produce young black spruce stands. As with all the harvest rules, the harvest target for the first rule (release treatment) is the same as the global target. This permits all of the volume harvested for the period to come from this treatment if sufficient stands existed.

After the release treatment was applied to all eligible stands and if the global harvest target had not been met, the second harvest priority rule was applied. The second harvest rule applied the partial harvesting treatment to older stands as described earlier. Only those stands which were of the working group types described in the HAL file <bas_hold.hal> (Appendix VI) were eligible to receive this treatment. Treated stands were partially harvested by removing 30% of the stocking for the listed species. Stands which received this treatment were ineligible for harvest for 30 years.

3.3.3 Combined Management Strategy

The combined management strategy represents a more realistic application of alternative silvicultural systems than the no-clearcut strategy. The combined management strategy harvests the maximum long-term sustained-yield from the forest by first harvesting wood volume with alternative silvicultural systems. If harvest targets are not met, volume is harvested with clearcut silvicultural systems. The silvicultural systems used in the combined management strategy are identical to those used in the clearcut and no-clearcut strategies. Only the combination is different. The treatments applied in the combined management strategy are defined in the silvicultural ground rules (Table 3.3.3).

Table 3.3.3. Silvicultural ground rules for the combined management strategy.

Original WG	New WG	Harvest Treatment	Site prep	Regeneration	Tending	Treatment	Cost ($/ha)
Pj X,1,2 (40-60yrs)	Sb	release (100%)	none	natural -some fill in planting -Sb	if required	Release	200
Pj all sites	Sb	partial (30%; hold 30yrs)	none	natural (Pj >80yrs)	none	Partial	none
Pj X, 1, 2	Pj	clearcut	mechanical	plant Pj	if required	Basic	600
Pj 3, 4	Pj/Po	clearcut	mechanical	aerial seed Pj	if required	Extensive	300
Sb all (100 +yrs)	Sb	partial (30%; hold 30yrs)	none	natural (Sb >100yrs)	none	Partial	none
Sb X, 1, 2	Sb	clearcut	mechanical	plant Sb	if required	Basic	600
Sb 3, 4	Sb	group seed tree	none	natural	none	Extensive	none
Sw all (130+yrs)	Sw	partial (30%; hold 30yrs)	none	natural (Sw >100yrs)	none	Partial	none
Sw X,1,2,3	Sb	clearcut	mechanical	plant Sb	if required	Basic	600
Sw 4	Sb	clearcut	none	natural	none	Extensive	600
B all (60+yrs)	B	partial (30%; hold 30yrs)	none	natural (B >60yrs)	none	Partial	none
B X,1,2	Sb	clearcut	mechanical	plant Sb	yes	Basic	700
B 3,4	Po/Bw/Sb	clearcut	none	natural	none	Extensive	none
Po X,1,2,3 (>90yrs)	Sb/Po	partial (30%; hold 30yrs)	none	natural (Po >70yrs)	none	Partial	none
Po all sites	Po	clearcut	none	natural	none	Extensive	none
Bw X (>80)	Sw	partial (30%; hold 30yrs)	none	natural (Sw >80yrs)	none	Partial	none
Bw X,1,2	Sb	clearcut	mechanical	plant Sb	yes	Basic	650
Bw 3,4	Bw/Po/Sb	clearcut	none	natural	none	Extensive	none

Original WG	New WG	Harvest Treatment	Site prep	Regeneration	Tending	Treatment	Cost ($/ha)
Pw all sites	Pw/Po	clearcut	none	natural	none	Extensive	none
Pr X, 1, 2	Pr	clearcut	mechanical	plant Pr	if required	Basic	600
Pr 3,4	Pr/Po	clearcut	none	natural	none	Extensive	none
Ce all sites	Ce/Sb/Po	clearcut	none	natural	none	Extensive	none
L X, 1, 2	Sb	clearcut	mechanical	plant Sb	if required	Basic	600
L 3,4	Sb/Po	clearcut	none	natural	none	Extensive	none
other hardwood X-4	Po/Ab/ Ms/Bw	clearcut	none	natural	none	Extensive	none

Activity File of the Combined Management Strategy

The combined management strategy was simulated through the <sr_alt1.act> *activity files* (Appendix IV). The actual *STEP* command from a combined management scenario is shown below:

```
#
STEP 5 : Pj/Sb/Sw/Po/B/Bw=230000: Rule_2-{Release-100}[pj_rel.hal]-
Pj/Sb/Sw/Po/B/Bw=230000(50), Rule_2-{Partial-30}[bas_hold.hal;30]-
Pj/Sb/Sw/Po/B/Bw=230000(50), Rule_2-Pj/Sb/Sw/Po/B/Bw=230000(50)
#
```

This *STEP* command is a combination of the no-clearcut and the clearcut *STEP* commands. The first two harvest rules in the command apply the two alternative silvicultural treatments used in the no-clearcut strategy. The final harvest rule applies the clearcut harvest treatment used in the clearcut strategy.

This *STEP* command will first apply the release harvest treatment. If the harvest target has not been met, the partial harvest treatment will be applied. If the harvest target has not been satisfied after both the partial and release treatments, the clearcut harvest treatment will be applied until either the harvest target is satisfied or the list of eligible stands is exhausted. Used in this manner, the clearcut harvest rule acted as a harvest volume "top-off" to reach the global harvest target. Regeneration was applied to the clearcut stands using the same procedure as in the clearcut strategy. HSG runs were made with increasing harvest targets until the maximum long-term (200 year) even-flow sustained yield was determined to the nearest 5,000 m^3/yr.

3.3.4 Volume Curve Development

Time-dependent pure-species volume curves, adjusted for site conditions, are used by HSG to track and describe stand volumes. Previous studies (Williams 1990b;

Willcocks *et al.* 1990; Whitmore 1995), show that volume curve changes have a large impact upon the results of forest-level models. Therefore, accuracy in yield curves is important. One set of yield curves was developed for this study and used in all the simulations. The following process was used to develop the yield curves.

Plonski's (1981) yield curves were used as a base for the development of the pure-species yield curves. In all cases merchantable volumes were used. These curves were refined in two steps. Stone Consolidated has established permanent sample plots (PSP) for the jack pine working group on the SRF and the adjacent forest to the west, the Manitou forest. Approximately 300 PSP have been established since 1955 and remeasured each decade. This data set was made available and used to adjust Plonski's jack pine yield curves for local site conditions. The relative adjustment to the jack pine curves was then applied to the other species. Professional judgement, aided by a two-day field trip to the SRF, was used to refine the yield curves (shown in tabular format in Appendix III).

3.3.5 State Table Development

The *state table* is used to describe a forest's successional pathways, the stand structure resulting from clearcut regeneration treatments, natural regeneration and alternative silvicultural treatments. No modifications were made to the *state table* operation in Version 3.0. The difference in application of the *state table* between this study and previous studies was in its use to describe future stand conditions after partial and release harvest treatments.

Special simplistic *state tables* were constructed for the hypothetical forests used to test and debug the HSG 3.0 model. These tables are not included in this report. A single *state table* (<state12.dat> Appendix VII) was used for all the scenarios in this study. The *state table* and yield curves were constructed so that all the scenarios could be run with the same data.

State tables describe the natural dynamic systems in the forest. One such system represents the natural transitions occurring within the forest. For the duration of the simulation these processes remain constant and are not affected by human actions. As a result, the natural succession rules in the *state table* remain constant with different management options. Following this logic, the procedure used in the development of the *state table* was as follows:

1. A *state table* describing stand succession for the SRF was developed for the previously constructed yield curves.
2. Extensive regeneration (usually no artificial regeneration treatment) following clearcutting was incorporated into the table for each species in the inventory.
3. Regeneration rules were added to the *state table* to represent the silvicultural ground rules to be applied.

3.3.6 Development of Economic Inputs

Once the biological components were defined for each scenario, economic data sets were developed. These data sets were necessary to test both the economic aspects of alternative silvicultural systems and the efficiency of different harvest scheduling methods. The following sections describe the development of the economic data.

3.3.6.1 Price and Product Value Curves

In this study, price is the highest value that would be paid for the optimum combination of products at the mill gate, that could be produced from a fully-stocked, pure-species stand for any given age and site combination. The harvesting system was assumed to have no effect upon the value of potential products.

The main factors that affect the price for each species are piece size, quality, and the value of the end-use products. For this study, veneer and sawlogs were assumed to be more valuable than pulpwood. The general shape of the price curves followed the shape of the volume curves. The assumption used was that price increases as piece size increases, to a point after which it decreased to reflect the loss in value from cull.

For each species, the upper and lower limits of price were determined for site class 1 based upon the expected mix of the potential products. The upper price limit was established for each species at a point just past maximum volume. The lower limit was established at the first age when volume exceeded 50 m^3/ha. Price curves were then developed for the other site classes based upon the expected product mix, piece size and cull. The maximum price used was \$90.00/m^3 for white spruce and lowest price was \$40.00/m^3 for balsam fir pulpwood. The curves were then expressed as age-dependant lookup tables (Appendix III).

3.3.6.2 Harvest Costs

For this study, harvest costs were the total costs accrued in producing wood products at roadside. Harvest costs were segregated into felling cost, off-road transport cost and slashing or processing cost. The largest contributing factor in harvest cost is piece size (Gringras 1988; Sunderberg and Silversides 1988; Gringras 1989; Silversides and Sunderberg 1989; Mellgren 1990; Chylinski 1992; OMNR 1993c; Nautiyal *et al.* 1995). As a general rule, as piece size increases, harvest costs decrease. Piece size is primarily a function of site conditions and age. The HSG variables used for this relationship were site type and species age. Harvest costs vary with the harvesting method employed. Harvest costs were expressed as a set of age-dependent lookup tables for each species/site combination (Appendix III).

The harvest costs used in this study were not adjusted for changes in stocking (density). The only impact stocking had on harvest costs was through changes in stand volume. In HSG, density is related to stocking. Gingras (1988) reported that stand density has a significant impact on harvest cost only when combined with tree size to produce a volume per area. In natural stands, changes in density usually accompany changes in piece size. Newman (1971, in Sunderberg and Silversides 1988) reported that density had only a small influence on productivity (hence cost) of multi-function machines.

Terrain also affects harvest costs (Gingras 1989; Mellgren 1990). However, the FRI data set used to describe the forest had no terrain information. Since no information was available, this factor was not considered for this study.

The following procedure was used to determine the clearcut harvest costs for the study.

1) site-class 1 was used as a baseline from which all other sites were scaled;
2) average total harvest cost for the operable range was estimated for each species;

3) minimum and maximum costs were determined for each species based upon the average cost;
4) using the yield curve for each species, a cost curve was then drawn which reflected the change in harvesting cost with piece size (the maximum harvest cost was assigned to the age where stand volume dropped below 50 m^3/ha, with costs decreasing to a minimum just as volume began to decrease); and
5) the completed site-class 1 cost curve was then used as a base from which the remaining site classes were derived.

Once clearcut harvest costs were determined, costs were developed for the alternative silvicultural systems. There are few published reports dealing with harvesting costs of alternative silvicultural systems in the boreal forest. Although thinning was not examined in this study, thinning costs were investigated as a means of calibrating the harvest costs associated with alternative silvicultural systems. Metsäteho (1983) and Pulkki (pers. comm., 1995) report the industry average cost of thinnings in Finland is about 70-80% greater than the clearcut costs excluding road costs. Total costs can be expected to be double the clearcut harvesting costs do to the protection of residuals. The doubling of costs applies to smaller piece sizes for thinnings than in clearcuts and may not hold true when mature stands are partially harvested. Published relationships between clearcut harvesting and alternative silvicultural systems are summarised in Table 3.3.6.2.

Table 3.3.6.2. Comparison of different stand-level alternative silvicultural system harvesting costs expressed as a percentage of clearcut harvesting to roadside.

Author (date) Location	Harvest System	Seed Tree	Shelter-wood	Group Selection	Single Tree Selection
Beese and Dunsworth (1994) B.C.	hand felling; FMC & hoe forwarding	1.2	1.4	1.5	
Navratil *et al.* (1994) Alberta	Feller-buncher (medium regen. protection)		1.1		
Navratil *et al.* (1994) Alberta	Feller-buncher (high regen. protection)		1.5		
Keegan *et al.* (1995) Montana	Tractor & hand felling		1.1		1.1
Keegan *et al.* (1995) Montana	Tractor & mechanical felling	1.1	1.1	1.1	

The greatest change in harvesting costs are expected when thinning treatments are applied. Thinning can increase harvesting costs by 200% of the clearcut costs. The least change in harvesting costs are the seed-tree treatments which are the same or only slightly greater than clearcut harvesting costs. When all other conditions are equal, the increase in harvesting costs due to alternative silvicultural systems is dependent on the percent of the stand removed (Beese and Dunsworth 1994; Navratil *et al.* 1994).

Published results were used to develop separate harvest costs for each species/site and harvest method used in the study. The clearcut cost was used as a baseline and scaled upward by a factor of 1.5.for partial harvest and 1.3 for release harvesting. The factor of 1.5 times the clearcut cost for partial harvesting was the result of increased costs when harvesting 30% of the volume from mature stands (Appendix III).

3.3.6.3 Crown Charges

In Ontario, a number of charges on wood harvested from Crown land are collected by the Government under the Crown Forest Sustainability Act. These charges apply to both the area under license and the wood harvested. For this study, only two of these charges were included: the $1.50 charge on all hardwood species harvested and the $7.00 charge on all conifer species harvested. These charges apply to all harvested volume regardless of the silvicultural system used.

3.3.6.4 Regeneration Costs

Regeneration costs vary with the regeneration treatment applied, the site conditions, harvested stand conditions, and the harvest method used. The *silvicultural treatment file* <BASIC_80.TRT> (Appendix V) was used for scenarios run with Rule_2 (minimise volume loss) and the *regeneration treatment cost file* <BASIC.RTC> (Appendix V) was used for those scenarios run with Rule_3 (opportunity cost of harvest delay).

The regeneration treatment cost data were determined by adding the individual treatment costs to obtain and average treatment cost per hectare. This value was reduced to reflect a reduction in actual net area treated. The costs of each stand's regeneration treatment was calculated according to the method suggested by Moore *et al.* (1994). After the run was completed, the actual regeneration costs were combined with the appropriate wood cost for the time-period to produce a total cost for the scenario. These total costs were not used for scheduling of treatment activities. They were determined and reported upon only after a run was completed.

3.3.6.5 Transportation Costs

Transportation costs are all those costs that can be expressed as a function of stand distance from the mill. The SRF is almost completely accessed with primary and secondary roads. Little new road construction is required. In a long-term study of this nature, all areas of the forest should be eligible for harvest. If the forest is only partially accessed, some areas will contain high transportation costs even after the roads are developed. HSG 3.0 permits new *transportation cost files* to be loaded during a simulation to account for additional road construction or abandonment. The costs of new road networks can be included in the appropriate time period. However, in this study only one fully developed road network was used and thus no primary or secondary road construction costs were assigned. Primary and secondary road maintenance costs were assigned as a component of transportation costs.

The assumption used in this study was that tertiary roads were constructed each time a stand was harvested. The amount of tertiary road constructed and maintained was a factor of stand area and not on the distance to a primary or secondary road. Tertiary roads were assumed to be regenerated to productive forest when the silviculture treatment was applied. An average cost for tertiary road construction was included in the harvest cost.

In order to run the economic model, a transportation cost was required for each stand in the inventory. Transportation costs for each of the road classes were established (Table 3.3.6.5).

Table 3.3.6.5. The round trip cost in dollars to move one cubic metre of wood one kilometre for each of the road classes used in the study.

Road Class	Haul Cost	Transport People	Road Maintenance	Total Cost
Highway	.0375	.0215		.0590
Primary	.0600	.0350	.0094	.1044
Secondary	.1000	.0585	.0040	.1625
Tertiary	.2000	.1165		.3165

The assumptions used in the development of transportation costs were:

Four classes of roads were used;

A. Provincial Highway (truck travel speed 80 km/h, no incurred road maintenance costs)
B. Primary Road (truck travel speed 50 km/h, with maintenance costs)
C. Secondary Road (truck travel speed 30 km/h, with maintenance costs)
D. Tertiary Road (truck travel speed 15 km/h, maintenance cost included in construction costs)

Haul costs were based upon a broker rate of $75.00/hour (including driver, Workers Compensation etc., for quad axle truck and trailer).

III. Transportation costs included the following: wood hauling, transport people, transport supplies and parts, floating, road maintenance, loss in machine productivity/availability due to longer distances.

The tertiary road transport cost was assigned to all forest pixels. The non-forest pixels, such as water and bogs, were assigned high transportation costs to force the tertiary roads to follow land. A transportation cost surface was then developed using the IDRISI COSTGROW module (Eastman 1992a; 1992b). This module calculated a cost for each cell based upon a predetermined destination, and the cost surface employed.

The transportation cost surface was linked with the inventory image and an average cost for each stand was calculated, and reformatted for HSG. Two transportation cost files were developed for use in this study; one for the SRF, described above, and a simplified one used with the hypothetical forests. The hypothetical transportation cost used a straight-line distance with a fixed cost for each pixel.

Transportation costs (M) were used by the model in the calculation of opportunity cost of harvest delay and the calculation of RTV to determine if a stand was economically feasible to harvest. The transportation cost was constant for all species and products in a stand. The total stand transportation cost (M) was calculated by multiplying total stand volume (m^3) by the transportation cost ($\$/m^3$) for that stand.

HSG simulations were begun once the scenarios, activity and data files were constructed. Two hundred-year simulations were conducted with increasing even-flow harvest levels until the maximum sustained harvest level was found for each scenario (Long Term Sustained Yield (LTSY)). Additional runs were conducted at specific harvest levels to gain insight in model behaviour.

Once LTSY was established, *schedule* and *summary files* were produced for each scenario (Appendix VI). Queries were constructed to extract the required information from the *summary* and *schedule files*. Results from these queries were charted and printed in Excel.

4 RESULTS

4.1 Management Strategy Results

4.1.1 Biological Indicators

Clearcut management produced the highest LTSY (Table 4.1.1). A 24% reduction in the allowable harvest occurs when clearcut management is replaced by combined management. The reduction in LTSY is even more pronounced with no-clearcut management: a 65% reduction from 310,000 to 115,000 m^3/yr. This result supports what most foresters have traditionally believed, that in the boreal forest, maximum volumes are obtained from even-age management.

Table 4.1.1 Predicted 200 year average results for the SRF comparing annual target maximum long-term sustained yield (LTSY); annual harvest area; harvest volume divided by harvest area; and annual harvest volume divided by total SRF productive forest land base (184,427 ha).

SRF Harvest Scenario	LTSY (000 m^3/yr)	Harvest Area (ha/yr)	Harvest Yield (m^3/ha)	Forest Yield (m^3/ha/yr)
Economic Harvest Rules				
Clearcut management	310	2,300	136	1.7
No-clearcut management	115	3,100	37	0.6
Combined management	235	3,700	64	1.3
Clearcut (constrained)	235	1,500	159	1.3

On an annual basis, clearcut management disturbs less area than either no-clearcut management or combined management (Table 4.1.1). The difference in area disturbed is even more pronounced when the volume produced by each hectare harvested (harvest yield) is considered. Clearcut management is far more productive; the volume of timber recovered per hectare is 2.2 times that of combined management (136 vs. 64 m^3/ha) and 3.7 times that of the no-clearcut management scenario (136 vs. 37 m^3/ha).

These results show that clearcut management produces more volume while disturbing less forest area annually than either no-clearcut or combined management.

An additional clearcut scenario (Table 4.1.1) applied a clearcut management strategy but the annual harvest level was constrained to that achieved by the combined management scenario (a 24% reduction to 235,000 m^3/yr). This provided for two scenarios with different management strategies which can be compared on closer to an even footing because the volumes produced by each are equal.

When the clearcut scenario is constrained, the harvest becomes more productive in terms of volume harvested per hectare (Table 4.1.1). Harvest area decreases 35% from 2,300 to 1,500 ha/yr, thus recovered volume increased from 136 to 159 m^3/ha. This increase in yield was due to the greater volume present in the stands harvested by the constrained clearcut scenario. The model first harvested those stands which cost the most to leave. Stands that have low value (i.e. low volume), can only lose a little and were therefore ranked and harvested last if at all. The higher harvest level in the clearcut scenario forced the model to harvest lower value (and volume) stands from the bottom of the ranking.

When compared to the combined scenario, the constrained clearcut scenario required only 41% (1,500 vs. 3,700 ha/yr) of the total area to produce the same yield. Clearcut management is perceived by many to have a greater detrimental impact upon the forest. However, since clearcut management required only 41% of the annual harvest area of combined management, one might well question which management alternative actually has greater impacts upon the forest.

The volume harvested from the partial-harvest silvicultural treatment varied widely through time (Figure 4.1.1a), compared to the no-clearcut scenario (Figure 4.1.1b).

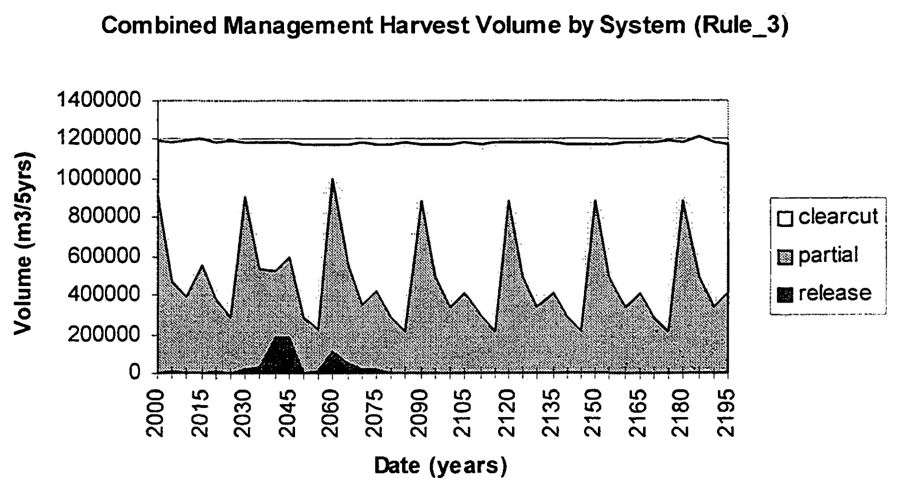

Figure 4.1.1a. SRF 5-year harvest volumes by silvicultural system produced from combined management, using economic-based harvest priority rules (Rule_3).

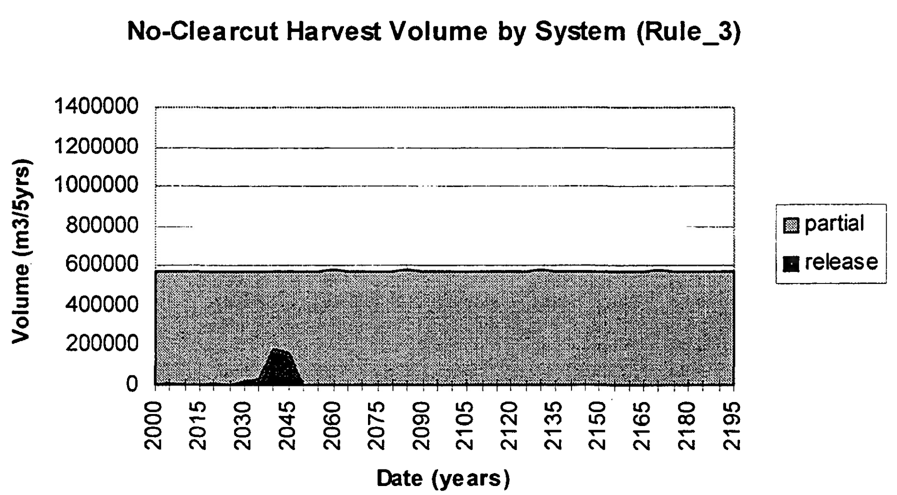

Figure 4.1.1b. SRF 5-year harvest volumes by silvicultural system produced from no-clearcut management, using economic-based harvest priority rules (Rule_3).

This harvest volume variation is a result of the harvest rules used. There was no constraint on the percent of the total volume harvested by any one treatment or the variation between periods; only the total volume was constrained. The combined and no-clearcut scenarios attempted to harvest all of the volume by alternative silvicultural treatments. In the combined management scenario, all of the stands eligible for harvest by alternative treatments were harvested. Clearcutting was the last rule and the remaining stands were clearcut until the global 5-year target was met. All of the forest's stock of eligible stands for alternative silvicultural treatments were used up in the first 5-year period (Figure 4.1.1a). Only the aging of the forest will provide new eligible stands since each stand harvested by the partial treatment was protected from harvest for thirty years, after which it was eligible for harvest again. As a result, in the second 5-year period, the only stands eligible for partial harvest are those that reach the required minimum age. The large peak every thirty years in the volume partially harvested is due to the thirty-year no-harvest restriction expiring. This harvest format was designed to achieve the greatest harvest level with alternative silvicultural systems.

Another noticeable result (Figures 4.1.1a and 4.1.1b) is the relatively low level and the total lack of volume harvested after the year 2115 by the release treatment. The release treatment required young jack pine stands. In the absence of fire, these stands can only be created by jack pine regeneration treatments. The only jack pine regeneration treatments used in this study were those applied to jack pine stands. The release treatment in this study converted jack pine stands to spruce stands and no treatment was assigned to convert a portion of the spruce back into jack pine. The release treatment would likely of produced more volume had this conversion been allowed.

The results (Table 4.1.1) clearly favour clearcut management. However, producing higher levels of fibre at the expense of desirable forest conditions may not be acceptable. This raises the question of what future forest structures developed from each of these scenarios. The variation in the predicted residual forest structure during and at the end of a simulation can describe the impact and thus a scenario's desirability. One measurement of forest structure is age-class distribution (Figures 4.1.1c, d, e).

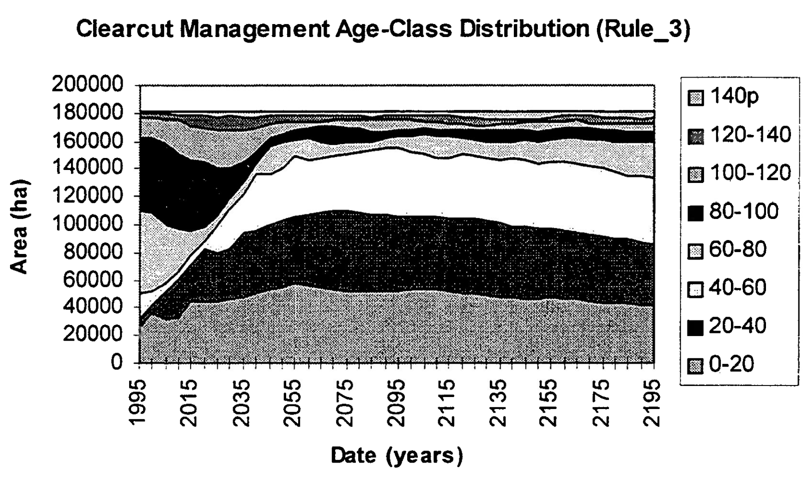

Figure 4.1.1c. SRF predicted age-class distributions (ha) of the residual forest resulting from clearcut management at 310,000 m^3/yr using economic-based harvest rules (Rule_3).

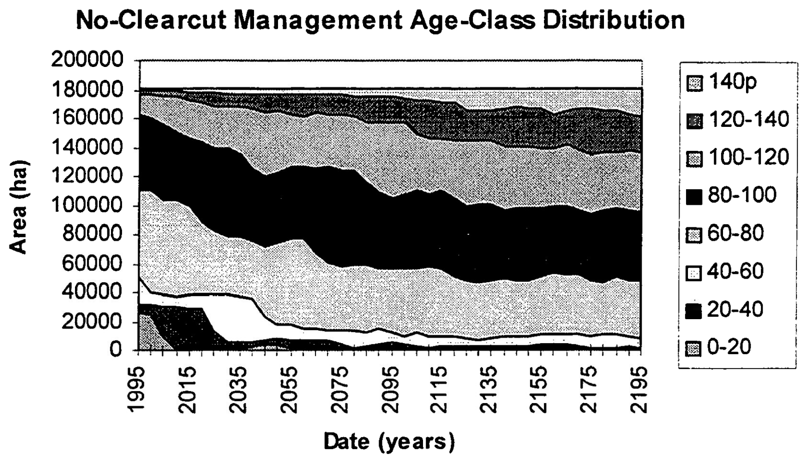

Figure 4.1.1d. SRF predicted age-class distributions (ha) of the residual forest resulting from no clearcut management at 115,000 m^3/yr using economic-based harvest rules (Rule_3).

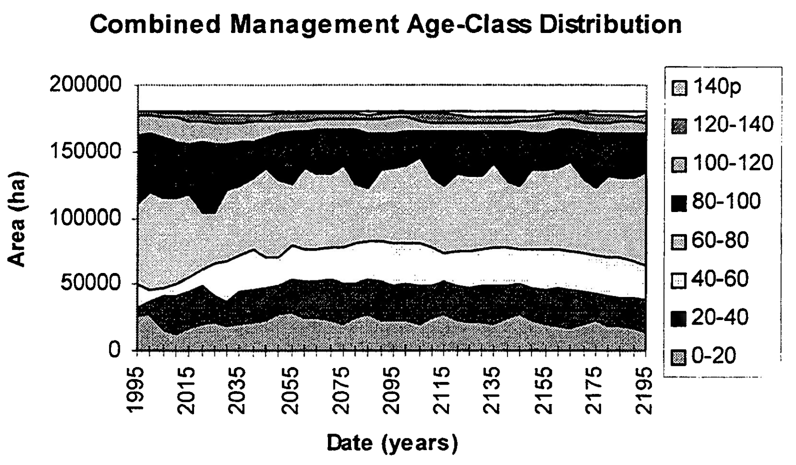

Figure 4.1.1e. SRF predicted age-class distributions (ha) of the residual forest from combined management at 235,000 m^3/yr using economic-based harvest rules (Rule_3).

Clearcut management (Figure 4.1.1c) altered the forest structure from an initial medium/old-aged forest with an uneven age-class distribution to a young regulated forest. The 2195 clearcut forest structure is composed largely of equal areas of forest less than 60 years old (three 20-year age classes). Actually the clearcut management scenario regulated the forest after only 60 years. This forest structure is the result expected from traditional volume regulation (Davis and Johnson 1987). Whether this is a desirable forest structure depends upon the management objectives which is beyond the scope of this study.

The no-clearcut scenario's predicted age-class structure grew older throughout the simulation (Figure 4.1.1d). The amount of area in the older age classes continually increased. After 200 years, there is little area less than 40 years of age in the forest.

Combined management (Figure 4.1.1e) produced a future forest age-class structure that can be classified as between that of clearcut (Figure 4.1.1c) and no-clearcut management (Figure 4.1.1d). Combined management did not change the initial forest structure as abruptly, nor to the same extent as the other two management strategies. Other than the expected 30-year fluctuations, the initial age-class structure remained largely unchanged throughout the simulation period.

In HSG, stand age is the age of the leading species (the dominant species in the stand). Although five separate ages can be tracked in an HSG inventory, one stand age cannot express the range of ages found within an uneven-aged stand. Stands which were partially harvested would become uneven-aged stands and thus have a wide range of ages. Clearcut stands remained even-aged stands. Therefore, a direct comparison between the clearcut and partially harvested stands based on leading species age has limited validity.

The constrained clearcut scenario (Figure 4.1.1f) produced a more balanced age-class distribution, at the end of the planning period, over a wider range of ages than any of the other scenarios displayed. Six age classes from 0 to 120 years comprise most of the forest. One of the primary reasons for this balanced distribution is the lower harvest level of 235,000m^3/yr.

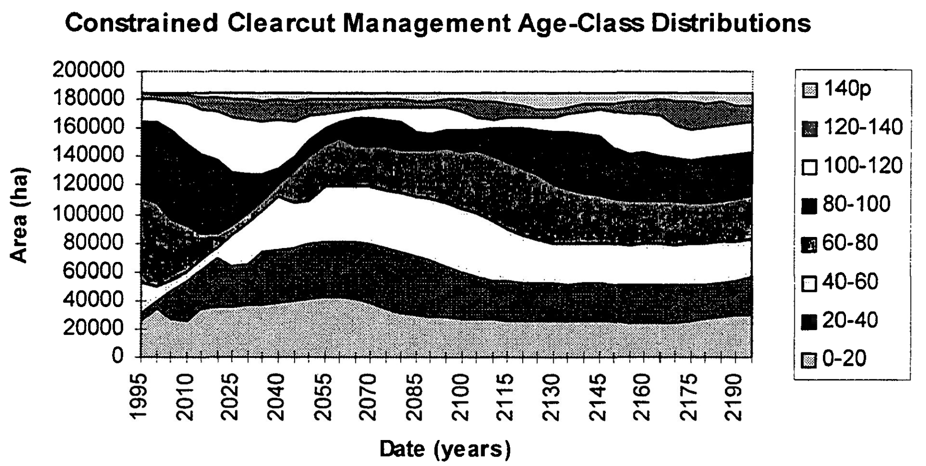

Figure 4.1.1f. SRF predicted five-year age-class area distributions of the residual forest resulting from the constrained clearcut management scenario at 235,000m^3/yr using economic-based harvest scheduling (Rule_3).

The comparison between the age-class distributions of the combined and the constrained clearcut scenarios is useful because both produce the same volume of timber. The constrained clearcut scenario has an age-class distribution which is more evenly distributed than that of the combined management scenario. This result was somewhat unexpected given that a combined management strategy is widely perceived to produce forest structures which are environmentally friendly. The reason for the large area in the 60 to 100 year age-class (Figure 4.1.1e) was the partial harvesting treatment which kept stands within a narrow age range while repeated partial harvest treatments were applied.

4.1.1.1 Initial Forest Age-Class Effect on LTSY

Each of the three management scenarios - clearcut management, combined management and no-clearcut management - was run with each of the three hypothetical forest inventories to determine LTSY. For each scenario, the percent change in the LTSY from the normal forest's LTSY was determined (Table 4.1.1.1 and Figure 4.1.1.1).

Table 4.1.1.1. LTSY (000's m^3/yr) of three different age-class distributions for the clearcut, combined and no-clearcut management scenarios.

	Clearcut management		Combined management		No-clearcut management	
Forest	**LTSY** (000 m3/yr)	% Change	**LTSY** (000 m3/yr)	% Change	**LTSY** (000 m3/yr)	% Change
Young	306	-10	277	-7	60	-30
Normal	341	0	297	0	85	0
Old	346	2	257	-14	95	12

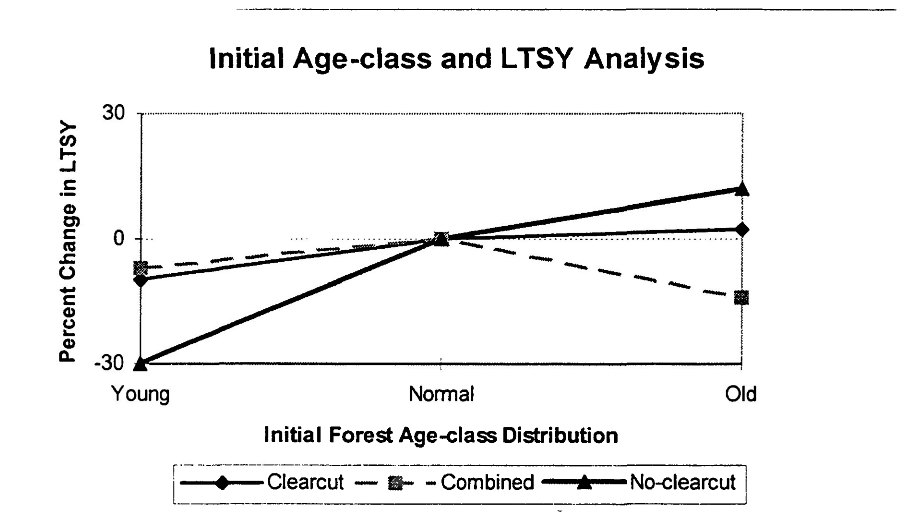

Figure 4.1.1.1. The percent change in LTSY resulting from different initial forest age-class distributions for the three management scenarios; clearcut, combined and no-clearcut management.

The results show that the effects of changing age-class distributions upon the LTSY were not consistent. For the younger forest initial conditions, all three scenarios show a reduction in LTSY compared to the normal forest. The reduction is greatest (30%) for the no-clearcut scenario, while the combined and clearcut scenarios experienced reductions of 7% and 10%, respectively. The no-clearcut scenario experienced the greatest reduction in LTSY due to the specific stand structures required for harvest. Since the required stands types are older, a younger forest has fewer stands eligible for harvest. The reduction in LTSY for the other scenarios was the expected result when moving from a regulated forest to a non-regulated forest.

When the initial forest is older than normal, the differences in LTSY among the three scenarios was inconsistent (Figure 4.1.1.1). The LTSY for the no-clearcut scenario increased while that for the combined scenario decreased. The clearcut scenario experienced only a slight (2%) increase in LTSY. The increase in the no-clearcut scenario's LTSY is due to the older stand structures required for harvest eligibility. The decrease in LTSY associated with the combined scenario was unexpected considering that this scenario is a combination of the other two scenarios, both of which had increased LTSY. This result is likely explained by the larger number of stands which were tied up in the partial harvest treatment for the older forest. The partial harvest treatment was applied before clearcutting, and an older forest would have had more eligible older stands. The remaining stands which were clearcut, were insufficient in number to raise the harvest volume above that achieved for the normal forest. The combined result is a lower LTSY for the older forest.

4.1.2 Economic Indicators

Table 4.1.2a displays the economic results (per m^3) of the scenarios discussed previously, and one additional clearcut scenario where LTSY was determined with no minimum economic criteria for harvest eligibility.

Table 4.1.2a. Two hundred year average value ($\$/m^3$) results for the SRF and the following indicators: maximum long-term sustained yield (LTSY), harvest cost to roadside (Harvest), transportation cost to mill (Tran), regeneration cost (Regen), total delivered wood cost (Total) and delivered wood residual timber value (RTV), produced from alternative management scenarios.

SRF Harvest Scenario	LTSY (000 m^3/yr)	Harvest ($\$/m^3$)	Tran ($\$/m^3$)	Regen ($\$/m^3$)	Total ($\$/m^3$)	RTV ($\$/m^3$)
Economic Harvest Rules						
Clearcut management	310	25.55	18.72	3.45	47.72	13.41
No-clearcut management	115	31.59	16.46	0.04	48.09	26.30
Combined management	235	27.92	19.24	2.28	49.44	16.16
Constrained clearcut mgmt	235	21.96	18.15	3.18	43.29	27.84
Clearcut mgmt (no eco min)	315	26.52	24.33	3.70	54.55	6.42
Clearcut mgmt (no eco min)	310	25.12	23.89	3.43	52.44	10.15

There was little variation in the total wood cost (Table 4.1.2a) from the three original management scenarios (i.e. clearcut, no-clearcut and combined). The greatest difference was \$1.72 which is less than 4%. The largest total difference was in the residual timber value (RTV). Among the original three scenarios, the no-clearcut scenario produced a RTV which was almost double that of the clearcut management scenario. However, when the clearcut scenario was constrained to the level of the combined scenario, the constrained clearcut scenario produced the highest RTV. This would suggest that harvest level has a large impact on RTV. Therefore, changes in harvest levels should be considered when comparing RTVs for silvicultural systems.

The variation in total wood costs among the scenarios was less than expected. The variation in harvest cost was approximately half the variation in RTV. This result demonstrates the problem of using only cost in an analysis. The combined impact of price and cost may be more important than either one alone.

The amount spent on regeneration when compared to harvest and transportation costs are insignificant (Table 4.1.2a). The regeneration costs presented here are forest-level average regeneration costs which are lower than the stand-level regeneration costs due to the addition of the hardwood species which have no regeneration costs. Even if regeneration costs were doubled, the significant costs remain those that directly affect roundwood production levels (harvest and transportation). The potential savings in regeneration from alternative silvicultural systems are only significant if there is minimal associated change in harvest and delivery expenses. One of the this study's primary questions about the use of alternative silvicultural systems was: would the expected savings in regeneration costs pay for the expected increase in harvesting costs? From the long-term average results in Table 4.1.2a, the answer is clearly no.

The clearcut scenario with no economic eligibility minimum retained a positive but reduced RTV. In addition, the economic eligibility minimum appeared to have little impact on LTSY, which increased from 310,000 to 315,000 m^3/yr. This would suggest that the economic eligibility minimum has little impact upon the selection of stands for harvest for the assumptions used in this study. The reason for this lack of impact is that opportunity cost inherently considers the net value of the stands when ranking them; stands with a lower net value will be ranked lower than stands with a higher net value, all else being equal.

Care must be exercised when reading the values in Table 4.1.2a. The marginal harvest cost of producing the additional 5,000 m^3/yr, between the clearcut scenarios with and without the economic minimum, is \$86.66/m^3 (Table 4.1.2a). How can this be possible when the highest clearcut harvest cost is \$45.00/m^3? The answer lies in the difference in scheduling of the stands and thus those selected for harvest. When no economic minimum is used, the cost of harvesting stands is greater because more unprofitable stands are harvested throughout the simulation, raising the average harvest cost. The stands which produced the last 5,000 m^3 did not have a harvest cost of \$86.66/m^3 as is suggested by Table 4.1.2a, rather the total value of all the harvested stands \$26.52/m^3.

To confirm the forest-level marginal cost effect and the operation of the economic minimum, an additional clearcut management scenario was run with no economic minimum and a harvest level of 310,000 m^3/yr (Table 4.2.1a). As predicted, the costs were slightly lower and the RTV was higher. The direction and magnitude of the changes was similar to that observed between the clearcut scenarios run with the economic minimum. The forest-level marginal total wood cost of harvesting the additional 5,000 m^3/yr was \$185.37 /m^3.

This forest-level result is also present in the comparison between the total wood cost and the RTV for clearcut and no-clearcut management. The no-clearcut management had a greater total wood cost (\$48.09 vs \$47.27), and almost double the RTV (\$26.30 vs \$13.41). The increase in RTV is due to the increase in profit of each harvested stand. The treatment rules for the no-clearcut management, only permitted harvesting stands, which contain older, larger and thus more profitable timber (Appendix III). The trade-off to harvest only these older stands is a drastically lower harvest level.

Silvicultural treatments that increase timber size could be applied to reduce the harvest level trade-off experienced in this study. Control of initial plant spacing or thinning treatments, could produce larger timber at younger ages (Willcocks *et al.* 1990). These stand-level treatments should be evaluated at the forest level to access their applicability to a forest management strategy.

When combined and clearcut management were conducted at the same harvest level, clearcut management produces a greater RTV by $11.68/m^3 ($27.84 - $16.16). This 72% increase would result in an additional profit of $2.7 million per year from the forest. Since the economic results in Table 4.1.2a are expressed per m^3, the variation in harvest levels among the scenarios is not apparent. To capture the impact of harvest levels, total annual results were calculated (Table 4.1.2b).

Table 4.1.2b. Total annual results from the SRF, comparing maximum long-term sustained yield (LTSY), harvest cost to roadside (Harvest), transportation cost to mill (Tran), regeneration cost (Regen), total delivered wood cost (Total) and residual timber value (RTV), produced from alternative management scenarios.

SRF Harvest Scenario	LTSY (000 m^3/yr)	Harvest ($million)	Tran ($million)	Regen ($million)	Total ($million)	RTV ($million)
Economic Harvest Rules						
Clearcut management	310	7.9	5.8	1.1	14.8	4.2
No-clearcut management	115	3.6	1.9	-	5.5	3.0
Combined management	235	6.6	4.5	0.5	11.6	3.8
Constrained clearcut mgmt	235	5.2	4.3	0.7	10.2	6.5
Clearcut mgmt (no eco min)	315	8.4	7.7	1.2	17.2	2.0
Clearcut mgmt (no eco min)	310	7.8	7.4	1.1	16.3	3.2

The total annual RTVs (Table 4.1.2b) are quite different from the RTVs expressed per m^3 (Table 4.1.2a). While both the no-clearcut and the clearcut constrained scenarios produced high per-m^3 RTV's (\$26.30 and \$27.84 respectively), when the totals are considered the constrained clearcut scenario is clearly the most profitable choice at \$6.5 million/year. The second most profitable scenario is the unconstrained clearcut scenario followed by the combined scenario. Of particular note is the no-clearcut scenario, which drops from a close second in terms of the greatest RTV when compared on a m^3 basis, to the lowest value when compared on a total volume basis.

Consider the total RTV from the clearcut management scenarios. As LTSY decreases, RTV increases. This relationship is a result of the cost to harvest the more marginal stands being less than the return derived from those stands. In economic terms, marginal revenue is less than marginal cost, and thus these stands should not be harvested. Considering strictly profit and a landholder accounting stance, perhaps a forest should not be harvested at the LTSY harvest level.

For the clearcut scenario, the harvest level with the greatest RTV is 250,000 m^3/yr, compared to the LTSY maximum of 310,000 m^3/yr (Figure 4.1.2a). For the clearcut scenarios, the same profit level can be obtained when the LTSY is reduced by half from 310,000 to 150,000 m^3/year. The combined scenario shows the same trend, with the greatest RTV harvest level at 200,000 m^3/yr compared to the LTSY maximum at 235,000 m^3/yr. In both of these scenarios, the most economically efficient harvest level is less than the maximum LTSY harvest level.

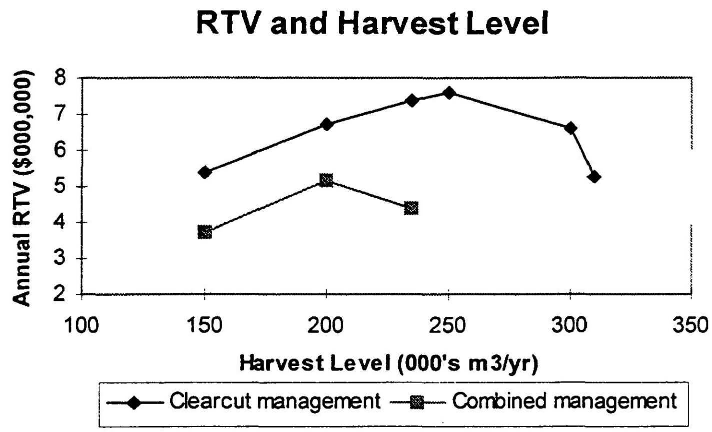

Figure 4.1.2a. RTV's from different harvest levels for clearcut and combined management on the SRF. Harvest levels are expressed in thousands of m^3/year and RTV as 200-year average annual in $millions.

The economic results presented to this point have been 200-year totals or averages. However, just as the volume-based results changed throughout the simulation, so did the economic results. All three scenarios followed the same general trend - an initial high RTV followed by a drop in profitability after 50 years (Figure 4.1.2b). The combined and the clearcut management scenarios followed the same trend of a drop in RTV followed by increasing values as a more profitable forest structure replaces the initial forest. The constrained clearcut scenario maintained a more consistent level throughout the simulation (it dropped less and recovered to the original RTV).

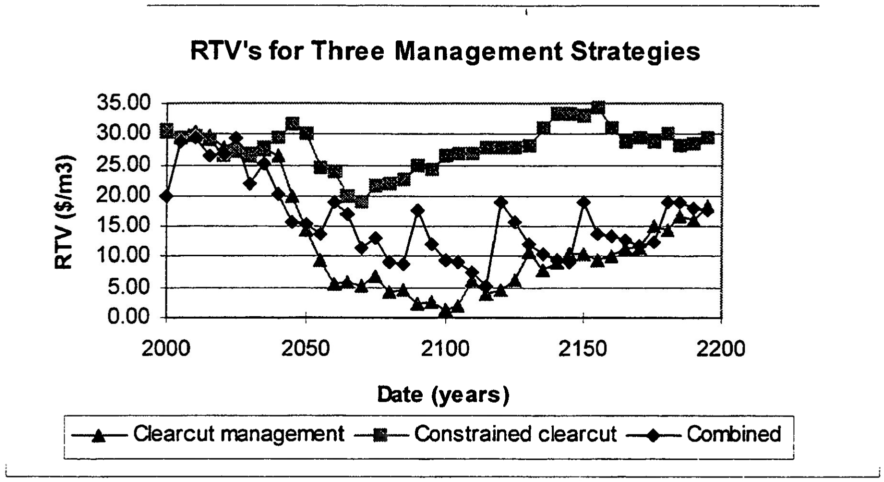

Figure 4.1.2b. 200-year RTV's for clearcut, constrained clearcut and combined management strategies for the SRF.

The 200-year average RTV is predicted to be 72% greater for constrained clearcut management than for combined management ($27.84/m^3 vs $16.16/m^3). In addition, constrained clearcut management produces a RTV with less periodic variation than combined management (Figures 4.1.2c and 4.1.2d). The constrained scenario is a superior alternative from an economic accounting stance.

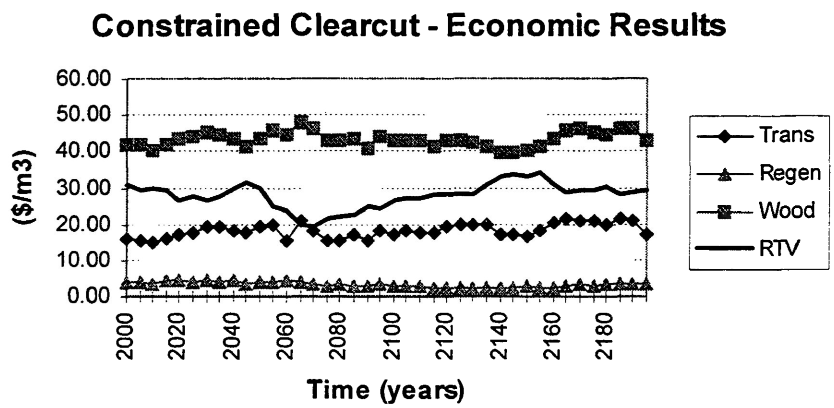

Figure 4.1.2c. SRF predicted economic results (transportation cost, regeneration cost, delivered wood cost and RTV), for the clearcut management scenario constrained to 235,000 m^3/yr using economic harvest scheduling (Rule_3).

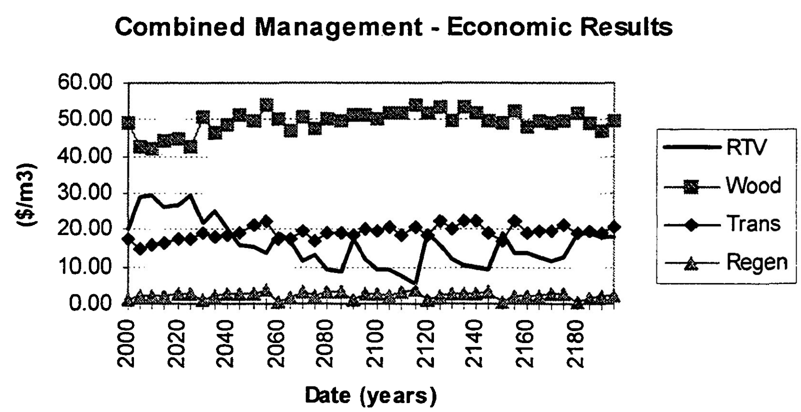

Figure 4.1.2d. SRF predicted economic results (transportation cost, regeneration cost, delivered wood cost and RTV), for the combined management scenario at 235,000 m^3/yr using economic harvest scheduling (Rule_3).

The wood costs presented (Figures 4.1.2c and 4.1.2d) are delivered wood costs which are the sum of harvest cost and transportation cost and are consistent throughout the simulation for both scenarios. The fluctuations in the transportation cost follow those of the delivered wood cost. Any deviation between the two costs is due to the deviation in harvest cost. Therefore, harvest, transportation and regeneration costs are consistent throughout the simulation. Since RTV is price less delivered wood cost, the deviations between delivered wood cost and RTV are due to fluctuations in price. In both the constrained clearcut and combined management scenarios, price is the economic variable with the greatest periodic variation.

The hypothetical forests were also used to determine the economic effects of different age-class distributions. The RTV's were determined for each of the scenarios described earlier and the percent change from the normal forest's RTV determined (Table 4.1.2c and Figure 4.1.2e).

Table 4.1.2c Results from three different age-class distributions for the clearcut, combined and no-clearcut management scenarios upon annual RTV(000's/yr).

	Clearcut Management		Combined Management		No-clearcut Management	
Forest	**RTV** ($000's /yr)	% Change	**RTV**($000's /yr)	% Change	**RTV**($000's /yr)	% Change
Young	10.25	-3	8.18	-23	22.94	-7
Normal	10.53	0	10.16	0	24.68	0
Old	13.31	26	17.50	65	26.09	6

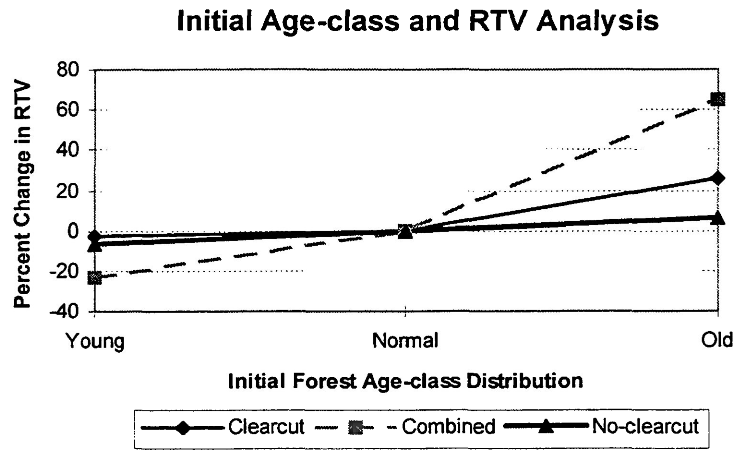

Figure 4.1.2e. The percent change in RTV from the normal forest for young and old forest age-class distributions and the three management scenarios.

Two important results stand out (Figure 4.1.2e). Unlike the LTSY results, the direction of change in RTVs is consistent for all scenarios. Secondly, the percent of change varies widely, with the greatest being 65% and the least 3%. However, the responses among the scenarios are not consistent. All the scenarios show an increase in RTV, with the combined management scenario showing the greatest increase in RTV. This increase in RTV is due to the harvest of older stands from the older forest and would suggest that combined management profits are the most sensitive to forest age-class structure. However, this increase in RTV for each m^3 of wood is obtained at a reduction in LTSY. This is the only scenario to show a reduction in LTSY for an older forest. When the reduction in volume is combined with the increase in RTV/m^3, the result for the total RTV is an increase of 143% for combined management and 128% for clearcut management. Therefore, combined management profit is the most sensitive to forest age-class distribution changes, but the total profit for combined management is still below that of clearcut management due to a lower harvest volume.

4.2 Biological vs Economic Harvest Scheduling

Simulation results from economic harvest scheduling (Table 4.1.1) were compared to results from volume-based harvest scheduling (Table 4.2a). Both harvest scheduling methods produced the same general trends (Figure 4.2a).

Table 4.2a. Results from the SRF comparing target maximum long-term sustained yield (LTSY); annual area harvested; timber volume harvested divided by area harvested; and annual timber volume harvested divided by total SRF productive forest land base (184,427 ha).

SRF Harvest Scenario	LTSY (000 m^3/yr)	Harvest Area (ha/yr)	Harvest Yield (m^3/ha)	Forest Yield (m^3/ha/yr)
Volume Harvest Rules				
Clearcut management	375	2,900	131	2.1
No-clearcut management	150	4,000	38	0.8
Combined management	230	4,500	52	1.3

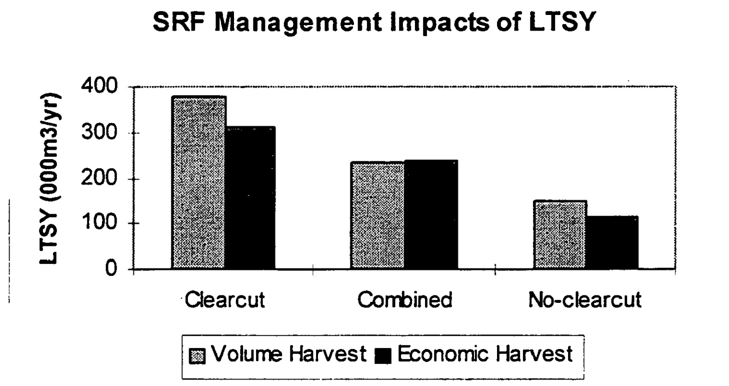

Figure 4.2a. SRF 200-year LTSY produced by volume-based and economic-based harvest rules, for clearcut, combined and no-clearcut management scenarios.

Clearcut management produced the greatest LTSY, followed by combined management and no-clearcut management. However, volume-based scheduling did not always produce the greatest LTSY for each management scenario. Combined management had a higher LTSY with Rule_3 than with Rule_2. This difference is small (5,000 m^3/yr) and attributable to the number of stands eligible for alternative silvicultural treatments. Recall that in these scenarios, Rule_3 required that a stand's RTV be positive for it to be eligible for harvest. In addition, harvesting costs were greater for both the alternative silvicultural treatments than for clearcutting. Therefore, stands that are ineligible for alternative silvicultural treatments could be eligible for clearcut due to the lower harvest cost of the clearcut treatment. In other words, stands which receive a clearcut treatment can have a greater transportation cost and still retain a higher (positive) RTV than stands which receive alternative silvicultural treatments. As a result, the economic operable land base is greater for clearcutting than for alternative silvicultural treatments. This greater area represents a greater potential operable volume as a result of lower harvesting costs.

The reason for the increase in the combined scenario's LTSY with economic harvest rules was the fewer number of stands which are eligible for alternative silvicultural treatments under Rule_3 as compared to Rule_2. As a result, a greater percentage of the total harvested stands were clearcut under Rule_3 combined management than under Rule_2 combined management. The additional volume produced from these clearcut stands was more than sufficient to make up for the loss attributable to a reduction in the total number of harvested stands.

All three scenarios run with Rule_2 produced negative RTVs (Table 4.2b). No rational forest manager would or could harvest timber which over the long term produces a loss on every m^3 harvested; the result would be insolvency. Note that harvest costs are roughly equal between the scenarios run with Rule_2 and Rule_3 (Table 4.2b). However, transportation costs are more than double for the scenarios run with Rule_2 than for the comparable ones run with Rule_3. The main reason for these negative

RTV's is the large transportation cost associated with the volume-based harvest scheduling scenarios. The friction surface used to generate the transportation cost placed large costs on water crossings. This produced a transportation cost structure that contained a few stands with transportation costs in excess of $1000/m^3. These are extreme costs, but they serve to demonstrate what happens when no economic bounds are put on harvest areas. The stands with the extreme transportation cost were not harvested by the economic harvest rules.

Table 4.2b. Results from the SRF, comparing maximum long-term sustained yield (LTSY), harvest cost to roadside (Harvest), transportation cost to mill (Tran), regeneration cost (Regen), total delivered wood cost (Total) and (residual timber value) RTV produced from alternative management scenarios.

SRF Harvest Scenario	LTSY 000(m^3/yr)	Harvest ($/$m^3$)	Tran ($/$m^3$)	Regen ($/$m^3$)	Total ($/$m^3$)	RTV ($/$m^3$)
Volume Harvest Rules	**Target**					
Clearcut management	375	26.56	43.11	3.57	73.24	-16.20
No-clearcut management	150	31.83	42.28	0.12	74.23	-1.03
Combined management	230	36.21	43.69	1.57	81.47	-7.61
Economic Harvest Rules						
Clearcut management	310	25.55	18.72	3.45	47.72	13.41
No-clearcut management	115	31.59	16.46	0.04	48.09	26.30
Combined management	235	27.92	19.24	2.28	49.44	16.16
Constrained clearcut mgmt	235	21.96	18.15	3.18	43.29	27.84
Clearcut mgmt (no economic min)	315	26.52	24.33	3.70	54.55	6.42
Clearcut mgmt (no economic min)	310	25.12	23.89	3.43	52.44	10.15

Both clearcut and combined management have an overall negative RTV. The clearcut management scenario oscillates from a high of over $20 to a low of less than -$80 (Figure 4.2b). This $100 change in 5-year average RTV between periods is undesirable. The same trends are true for the combined management scenario; although the oscillations are not as great, they are still unacceptable for forest management purposes.

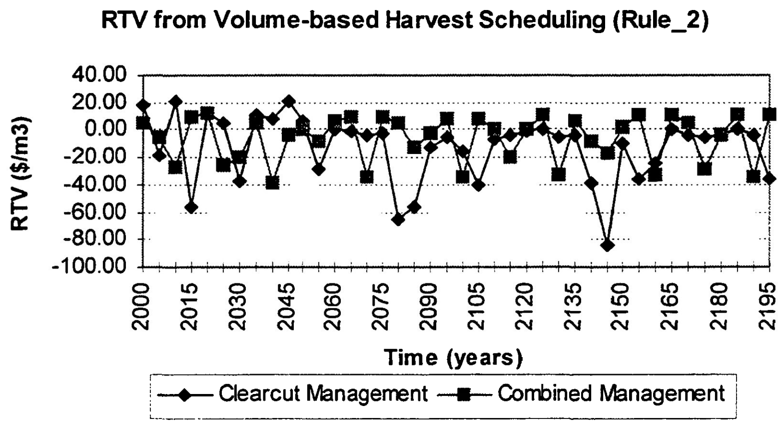

Figure 4.2b. Predicted 200-year 5-year average RTV from the clearcut and the combined management scenarios obtained with volume-based harvest rules (Rule_2) for the SRF.

Much of the oscillation pattern is an artifact of modelling and would not be allowed to occur in the real world. Forest managers would not harvest wood under such extreme conditions. However, any deviation from the model's harvest schedule to accommodate real world conditions will result in a reduction in harvest levels. This is exactly the result achieved by Rule_3. This suggests that Rule_3 may better represent real world conditions.

When RTV is compared for the two volume-based harvest scheduling scenarios (Figure 4.2b) against the economic-based harvest scheduling (Figure 4.1.2b), more consistent levels for the economically scheduled scenarios are immediately apparent. Rule_3 produces not only greater overall economic efficiency, but smaller fluctuations between periods. This greater economic efficiency comes at the expense of lower overall harvest levels. Rule_3 produces less economic fluctuation because stands are queued and harvested by economic inputs, which are ignored by Rule_2. Again, this raises the question of an appropriate LTSY - is the cost to harvest at the higher volume-based levels worth the additional volume gained.

5 DISCUSSION

Some of the professed stand-level benefits of using alternative silvicultural systems, such as reduced harvesting impacts (thus providing better integration with other forest users) and lower regeneration costs leading to reduced wood costs, have been assumed to apply at the forest level. The results in this study display quite the opposite. When clearcutting is replaced with alternative silvicultural systems, nearly twice the forest area must be operated annually to produce the equivalent wood volume. Alternative silvicultural systems spread the harvest activity across the forest landscape, increasing the annually affected area and thus the impacts of logging upon the forest. This may make integration with other uses more difficult not easier. The lower regeneration costs resulting from reduced artificial regeneration were not sufficient to offset the increased harvesting and delivery costs. The overall impact of replacing clearcut harvesting systems with alternative silvicultural systems was a reduction in sustainable harvest levels of up to 65% and a decrease in RTV's of 29%.

5.1 Biological Impacts

The yield assumptions used in this study reflect my belief that alternative silvicultural systems used as a replacement for clearcutting systems in northwestern Ontario's boreal forest are, overall, less biologically efficient at the stand level. The study found that the stand-level reductions in yield (due to lower densities and older harvest ages) are amplified at the forest level. The limitations on the range of stand conditions eligible for treatment with alternative silvicultural systems, compared to the greater flexibility of clearcut systems, is responsible for alternative silvicultural system's forest-level amplification in the reduction to LTSY. Natural stands lack the robust stand structures and are not as receptive to stand manipulation as managed stands designed for this purpose. Planned managed stands should provide more flexibility in the application of alternative silvicultural systems.

Clearly the underling assumptions of stand-level behaviour require full verification and testing. To quantify stand-level behaviour, the Canadian Forest Service initiated a multi-disciplinary study exploring responses to alternative silvicultural systems in the Black Sturgeon forest northeast of Thunder Bay (J. B. Scarratt pers. comm. 1994). Results from these studies could be easily incorporated into forest-level analysis using the methods developed and tested in this study.

The forest-level reduction in LTSY (63%) due to alternative silvicultural systems, is greater than the stand-level reduction (62% to 35%) when the same silvicultural treatments are applied (Table 5.1).

Table 5.1. Maximum stand-level MAIs for clearcut harvesting (site class X and fully-stocked stands) compared to continuous partial harvest MAIs (from the rules in the *state table*).

Species/WG (site class X)	Maximum Clearcut MAI (m^3/ha) - Age	Partial harvest MAI (m^3/ha)	% reduction from clearcut MAI
Pj	3.9 @ 60 years	1.5	62%
Sw	4.1 @ 60 years	1.7	59%
Sb	2.9 @ 70 years	1.9	35%
Po	5.2 @ 50 years	2.2	58%

The MAIs described in Table 5.1 are a result of the yield curves and harvest treatment combinations used in the study. It is not the stand-level MAIs that are of interest to this study, but rather that the stand-level affect of alternative silvicultural systems does not account for all of the LTSY reduction observed at the forest level. This study confirms that the forest-level affects of silvicultural treatments cannot be determined from the stand-level impacts alone. The amplified forest-level reduction is ultimately attributable to the alternative silvicultural system's inflexible harvest scheduling. Once a stand is partially harvested, it is locked into a treatment schedule of 30-year, 30 percent removals (refer to Appendix VII). In contrast, the clearcut treatment is more flexible in terms of treatment age. The alternative silvicultural strategy was unable to alter the harvest age to minimise the affect of the unbalanced initial forest structure, and thus the forest-level reduction in LTSY is greater.

Alternative silvicultural system's forest-level reduction in LTSY is even more remarkable considering that the clearcut MAI's in Table 5.1 represent the maximum yield conditions (site class X, fully stocked stands and optimum harvest age). Most of the stands clearcut in the SRF are not harvested at the optimum harvest age reported in Table 5.1. As a result, the stand-level reduction achieved in the simulations was less than shown in Table 5.1. Therefore, the penalty in applying alternative silvicultural systems was actually greater than the 35-62% described in Table 5.1.

These results contrast with those obtained by Haight (1987), Haight and Monserud (1990) and Yang and Bella (1994). Their studies showed positive returns for alternative silvicultural systems. The contrast may be explained by the different forests used in each study. The stand-level biological and economically efficient treatments applied in these other studies may well be inapplicable to northwestern Ontario boreal forests.

More studies of stand-level responses to alternative silvicultural systems are required for a satisfactory explanation.

Applying a management strategy with clearcut harvesting would require less land base to produce the same timber volume compared to a management strategy based upon alternative silvicultural systems. The application of clearcutting results in less land being disturbed annually. For forest management, this means that the use of alternative silvicultural systems as a replacement for clearcutting will either reduce harvest levels or increase the forest area required. This result is similar to that achieved when intensive and extensive management are compared. Extensive management requires more land to produce the same timber volume compared to intensive management. When land or other resources are scarce, intensive management becomes feasible. Under an intensive management strategy, additional volume and larger trees at harvest can be achieved through thinning. Thinning and spacing could potentially increase the effectiveness and mitigate the losses of alternative silvicultural systems.

Replacement of clearcutting with alternative silvicultural systems in an attempt to reduce the impact of clearcutting on other forest users may have the opposite effect because more land will be required. Forest managers must balance the public desire for alternative silvicultural systems with their negative impacts. In practice, it has been difficult to determine this balance because of the lack of data and practical tools to analyse the problem. The modified model developed for this study provides forest managers with a powerful tool for forest management planning.

The results from the age-class tests with the hypothetical forest data set, supported the conclusion reached by Whitmore (1995), that initial forest structure is a significant short-term factor in forest projections. The direction of alternative silvicultural system's impact upon sustainable harvest levels was consistent between the SRF and the hypothetical forests. However, the impact of changing age-class structure upon sustainable harvest levels was not consistent. Establishing a normal forest as a base, the younger forest resulted in a reduction of sustainable harvest levels from 7% to 30% while the older forest resulted in a reduction for the combined strategy of 14%. With the same conditions, the clearcut and no-clearcut strategies increased sustainable harvest levels by 2% and 12% respectively. These results are counterintuitive, thus confirming that forest-level models are critical analysis tools in the planning process. Only through a program of rigorous testing of management alternatives can the potential long-term forest-level implications be determined.

5.2 Economic Impacts

Banning clearcut harvesting in the boreal forest could have serious economic consequences. The consequences of a reduction in the sustainable harvest levels and the residual timber value that accrues to the timber company may result in a reduction in the number the of timber-based facilities. Even with these harvest level reductions, industrial forest operations would continue to require the whole pre-reduction forest landbase. Moving to a management strategy of alternative silvicultural systems will not free up forest area for other uses. Therefore, a ban on clearcut harvesting will not necessarily result in the quiet undisturbed forested areas that are desired for other uses such as recreational activities.

The combined impacts of the dispersion of operations and the reduction in sustainable harvest levels, leading to possible job losses, suggests that the social effects of alternative silvicultural systems may be more important than the increased timber production costs. Communities in the boreal forest are highly dependant upon the continuous production of forest products (Beck *et al.* 1988, Nautiyal 1988). A drastic reduction in sustainable harvest levels could have serious consequences in some of these communities. The degree to which a dispersal of industrial harvesting activities would affect the tourism industry was not considered in this study. More research into the socio-economic costs of changing sustainable harvest levels and operational dispersion patterns should be considered.

No comparable forest-level economic studies of alternative silvicultural systems in the boreal forest could be found. However, the Ontario Ministry of Natural Resources (OMNR) recently conducted a study comparing clearcut strip harvest with natural regeneration and traditional clearcut and regeneration strategies on a boreal forest north of Thunder Bay (OMNR 1992). The results from the OMNR study support the findings produced here. The OMNR concluded that when alternative silvicultural systems are applied at the forest level, wood costs increase and allowable harvest levels drop. For example, the OMNR concluded that over a 20-year period, the annual cost to implement alternative silvicultural systems would be 13% to 55% greater than that of traditional clearcut harvesting.

The RTV used in this study is a measure of economic profit. This profit can accrue to the landowner or the processor of the timber, depending upon the price structure. RTV does not measure the net benefit to society, which is beyond the scope of this thesis.

RTV does, however, provide a useful measure of the value of timber and as such can be used to guide industrial forest activities.

In Ontario, a portion of the stumpage charges paid by industry are directed toward silvicultural trust funds to be used for regeneration. These charges are considered as a wood cost by the industry (P. Poschmann pers. comm. 1995). Therefore, the regeneration stumpage charges were added into the harvest costs used in this study. When calculating total costs from a scenario, wood cost was added to actual regeneration cost. This had the effect of paying twice for regeneration. However, since the regeneration stumpage charges on wood harvested are fixed and mandatory in the short term, it was reasonable to include them in the harvest costs. Also, by including the regeneration stumpage rates in the harvest costs, stumpage rates were considered in the harvest scheduling.

5.3 Biological vs Economic Harvest Scheduling

Economic harvest rules (e.g. Rule_3) produce not only greater overall economic efficiency, but smaller economic fluctuations between periods. This greater economic efficiency comes at the expense of lower overall harvest levels. Setting the allowable harvest level from a strictly biologically-based harvest scheduling method may overstate the LTSY. When determining allowable harvest levels, operational economic constraints should be considered. The economic costs to harvest at the higher levels produced by biological harvest rules may not be worth the additional volume gained.

Even when the sustainable harvest levels obtained with biological and economic harvest scheduling methods are similar, harvesting at the highest sustainable level does not produce the greatest profit. At high harvest levels, marginal, and sometimes unprofitable, stands are harvested. The results from this study suggest that for economic efficiency, LTSY is a poor response variable. Many forest-level analyses used in forest management do not consider marginal gains at the forest level. Marginal gains are more often found in economic wood supply studies (refer to Marshall 1990). The results produced here support traditional economic theory and economic studies (e.g. Williams 1990a) that describe an appropriate harvest level as a function of price and delivered wood costs.

Results of my study question the concept of a unique sustainable harvest level and challenges the validity of an optimum level of harvest. A model-derived optimum can be calculated but the quality of data and assumptions regarding various constraints, make a model-derived optimum suspect. One solution is to consider more than one response variable when establishing timber harvest levels (e.g. harvested timber volume, residual growing stock, future forest structure, RTV, delivered wood cost). However, as more information is considered in the planning process, the sustainable harvest level becomes more difficult to define. This lack of a definitive sustainable harvest level supports a negotiated solution. A negotiated solution will undoubtedly highlight attention upon the forest management goals and assumptions. It also would reinforce the correct application of computer models in forest management, as decision support tools, not the providers of the solution.

The large transportation costs produced under the volume-based scheduling scenarios appear to be too high (Table 4.2b). How can transportation costs double when the other costs remain approximately the same? When the transportation cost file was constructed for this study, water was assigned a value of $100/cell. This resulted in extremely high values for islands, and stands which required crossing water. As a result, delivered transportation costs varied from a low of $\$0.082/m^3$ to a high of $\$6500.81/m^3$. Of the 6086 forested stands in the inventory, the 100 stands with highest transportation cost, averaged $\$992.06/m^3$. These stands were harvested with the volume-based harvest rules, thus producing the extreme transportation costs. In effect, the economic harvest rule produced an economic landbase while the volume-based rule did not. A more realistic comparison could have been made, had the uneconomic stands been ineligible when volume-based scheduling was used. However, determining the true economic landbase outside of a forest-level model is difficult. The economic landbase decision rule requires inputs such as price, costs and treatments which are correctly a forest-level function.

The operable landbase is unique to every forest, management objectives and constraints. The difference in the number of stands harvested between the volume and economic harvest rules noted in this study may not exist in all forests under all conditions. In these cases, the economic landbase would be the same for both harvest rules. However, the economics of distance and treatment intensity would still present, but likely reduced. The only way know would be to conduct studies such as this one.

Traditionally, and to the present day, forest managers in Ontario, use volume-based rules to schedule stands for harvest. This method appears to be economically inefficient based upon this study's findings. The results also suggest that the allowable cuts estimated are probably too high for current wood value markets. In the boreal forest, economic wood supply can be significantly lower than the biological capacity of the forest to produce timber.

5.3.1 Behaviour of the Opportunity Cost of Harvest Delay

A stand's price, harvest cost and residual value (excluding transportation cost) change as a stand develops. Understanding these relationships is crucial to understanding the operation of Rule_3. To demonstrate these relationships and the application in this study, a Sb_5 Pj_5 stand[3] which breaks up into a Sb_8 Sw_1 at 130 years is used as an example (Figure 5.3.1a).

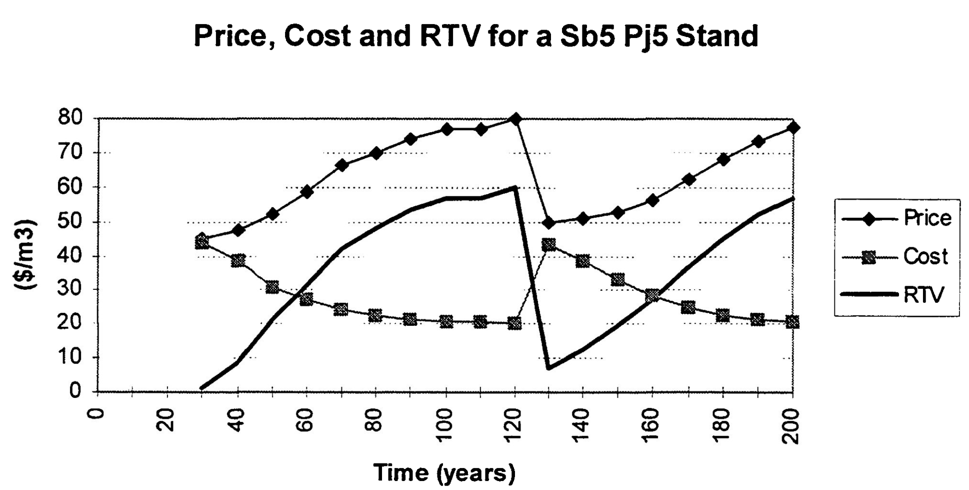

Figure 5.3.1a. Price, cost and RTV (price - cost) for a Sb_5 Pj_5 stand which undergoes break-up into a Sb_8 Sw_1 stand at 130 years.

[3] The Sb_5 Pj_5 refers to a stand which is 50% black spruce and 50% jack pine. In the OMNR - FRI definition the 50% would be the species composition based upon crown closure, where the total for the stand must equal 100%. The format used in this thesis follows to the HSG format. The 5 refers to 50% stand composition and stand stocking. Therefore, the Sb_8 is 80% of the fully-stocked black spruce volume and the Sw_1 is 10% of the fully-stocked white spruce volume. This stand is only 90% stocked.

The abrupt change in values between 120 and 130 years, is due to stand development and break-up. The economic operable range of the stand is defined by the economic operability minimum (i.e. in this study: the range of stand conditions where the RTV is positive). For example, if the transportation cost for this stand were $40.00 per hectare, the economic operable range would be in the stand ages of 68 to 123 years and greater than 173 years.

Stand development is reflected in the opportunity cost of harvest delay and stand volume (Figure 5.3.1b). To be eligible for harvest, volume-based conditions must also be satisfied. The operable volume range for this stand defined by the *OPMIN* command is between the ages of 40 to 130 years and then from 135 years onwards.

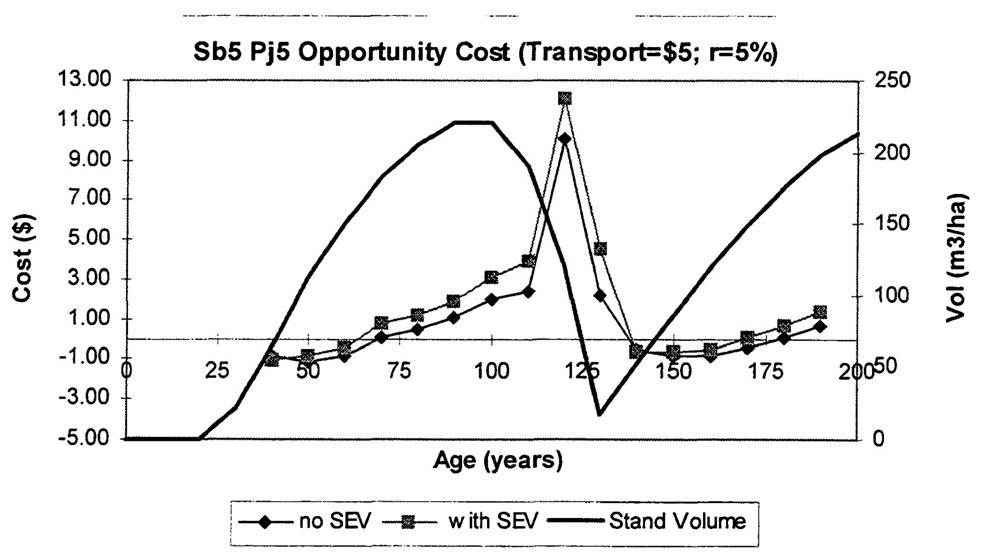

Figure 5.3.1b. The opportunity cost of harvest delay calculated both with and without SEV for a site-class-1 Sb_5 Pj_5 stand with a transportation cost of $5/m^3. The results are based upon the data used for the SRF and contain the break-up at 130 years to a Sb_8 Sw_1 stand.

The increase in the stand volume curve at 130 years is due to break-up and development of a new stand structure. The abrupt loss of volume after 110 years, is reflected in the spike in opportunity cost after 110 years. The opportunity cost is calculated using the average change in stand components over the next ten years, resulting in large changes between periods. The main factor which determines opportunity cost is the rate of change in stand value which in turn is driven mainly by change in volume. In the above example, a 120-year-old stand would be harvested first, then stands at 130 then 110 years of age, followed by other stands in decreasing order of opportunity cost (Figure 5.3.1b).

The most apparent trend for opportunity cost is that it increases with stand age from 30 years (Figure 5.3.1b). Recall that when opportunity cost is negative, the stand is growing in value at a rate greater than the interest cost to hold it, and should be left to grow. When the opportunity cost is positive, the cost to maintain the stand is greater than the increase in value so the stand should be harvested. The optimal economic rotation age is therefore when opportunity cost equals 0 or approximately 70 years with no SEV and 65 years with SEV. The biological efficient harvest age (age of maximum MAI) is 70 years, 5 years greater than the economic age of 65. Notice that the stand is still increasing in value (on a per cubic metre basis and in total volume) at age 70, but the opportunity cost of harvest delay is positive. This means that the stand should be harvested even though it is still increasing in value. The explanation is that the rate of increase in stand value is less than interest cost to keep the stand. The behaviour of the opportunity cost is as predicted; young stands should not be harvested and as the stand grows older, the cost to maintain it increases. In addition, the economic harvest age is less than the biological rotation age (when r is not equal to 0).

Thinning was not investigated in this study, however thinning would alter the volume present, the growth rate and the size of the trees in the stand, producing different product values. These combinations would produce a different opportunity cost of harvest delay curve than that shown in Figure 5.3.1b.

Rule_3 harvests stands in decreasing order beginning with the highest opportunity cost. In this case the oldest stand would be harvested first. However, when more stands with different stand compositions are introduced the situation is more complicated. The economic harvest rule contains an optional feature where the user can define an operability range based upon the stand's RTV. For this stand, the RTV is positive for all ages above 30 years and negative for all those below. Setting a minimum RTV of 0, ensures that the rise in opportunity cost present at the young ages (which is due to zero values for some of the inputs) will not permit a stand to be considered for harvest before it is 30 years old.

The type (b) opportunity cost (Duerr 1960) is calculated as the discount rate multiplied by the SEV (for this stand SEV=\$-2.22/m^3). For the opportunity cost with SEV, the cost of regeneration is included in the harvest cost. The difference in opportunity cost between the two methods is small for the conditions above. These differences remain small even when transportation costs are increased to large values. Small differences were not expected to have a significant impact upon the outcome. For these reasons, type (b) opportunity cost is not used in the determination of the opportunity cost of harvest delay by the HSG model. This is the same conclusion reached by Duerr (1960, 1993). Although it is technically incorrect to do so, the type (b) opportunity cost can be ignored due to its small effect.

The RTV has a large impact upon the opportunity cost of harvest delay. This can be demonstrated through changes in the transportation cost, which is one of the components affecting RTV. Figure 5.3.1c charts the opportunity cost of harvest delay with three different transportation costs, for the same stand used in the previous chart.

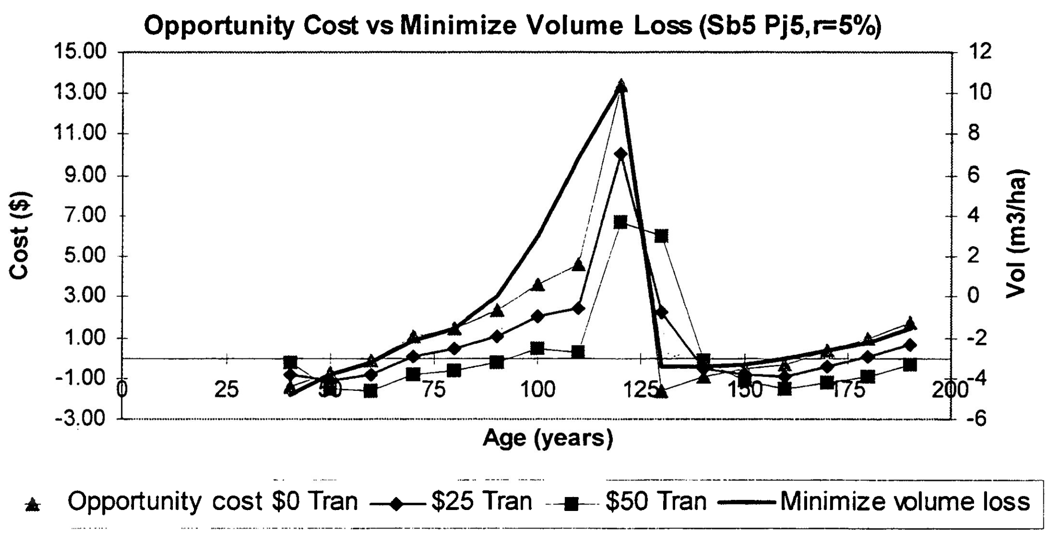

Figure 5.3.1c. Comparison of opportunity cost of harvest delay priority rule (Rule_3) for three different transportation cost levels and the minimise volume loss harvest priority rule (Rule_2) for a site-class-1 Sb_5 Pj_5 stand undergoing break-up at 130 years to a Sb_8 Sw_1 stand.

As the transportation cost increases (resulting in a lower RTV), the opportunity cost decreases. Therefore, stands with a lower RTV (profit) would be scheduled later. Stands with the greater RTV would be harvested at a younger age on a shorter harvest rotation. This is the result predicted by economic theory (Pearse 1967; Nautiyal 1988). Notice that at age 130, the opportunity cost for the $50 transportation cost is the greatest. This is the type of result that can be expected when no bounds are put upon the eligibility criteria for harvest. For the stand used in the above example, stand break-up takes place at 130 years of age. The new stand is actually a 35-year-old black spruce stand, but continuous ages are used in this example. Since stands must have 50 m^3/ha minimum volume to be eligible for harvest, this example stand is not eligible for harvest between approximately 128 to 140 years. Therefore, the opportunity costs in this range have no bearing upon harvest scheduling.

The strong correlation between the rate of change in stand volume (plotted as the solid line) and the opportunity cost of harvest delay is clearly shown. Stand volume is clearly the largest component of opportunity cost. Rule_3 is really a fine tuning of harvest scheduling compared to Rule_2 when RTV's are positive. Rule_3 takes into account distance, price, harvest costs and interest rates when allocating harvest, but volume is the largest component for the conditions used in this study.

Rule_3 schedules and applies harvest and regeneration using economic information. However, depending upon the constraints applied in the simulation, some of this scheduling may be meaningless. The partial and release treatments used in this study exhausted their list of eligible stands before their targets were met. As a result, all eligible stands within a period were treated. Therefore, the order in which they were scheduled and treated made no difference upon the outcome of the harvest rule. When all eligible stands are harvested, any scheduling rule can be used. In this study, Rule_3 was used with a positive economic eligibility minimum. Therefore, all stands harvested by Rule_3 had a RTV greater than or equal to 0. The economic harvesting rule did have an impact with clearcutting, since this treatment never exhausted the list of eligible stands.

Rule_3 will not harvest stands where either the current or future volume is zero. This restriction was added to prevent division by zero and thus null results which can cause programming errors. For this study, the *state table* was constructed to prevent stands moving to a future state with zero volume; therefore, this safety feature should have no effect upon model outcome.

The economic scheduling and application of regeneration treatments was similarly affected. The regeneration targets were set high enough so that regeneration treatments were not constrained. Although this negated any economic efficiencies that might have been gained through economic scheduling of regeneration, it did simplify the scenarios and made comparisons between scenarios simpler.

In summary, a large effort was put into the development of the economic harvest rule. However, only a portion of the capacities of Rule_3 were used in this study. Only the harvest was economically scheduled, not the regeneration treatments.

5.4 Study Assumptions and Recommendations

The study suggests that future forest structure is affected more by harvest level than by the silvicultural system employed. It was expected that the combined management scenario would produce the greatest diversity of forest structure. However, from the response variables used in this study, both the constrained clearcut scenario and the combined management scenario resulted in comparable forest structures. No broad-based, widely accepted quantitative comparison standard could be found for comparing forest structures. More research should be conducted to develop quantitative methods to compare forest structures.

The scenarios used in this study assumed that all of the forest area was available for timber harvesting without any restrictions. This is an unrealistic assumption. In Ontario, guidelines and regulations place restrictions upon timber harvesting and regeneration activities to protect wildlife and other forest values (OMNR 1995). Some of these restrictions are confined to specific zones such as riparian areas and others apply to the extent of treatment such as maximum cutover size. In such areas clearcutting is usually prohibited or constrained. However, in some of these zones alternative silvicultural systems might be used to remove timber. Used in this fashion, alternative silvicultural systems can actually increase sustainable harvest levels when applied to areas not available to clearcut systems. As a result, harvesting restrictions applied to the scenarios used in this study would be expected to reduce the sustainable harvest levels from scenarios employing clearcutting to a greater extent than those employing alternative silvicultural systems. No attempt was made in this study to determine this impact. Additional research in this area could be undertaken through the use of HSG 3.0's adjacency constraint and green-up delay function and rerunning the scenarios.

The traditional yield curve format used in forest-level models does not work well with alternative silvicultural systems. Better mechanisms are required to capture the complex stand dynamics and the response from treatments that manipulate stand structure (e.g. thinning, spacing, or multi-entry harvest treatments). For forest level analysis, silvicultural treatments that manipulate stand structure require yield curves to reflect this manipulation. The problem is that stand response can be vastly different for each treatment type, stand type and entry age. This could result in thousands of possible treatment combinations and yield curves. The data set thus becomes too large to comprehend.

One solution to the limitations of yield curves to model stand growth, is to replace them with stand models. This is the approach used in the Landscape Management System (LMS) (McCarter 1995). In this approach, yield curves are replaced with the Forest Vegetation System (FVS) (an individual-tree, distance-independent, stand-growth model). Although the LMS does not schedule stands for treatment and is limited to small areas, the approach could be used in a forest planning simulation model. An additional advantage of the approach is that a greater variation in stand types can be carried in the model than when yield curves are used. The biggest problem of applying a similar technique in Ontario's boreal forest is the lack of calibrated stand (or tree) growth models to replace yield curves.

The results produced in this study are based upon the assumptions in the scenarios. The individual scenarios are not wholly realistic and in some cases are purposefully extreme. For example, the no-clearcut management scenario is unrealistic because the reduction in sustainable harvest levels, compared to traditional clearcut harvesting, would be unacceptable to most forest managers. However, overall I am confident that the essential dynamics of the selected alternative silvicultural systems are captured within the simulations.

The combined management scenario is a more realistic application of alternative silvicultural systems. Not only does it permit greater flexibility and range of permissible systems, its negative impact upon future forest structure, sustainable harvest levels and profit is less than the no-clearcut scenario. When alternative silvicultural systems are planned, they should be integrated into the planning process and applied in the situations where they are best suited. This should reduce their negative impacts and enhance their positive traits.

A detailed sensitivity analysis was not conducted on the data set used in this study. Sensitivity analysis could have been conducted by changing one component at a time such as the volume yield curves. This would have provided insight into the growth assumptions used. Changing the economic yield curves would have provided insight into the sensitivity of product prices and harvesting costs. Different road structures could have been used to determine the impact of potential road networks. Other factors such as changes in the discount rate or the definition of sustainability could have been tested.

Caution must be exercised when applying these results to other forests or conditions - they are not directly transferable. Other forests could be examined for the economic impacts of various forest management strategies by applying a range alternative silvicultural systems and using methods similar to those developed for this study.

The results of this study are only truly applicable to the modelled world within the computer. There are differences between this modelled world and the real world. To increase the level of confidence in the results, other tools and systems knowledge, such as mathematical programming techniques (Elwood and Rose 1990), could be studied.

6 CONCLUSIONS

The use of alternative silvicultural systems in the boreal forest, as a replacement for traditional clearcutting, resulted in significantly decreased harvest volumes and a reduction in the residual value of the timber that accrues to the land owner. From 200-year computer simulations on the Seine River Forest, a management strategy using a combination of alternative silvicultural systems and traditional clearcutting resulted in a 24% decrease in sustainable harvest levels while a management strategy with a sole reliance upon alternative silvicultural systems led to a 65% reduction. The direction and magnitude of these results was confirmed by testing these management strategies on three hypothetical forests. Compared to an exclusive clearcut strategy, the combined-systems management strategy resulted in a 10% to 26% reduction in sustainable harvest levels while the strategy with a sole reliance upon alternative silvicultural systems led to a 73% to 80% reduction.

Alternative silvicultural systems disturb more area annually, and thus the impact of alternative silvicultural systems upon the forest as a whole may be greater than clearcut-based systems. This conclusion challenges the perception that alternative silvicultural systems have less of an impact on other uses and forest values.

Harvest level has a greater influence on future forest age-class distribution than the silvicultural system employed. In tests on the SRF, the traditional clearcut management produced a more balanced future forest age-class distribution over a wider range of ages than did alternative silvicultural systems when harvest levels were the same. This again challenges the perception of a lower impact using alternative silvicultural systems.

Alternative silvicultural systems are more site-specific and require more information to be successfully applied than do clearcut-based systems. With less flexibility in the range of application, alternative silvicultural system's impact is greater on sustainable forest-level harvest volumes than on stand-level harvest volumes.

The potential savings in regeneration costs generated by alternative silvicultural systems are only significant if there is a minimal associated change in harvest and delivery expenses. In results from the scenarios examined in this study, the savings in regeneration costs due to alternative silvicultural systems were more than offset by the increased harvest and transportation costs. From a purely economic stance, broad-based application of alternative silvicultural systems does not pay.

The negative forest-level results achieved in this study are applicable when alternative silvicultural systems are used as a replacement for clearcut systems. When applied wisely, and used in a mix with other systems, the negative impacts of alternative silvicultural systems could potentially be mitigated.

Residual timber value is strongly influenced by harvest level. In all scenarios, the maximum long-term even-flow sustained yield did not produce the greatest profit. In one test on the SRF using only clearcut harvesting, the same residual timber value was achieved when harvest levels were reduced by 52%.

Volume-based harvest scheduling fails to consider the economic costs and benefits of forest management, which could prove economically disastrous. On 200-year simulations of the SRF, volume-based harvest scheduling produced a sustainable harvest level which was 21% greater than that produced by economic-based harvest scheduling. However, on average, volume-based harvest scheduling produced a negative RTV of $16.25 on every cubic meter harvested, while economic-based harvest scheduling produced a positive RTV of $13.41 per cubic metre. Blindly following a policy of harvest planning based strictly upon volume scheduling could be expensive and may overstate the economically sustainable harvest level.

Determining an appropriate sustainable harvest level is difficult. The more complex the treatments and the number of response variables, the greater the difficulty. Sustainable harvest levels fluctuate with changing conditions and objectives; and therefore, they are better defined as a range. More than one response variable should be used when calculating a sustainable harvest level (e.g. harvested timber volume, residual growing stock, RTV, age-class distribution). This procedure will help to dispel the myth of a single sustainable harvest level for each forest.

7 LITERATURE CITED

Alberta Pacific Forest Industries Inc. 1996. Evaluating alternative silviculture systems on the Alberta-Pacific Forest Management Agreement Area: Preliminary Proposal. Forest Resource Improvement Program, Alberta-Pacific Forest Industries Inc., Lac La Biche, Alberta, Canada. 10 pages.

Anonymous. 1993. The state of Canada's forests 1993: fourth report to Parliament. Minister of Supply and Services Canada. Ottawa, Ontario, Canada, 112 pages.

Armstrong, G.W., W.E. Phillips and J.A. Beck, Jr. 1992. Optimal timber harvest scheduling under harvest volume constraints: a comparison of two opportunity cost criteria. Canadian Journal of Forest Research. **22**: 497-503.

Arnott, J.T., W. J. Beese, A.K. Mitchell and J Paterson. 1995. Montane alternative silvicultural systems (MASS), Proceedings of a workshop held June 7-8, 1995, Courtenay, British Columbia. Canadian-British Columbia Partnership Agreement on Forest Resource Development: FRDA II. Co-published by B.C. Ministry of Forests, Victoria, British Columbia. FRDA report 238. 122 pages.

Baskerville, G. 1986. An audit of management of the crown forests in Ontario. Ontario Ministry of Natural Resources. Toronto, Canada.

Beck, J.A., R.G. Anderson, G.W. Armstrong and G.H. Farrow. 1988. Alberta economic timber supply study: final report. Canada-Alberta Forest Resource Development Agreement. Supply and Services Canada. Ottawa, Ontario, Canada.

Beese, W.J. and B.G. Dunsworth. 1994. Montane alternative silvicultural systems (MASS): final progress report - year 3 (1993/94). MacMillan Bloedel Limited, Nanaimo, British Columbia, Canada. 14 pages + appendices.

Boast, L. 1995. New plywood mill for region. The Chronicle-Journal. Thunder Bay, Ontario, Canada. April 18.

Canadian Forest Service. 1995. Silvicultural Terms in Canada: second edition. Policy, Economics and International Affairs Directorate, Canadian Forest Service, Natural Resources Canada. Ottawa, Ontario, Canada. 109 pages.

Canadian Pacific Forest Products Ltd. 1991. Timber management plan for the Black Sturgeon Forest for the twenty-year period 1991 to 2011. Avenor Inc. (formally Canadian Pacific Forest Products Ltd), Thunder Bay, Ontario, Canada.

Carlton, T.J. 1995. More than a change of heart is needed to preserve the forest. Globe and Mail. Toronto, Ontario, Canada. August 1.

Clarkson, M.E. 1993. The impact of a single insect infestation on stand and forest level wood supplies: jack pine budworm and jack pine. M.Sc. F. thesis, Faculty of Forestry, University of Toronto. Toronto, Ontario, Canada. 150 pages.

Chapeskie, D.J., D.F. Galley, J.R. Mitchell, N.W. Quinn, and H.H. Struik. 1989. A silvicultural guide for the white pine working and red pine groups in Ontario. Forest Resources Group, Ontario Ministry of Natural Resources. Toronto, Ontario, Canada. 102 pages.

Chylinski, S. 1992. The effect of stand conditions on the performance of the Caterpillar 227 feller-buncher equipped with the Risley Rotosaw model 2200T in Northwestern Ontario. B.Sc.F. thesis, School of Forestry, Lakehead University, Thunder Bay, Ontario, Canada. 37 pages.

Davis, L.S. and K.N. Johnson. 1987. Forest Management, third edition. McGraw-Hill, Inc. New York, New York, USA. 790 pages.

Davis, R. 1994. Strategic forest management model: description and user's guide (Draft). Forest Resources Assessment Project. Ontario Ministry of Natural Resources. Sault Ste. Marie, Ontario, Canada. 46 pages.

Delorie, D.J. 1995. Djgpp 32-bit C and C++ development environment for DOS. Rochester, New Hampshire, USA.

Dodds, D. 1994. Toward sustainable forestry in Canada. Forestry Chronicle. **70**(5):538-542.

Duerr, W.A., 1960. Fundamentals of Forestry Economics. McGraw-Hill Book Company Inc., New York, USA. 579 pages.

Duerr, W.A., 1993. Introduction to Forest Resource Economics. McGraw-Hill Inc., New York, USA. 484 pages.

Eastman, J.R., 1992a. IDRISI technical reference. The IDRISI Project, Clark University, Graduate School of Geography, Worchester, Massachusetts, USA. 213 pages.

Eastman, J.R., 1992b. IDRISI user's guide. The IDRISI Project, Clark University, Graduate School of Geography, Worchester, Massachusetts, USA. 178 pages.

Elwood, N.E. and D.W. Rose. 1990. Heuristic simulation: An alternative to linear programming in developing forest management schedules. Forest Ecology and Management. **35**: 303-310.

Environmental Systems Research Institute Inc. 1994. ARC/INFO Data Management: Concepts, Data Models, Database Design, and Storage. Environmental Systems Research Institute Inc., 380 New York Street, Redlands, California, USA.

Fowells, H.A. 1965. Silvics of Forest Trees of The United States. Division of Timber Management Research, Forest Service, US Department of Agriculture. Washington, DC. Agriculture Handbook Number 271. 762 pages.

Gingras, J.-F. 1988. The effect of site and stand factors on feller-buncher performance. Forest Engineering Research Institute of Canada. Montreal, Canada. Technical Report TR-84. 16 pages.

Gingras, J.-F. 1989. Feller-buncher performance in adverse stand and terrain conditions. Forest Engineering Research Institute of Canada. Montreal, Canada. Technical Report TR-89. 10 pages.

Haight, R.G. 1987. Evaluating the efficiency of even-aged and uneven-aged management. Forest Science. **33**: 116-143.

Haight, R.G., and R.A. Monserud. 1990. Optimizing any-aged management of mixed-species stands: II. Effects of decision criteria. Forest Science. **36**:125-144.

Hall, T.H. 1977. Instruction manual. New Brunswick Department of Natural Resources, Fredericton, New Brunswick, Canada. Unpublished.

Hall, T.H. 1978. Toward a framework for forest management decision-making in New Brunswick. New Brunswick Department of Natural Resources, Fredericton, New Brunswick, Canada. Unpublished.

Hearnden, K.W., S.V. Millison and W.C. Wilson. 1993. A report on the status of regeneration. Queen's Printer for Ontario. Toronto, Ontario, Canada. 117 pages.

Hoganson, H.M. 1981. Timber management scheduling under uncertainty: two alternative approaches. Ph.D. Thesis, University of Minnesota, College of Forestry, Minneapolis, Minnesota, USA. 150 pages. (Cited in Elwood, N.E. and D.W. Rose. 1990).

Hunter, M.L. 1990. Wildlife, Forests, and Forestry : Principles of Managing Forests for Biological Diversity. Prentice-Hall Inc. Englewood Cliffs, New Jersey, USA. 370 pages.

Iverson, D.C., and R.M. Alston. 1986. The genesis of FORPLAN : a historical and analytical review of forest service planning models. Intermountain Research Station. Forest Service, US Department of Agricultural. General Technical Report. INT-214. 31 pages.

Jeglum, J.K., and D.J. Kennington. 1993. Strip clearcutting in black spruce: a guide for the practising forester. Forestry Canada, Ontario Region, Great Lakes Forestry Centre, Sault Ste. Marie, Ontario, Canada. 102 pages

Keegan, C.E., C.E. Fiedler and F.J. Stewart. 1995. Cost of timber harvest under traditional and "new forestry' silvicultural prescriptions. Western Journal of Applied Forestry. **10**(1): 36-42.

Kimmins, H. 1992. Balancing Act : Environmental Issues in Forestry. University of British Columbia Press. University of British Columbia, Vancouver, British Columbia, Canada. 244 pages.

Koven, A., E. Martel. 1994. Class environmental assessment by the Ministry of Natural Resources for timber management on crown lands in Ontario - reason for decision and decisions. Ontario Environmental Assessment Board. Ontario Ministry of the Environment, Toronto, Ontario, Canada. EA-87-02. 561 pages.

Legislative Assembly of Ontario. 1994. Bill 171: Crown Forest Sustainability Act. An act to revise the Crown Timber Act to provide for the sustainability of Crown forests in Ontario. Legislative Assembly of Ontario. Toronto, Ontario, Canada. 37 pages.

Lee, K. N. 1993. Compass and Gyroscope: Integrating Science and Politics for the Environment. Island Press, Washington, DC 243 pages.

Lewis, R. 1995. When a tree falls. Macleans. **108**(29): i.

Lieffers, V.J., R.B. Macmillian, D. MacPherson, K. Branter and J.D. Stewart. 1996. Semi-natural and intensive silvicultural systems for the boreal mixedwood forest. The Forestry Chronicle. **72**(3): 286-292.

Lockwood, C. 1995. The Midas Algorithm. *In* spatial harvest scheduling workshop proceedings. 1995. Natural Resources Canada, Petawawa National Forestry Institute. Petawawa, Ontario. Unpublished.

Lougheed, W.H. 1988. Spatial analysis in timber management planning. MSc. F. Thesis, Lakehead University, Thunder Bay, Ontario, Canada. 150 pages.

Marshall, J.E. 1990. The changing nature of allowable annual cut and harvest forecasting. Economics and Statistics Directorate, Forestry Canada. Ottawa, Ontario, Canada. 14 pages.

McCarter, J. 1995. Landscape management system. Silviculture Laboratory, University of Washington, College of Forest Resources, AR-10 Seattle, WA.

Mellgren, P.G. 1990. Predicting the performance of harvesting systems in different operating conditions. Forest Engineering Research Institute of Canada. Montreal, Canada. Special Report SR-67. 22 pages.

Metsätecho. 1983. Metsätehon opas: leimikon suunnittelu. Painovalmiste Ky, Helsinki. (*Cited in* Pulkki 1994).

Microsoft Corporation. 1993. Microsoft FoxPro Language Reference. Microsoft Corporation. One Microsoft Way. Redmond, Washington. 98052-6399. Document No. FX37557-1292. approx. 1200 pages.

Mitchell, S.J. 1995. The windthrow triangle: a relative windthrow hazard assessment procedure for forest managers. Forestry Chronicle. **71**(71): 446-450.

Moore, T.G.E. and C.G. Lockwood. 1990. The HSG wood supply model: description and user's manual. Forestry Canada. Publications Distribution Centre, Petawawa Forestry National Institute (PNFI), Chalk River, Ontario, Canada. Information Report PI-X-98. 31 pages.

Moore, T.G.E., J.S. Williams, and P. Duinker. 1994. The HSG forest modelling system - user's guide. Dendron Resource Surveys Inc. Ottawa, Ontario, Canada. 279 pages.

Mussell, A. and G. Fox. 1995. Trade-off analysis in protecting woodland caribou in multiple-use forestry management in northwestern Ontario. Work in progress, presented at "Northern Exposure", February 8-9, 1995, Dryden, Ontario, Canada.

Nautiyal, J.C. 1980. An anatomy of stumpage value. Canadian Journal of Forest Research **10:** 135-142.

Nautiyal, J.C. 1988. Forest Economics: Principles and Applications. Canadian Scholars' Press Inc. Toronto, Ontario. 581 pages.

Nautiyal, J.C., S. Kant and J.S. Williams. 1995. A mechanism for tracking the value of standing timber in an imperfect market. Canadian Journal of Forest Research. **25:**638-648.

Navratil, S., L.G. Brace, E.A. Sauder and S. Lux. 1994. Silvicultural and harvesting options to favour immature white spruce and aspen regeneration in boreal mixedwoods. Canadian Forest Service, Northwest Region, Northern Forestry Centre. Edmonton, Alberta, Canada. Information Report. NOR-X-337. 78 pages.

Newham, R.M., 1991. Logplan II: a model for planning logging and regeneration activities. Forestry Canada, Petawawa National Forestry Institute. Petawawa, Ontario, Canada. Information Report. PI-X-102. 38 pages.

Ontario Forest Policy Panel. 1993. Diversity: Forests, People, Communities - A Comprehensive Forest Policy Framework for Ontario. Queen's Printer for Ontario. Toronto, Ontario, Canada. 147 pages.

Ontario Ministry of Natural Resources. 1986. Timber management planning manual for crown lands in Ontario. Ontario Ministry of Natural Resources, Toronto, Ontario, Canada. 218 pages + updates.

Ontario Ministry of Natural Resources. 1992. Report to the environmental assessment board on a comparison of the cost and the results of applying two alternative silvicultural systems in the boreal forest. Ontario Ministry of Natural Resources, Toronto, Ontario, Canada. 234 pages.

Ontario Ministry of Natural Resources. 1993a. Ontario's stumpage history and procedures. Forest Values, Sustainable Forestry Program, Ontario Ministry of Natural Resources. Sault Ste. Marie, Ontario, Canada. 33 pages. plus appendices.

Ontario Ministry of Natural Resources. 1993b. Provincial silvicultural directions. Ontario Ministry of Natural Resources. Toronto, Ontario, Canada. Unpublished. 5 pages.

Ontario Ministry of Natural Resources. 1993c. Quantification of residual timber values -northern model. Forest Values, Sustainable Forestry Program, Ontario Ministry of Natural Resources. Sault Ste. Marie, Ontario, Canada. 61 pages. plus appendices.

Ontario Ministry of Natural Resources. 1995. Forest management planning manual for Ontario's crown forests. Ontario Ministry of Natural Resources. Final Draft, May 18. Toronto, Ontario Canada. 388 pages.

Pearse, P.H. 1967. The optimum forest rotation. Forestry Chronicle. **43:**178-195.

Pearse, P.H., 1990. Introduction to forestry economics. UBC Press. University of British Columbia, 6344 Memorial Road, Vancouver, BC V6T 1Z2. (*Cited in* Armstrong *et al.* 1992)

Plonski, W.L. 1981. Normal Yield Tables (Metric) for Major Forest Species of Ontario. Forest Resources Group, Ontario Ministry of Natural Resources, Toronto, Ontario, Canada. 40 pages.

Pulkki, R.E. 1994. Forest Harvesting, lecture notes for forestry 3211 on the procurement of wood with emphasis on boreal and Great Lakes St. Lawrence forest regions. Lakehead University, Thunder Bay. 173 pages.

Reed, F.L.C. 1995. Untitled letter to the editor. August 2. Globe and Mail. Toronto, Ontario, Canada.

Rollins, K., M. Forsyth, S. Bonti-Ankomah and B. Amoah. 1995. A financial analysis of a white pine improvement cut in Ontario. Forestry Chronicle. **71:** 466-472.

Rouck, K.B., and J.D. Nelson. 1995. Timber supply and economic impacts associated with sustained yield unit size. Forestry Chronicle. **71:** 647-656.

Rowe, J.S. 1972. Forest Regions of Canada. Canadian Forest Service, Natural. Resources Canada. Ottawa, Canada. 172 pages.

Ruel, Jean-Claude. 1995. Understanding windthrow: silvicultural implications. Forestry Chronicle. **71**(71): 434-445.

Sampson, F.B., and F.L. Knopf. 1982. In search of a diversity ethic for wildlife management. Trans. North American Wildlife Natural Resource Conference. **47**:412-431. (*Cited in* Hunter, 1990).

Schuster, E.G., L.A. Leefers and J.E. Thompson. 1993. A guide to computer-based analytical tools for implementing national forest plans. Intermountain Research

Station, US Department of Agriculture, Forest Service, Washington, DC Technical Report. INT-296. 269 pages.

Sessions, J., and J.B. Sessions. 1992. Scheduling and network analysis program (snap II), user's guide, Version 2.04. Oregon State University, Forest Engineering Department, Corvallis, Oregon, USA. 165 pages.

Smith, D.M. 1986. The Practice of Silviculture, eighth edition. John Wiley and Sons. New York, New York, USA. 527 pages.

Silversides, C.R., and U. Sunderberg. 1989. Operational Efficiency in Forestry, Volume 2: Practice. Kluwer Academic Publishers, Dordrect, The Netherlands. 169 pages.

Sunderberg, U., and C.R. Silversides. 1988. Operational Efficiency in Forestry, Volume 1: Analysis. Kluwer Academic Publishers, Dordrect, The Netherlands. 219 pages.

Timberline Forest Inventory Consultants. 1995. FORMAN +1 User Manual Version 2.1. Timberline Forest Inventory Consultants. Victoria, British Columbia, Canada. 188 pages.

Thomas, J.W. 1979. Wildlife habitats in managed forests: the Blue Mountains of Oregon and Washington. US Department of Agriculture, Forest Service.. Washington, DC. Agriculture Handbook Number 553. 512 pages. (*Cited in* Hunter 1990).

Ulley, W. 1995. Untitled letter to the editor. August 2. Globe and Mail. Toronto, Ontario, Canada.

Wang, E., T. Erdle and T. Roussell. 1987. FORMAN wood supply model - user manual. N. B. Executive Forest Resources Committee Inc. Frederiction, New Brunswick, Canada. 61 pages.

Wedeles, C.H.R., L. Van Damme, C.J. Daniel, and L. Sully. 1995. Alternative silvicultural systems for Ontario's boreal mixedwoods: a review of potential options. Natural Resources Canada, Canadian Forest Service-Sault Ste. Marie, Great Lakes Forestry Centre, Sault Ste. Marie, Ontario, Canada. Northern Ontario Development Agreement (NODA/NFP) Technical Report. TR-18. 61 pages.

West, E.G., and R.L. Miller. 1978. Economics Today-The Micro View, Canadian Edition. Harper and Row Publishers Inc. New York, New York, USA. 440 pages.

Whitmore, G.J. 1995. Implications of alternative herbicide-use policies for forest management in Ontario. M.Sc.F. thesis, Faculty of Forestry, Lakehead University, Thunder Bay, Ontario, Canada.

Willcocks, A.J., F.W. Bell, J.W. Williams, and P.N. Duinker. 1990. A crop-planning process for northern Ontario forests. Northwestern Ontario Forest Technology

Development Unit, Ontario Ministry of Natural Resources, Thunder Bay, Ontario, Canada. Technical Report #30. 159 pages.

Williams, D.H. 1990a. Counting the trees is not enough: measurement and projection of economic timber supply. Economics and Statistics Directorate, Forestry Canada. Ottawa, Ontario, Canada. 10 pages.

Williams, J. 1990b. Crop planning manual for northern Ontario. Northwestern Ontario Forest Technology Development Unit, Ontario Ministry of Natural Resources, Thunder Bay, Ontario, Canada. Technical Report #65. 110 pages.

Williams, J. 1994. Lecture notes from Forestry 5132: Advanced Studies in Forestry. Lakehead University. Thunder Bay, Ontario, Canada. Unpublished.

Wykoff, W.R., N.L. Crookston and A.R. Stage. 1982. User's guide to the Stand Prognosis Model. US Department of Agriculture, Forest Service. General Technical Report INT-133. Washington DC. USA.

Yang, R.C., and I.E. Bella. 1994. Releasing white spruce from trembling aspen-a yield analysis. Natural Resources Canada, Canadian Forest Service, Northwest Region, Northern Forestry Centre, Edmonton, Alberta, Canada. Forest Management Note 60. 6 pages.

Zundel, P. 1993. Comparison of full-tree central processing against roadside and stump-area processing considering harvesting, silviculture and road costs. Faculty of Forestry, University of New Brunswick, Frederiction, Canada. Unpublished. 25 pages.

8 GLOSSARY

This section contains a glossary of terms used in the report. HSG commands are in UPPERCASE letters.

Term	Description
AAC	the annual allowable cut or harvest level
activity file	the file used to list and control the actions for a simulation
CONSTRAINTS	a command which applies spatial harvest constraints from an externally developed file
ECONOMIC	a HSG command used to specify the economic information for a run and to set the economic operability minimum
economic operability minimum	a global applied economic minimum operability limit (expressed in $/m^3 for the listed species present in the stand) which must be present for a stand to be eligible for harvest
eligibility constraint	1. an harvest scheduling constraint expressed in m3/ha of desired species. 2. a pre-defined spatially specific file used to control harvest areas.
FRI	forest resources inventory
HAL	a harvest allocation list used to control the eligible working group conditions for a harvest rule
harvest priority rules	a method which applies a criteria to rank stands for harvest
harvest priority rule eligibility list	the list of stands which are eligible for treatment for a given harvest rule.
harvest protection period	the number of years a stand is protected from harvest following a harvest treatment
MANDATORY	a command in which an existing schedule file can be used to control harvesting.
OPMIN	a global applied minimum operability limit (expressed in m^3/ha of total stand volume) which must be present for a stand to be eligible for harvest
Partial	a HSG used to apply partial harvesting to a harvest rule

regeneration treatment cost file	a file which contains the cost of treatments, the expected harvest age and the eligible working groups which they may be applied to.
Release	a HSG harvest rule modifier used to apply release harvesting to a harvest rule
RTV	residual timber value, can be used as a measure of economic profit
RULE3SILV	a command which loads the regeneration treatment cost file and specifies the target in $ for each regeneration treatment level.
schedule file	the HSG output file containing the stand by stand record of activities for a simulation. Since individual stands are listed in this file, it can be linked to a GIS system to produce maps.
SEV	soil expectation value, the value of forested land
state table	a file used to describe a new stand composition following a disturbance.
STEP	the STEP command is used to describe the number of years to advance the simulation as well as the harvest targets and methods to be used.
summary file	the HSG output file containing summarised information from a run. The information is summarised by date, species, age-class, working group, site type, and activity type.
TRANSPORT	a command which loads a transportation cost file into a HSG run
transportation cost file	a file which contains the transportation cost for each stand in the inventory
treatment priority list	a ordered file which contains a list of working groups and the regeneration treatments that will be applied to them (used for harvest rules other than Rule_3)
yield curves	a time dependent expression of volume for an individual species/site combination (expressed in tabular format for HSG)

9 APPENDIX I : HYPOTHETICAL FOREST COMPOSITION

This section contains the files and data used for the simulations.

The following three columns contain the stand compositions used in the development of the theory forests. Repeated stand compositions were used to control frequency.

PJ 0	SB 0	PO 0
PJ 0	SB 0	PO 0
PJ 9	SB 9	PO 9PJ 1
PJ 9	SB 9	PO 8PJ 2
PJ 9SB 1	SB 8	PO 7PJ 3
PJ 9SB 1	SB 8	PO 6PJ 4
PJ 8SB 2	SB 8PJ 2	PO 5PJ 5
PJ 8SB 2	SB 8PJ 2	PO 9SB 1
PJ 7SB 3	SB 8PO 2	PO 8SB 2
PJ 7SB 3	SB 8PO 2	PO 7SB 3
PJ 6SB 4	SB 6PO 4	PO 6SB 4
PJ 6SB 4	SB 6PO 4	PO 5SB 5
PJ 9PO 1	SB 6PJ 4	PO 7SB 3
PJ 9PO 1	SB 6PJ 4	PO 7BW 3
PJ 8PO 2	SB 5PJ 5	PO 8PJ 1SB 1
PJ 8PO 2	SB 5PJ 5	PO 6PJ 2SB 2
PJ 7PO 3	SB 5PO 5	PO 6PJ 3SB 1
PJ 7PO 3	SB 5PO 5	PO 6PJ 1SB 3
PJ 6PO 3	SB 8SW 2	PO 6PJ 1SB 2SW 1
PJ 6PO 3	SB 8BW 2	PO 5PJ 1SB 2SW 2
PJ 5PO 5	SB 6PJ 2PO 2	PO 4PJ 2SB 2SW 2
PJ 5PO 5	SB 6PJ 1PO 3	PO 5BW 1SB 2SW 2
PJ 5SB 5	SB 6PJ 3PO 1	PO 8SB 1SW 1
PJ 5SB 5	SB 7PO 1SW 2	PO 7SB 2SW 1
PJ 7PO 2SB 1	SB 7PO 2BW 1	PO 7SB 1SW 2
PJ 7PO 2SB 1	SB 6PO 2BW 2	PO 6SB 2SW 2
PJ 7PO 1SB 2	SB 6PO 2SW 2	PO 5SB 2SW 3
PJ 7PO 1SB 2	SB 6SW 2PO 1BW 1	PO 5SB 3SW 2
PJ 8PO 1SB 1	SB 5SW 2PO 2BW 1	PO 9
PJ 8PO 1SB 1	SW 6SB 4	PO 9PJ 1
PJ 6SB 2PO 2	SW 5PO 5	PO 8PJ 2
PJ 6SB 2PO 2	SW 5PO 3PJ 2	BW 0
PJ 6SB 1PO 3	SW 5PO 2SB 3	BW 9PO 1
PJ 6SB 1PO 3	SW 6SB 3PO 1	BW 7PO 3
PJ 6SB 3PO 1	SW 4SB 3PO 2BW 1	BW 7SB 3
PJ 6SB 3PO 1		BW 7PJ 3
PJ 0		BW 6PO 2SB 2
PJ 8SB 2		BW 4PO 2SW 2
PJ 8PO 2		BW 6PO 2PJ 2
		BW 4PO 2PJ 2SB 2

10 APPENDIX II: USING HSG 3.0

This appendix contains descriptions of the changes made to the HSG model. The information in this section is intended as a supplement to the HSG forest modelling system user's guide. It is written as a technical manual rather than an information source describing why the changes were made and their usefulness in forest modelling.

Two main changes were made in the stand scheduling and harvest functions. First, a method was incorporated to assign, conduct and track partial harvesting of stands, and secondly, a method of stand prioritisation using economic harvest and regeneration parameters was added. The modified version is referred to as HSG version 3.0, which is based upon version 2.0.

A minor change has been made in the screen output. Version 2.0 displays the area harvested with each step and the total harvest volume if the targets were unattainable. In version 3.0, the volume harvested by each harvest priority rule has been added to the screen output. The individual volumes from each rule in the step are listed in the order in which they are applied. The output is in the form: **rule 1 XXX.XX**, **rule 2 XXX.XX**, **rule 3 XXX.XX**, etc. The "**rule 1**", refers to order of the harvest priority rules in the STEP command, not the method of harvest priority ranking.

10.1 Partial Harvesting of Stands

HSG 2.0 harvests only by clearcutting. Two new partial harvesting functions; "Release" and "Partial" have been added. The only difference between these functions is their name, there is no difference in their operation. All of the harvesting function syntax changes occur within the harvest priority rule portion of the STEP command. The version 2.0 STEP command syntax is as follows:

STEP 10 : Sb/Sw=2000 : Rule_2-Sb/Sw=2000(50)

step step quota harvest priority rule

This command ages the forest 10 years; sets a harvest quota of 2000 m^3/year of black *and/or* white spruce for the entire step; then prioritises stands for harvest by determining the volume loss of black *and/or* white spruce for each stand (from stands with greater than 50m^3 /ha of Sb *and/or* Sw), and sets a harvest priority rule target of 2000 m^3/year of black and/or white spruce.

Version 3.0 retains all of the capacities of the original version and adds new harvesting methods and stand selection capacities to the harvest priority rule portion of the STEP command. An example of the modified priority rule syntax is shown below:

Rule_2-{Partial-60}[basic.hal;30]-Sb/Sw=2000(50)

This is the same priority rule as the one above, with the following changes. Replacing clearcutting, 60% of black *and/or* white spruce will be partially cut from the selected stands. The list of potential stands for harvest is the same between the two rules, except that stands must be of the type described in the Harvest Allocation List (HAL), "basic.hal" to be harvested by the modified rule. Stands not of this type are simply by-passed. Finally, once harvested, a stand is protected from harvest for the next 30 years.

These changes were made possible with the addition of modifiers. The two modifiers now permitted in the STEP command are {....} and [....]. Either of these modifiers can be used or omitted. This permits the harvest allocation list (HAL) and a protection from harvest to be used with the clearcut function. The first modifier must be preceded by a hyphen, ("-"), and the last modifier must be followed by a hyphen, but when both are used, there is no hyphen between them.

The {....} modifier contains two parts separated by a hyphen. The first part must contain either "**Partial**" or "**Release**", and the second part, the percent removal (an integer from 100 to 1) of the listed species to be harvested. The second modifier [....] also contains two parts, this time the parts are separated by a semicolon. The first part contains the file name of the harvest allocation list (HAL) to be applied in the current rule. A stand will be harvested only if it matches at least one record in the designated HAL file. A stand matches a record if, and only if, both of the following are true:

1. The species and site codes match exactly <u>and</u>
2. The stand age is <u>greater than or equal</u> to the lower bound and <u>less than or equal</u> to the upper bound.

There is no default extension for the HAL filename in the [....] modifier, and the file must be in the working directory, or a pathway must be stated. If a HAL file is used without a harvest protection number the semicolon is not included. The syntax then becomes: **[basic.hal]** . Instructions for the harvest allocation file format are discussed later in this section.

The second part of the [....] modifier is an integer representing the harvest protection number. This is the number of years into the future the harvested stand is protected from harvest. If this function is used without a HAL file, the semi-colon must be included. The syntax becomes: **[;30]** . This function operates by adding the number of years specified to the current date to obtain a reserve_date. A reserve_date is stored for each stand in the inventory. Before a stand is harvested, its reserve_date is compared against the current date. The stand is harvested only if the reserve_date is <u>less than or equal to</u> the current date. Therefore, if ten year STEPs are used, and you don't wish the next STEP to harvest the stand, a minimum of an 11 year reserve must be specified. Note: a default of one year is added if no date is specified to prevent rules within the same STEP command from harvesting a stand twice.

As with version 2.0, multiple quotas and/or harvest priority rules are permitted. However, there are some important differences. The partial and release functions harvest only those species listed in the rule, while the clearcutting function harvests all species in the stand, even those not in the quota and non-commercial species. In the boreal forest, the command **{Partial-100}-Pj/Sb/Sw/B/Po/Bw** will harvest much the same as clearcutting but produce some different results. Unlike the clearcut function, the partial and release functions actually change the species stocking in the stand record. For example, **{Partial-70}** will reduce a species stocking of 0.20 to 0.06. The result of the partial or release function upon a stand can be seen in the schedule file, as the modified stand's attributes are listed there. Compare this to the clearcut function where the undisturbed stand's attributes are listed in the schedule file. The clearcut harvested stand's attributes are modified later in the silviculture function; after printing the stand to the schedule file. Therefore, unlike the clearcut function, volumes harvested in the partial and release functions cannot be determined from the schedule file; these volumes can only be found in the summary file.

Another difference is in the application of the state table. The partial and release functions are matched to the state table immediately after harvest. This permits the operator to modify the stand's structure after partial or release harvest by including fields for "**hrvt partial**" or "**hrvt release**" in the state table. This match to the state table is the silvicultural treatment application for partial and release harvest. No other silvicultural treatment is possible (in HSG only clearcut stands have regeneration treatments applied). If no match is found in the state table, a warning message is sent to the screen, and the stand is left as modified by the partial or release harvest. By contrast, the clearcut function applies a harvest default to clearcut stands not matched in the state table during the silviculture function. This default function resets the clearcut stands age and volume to 0.

Note: the MANDATORY function has not been modified to reflect partial and release harvests and as a result will not function if the modifications described above are used. All of the other features of the HSG-lite package should function and reflect the changes.

10.1.1 Harvest Priority Rule Examples

This following provides some examples of possible harvest priority rule combinations.

Rule_2-{Release-60}-Sb/Sw=2000
-rank stands for harvest using minimise volume loss
-harvest 60% of Sb and/or Sw from stands
-target is 2000 m^3/yr. Sb and/or Sw

Rule_0-[basic.hal]-Sb=500(60)
-rank stands for harvest using oldest first
-clearcut stands that match basic.hal and have at least 60 m^3/ha Sb
-target is 500m^3/yr. Sb

Rule _1-{Partial-30}[hold.hal;40]-Pj=700(80)
-rank stands for harvest using maximise volume
-harvest 30% of Pj from stands that match hold.hal and have at least 80 m^3/ha
-protect stands from harvest for the next 40 years
-target is 700m^3/yr. Pj.

Rule_2-[;200]-Pw=1000(150)
-rank stands for harvest using minimise volume loss
-clearcut stands that have a least 150 M^3/ha Pw
-protect from harvest for the next 200 years
-target is 1000 m^3/yr. Pw

Rule _2-{Partial-30}[hold.hal;40]-Pj=700, Rule_2-[basic.hal]-Sb/Sw/Pj=5000(60)
-rank and harvest 30% Pj until Pj=700 m3
-then rank the remaining stands and clearcut until Sb/Sw/Pj=5000

10.1.2 Harvest Allocation List Preparation

This section provides instructions in the preparation and use of the harvest allocation list (HAL). The purpose of this list is to provide the operator with greater control over the attributes of the stands to be harvested. In version 2.0, non-spatial control over which stands are harvested is accomplished by minimum volume and by the harvest priority rule employed. The volume control is a minimum volume set in two ways, globally for all stands by the OPMIN command, and by the rule specific minimum volume of the listed (preferred) species.

In version 3.0, by specifying a HAL file in the harvest rule, each potential stand to be harvested must match at least one of the records in the HAL file or the stand will be by-passed for harvest. The fields included in the HAL file are: working group, site code and stand age. Unlike the file formats in version 2.0, this file format is fixed. No header is included nor is a field for DATA. The file must be an ASCII file with one record per line. Each record has four fields, which must be separated by one or more spaces or tabs. There is no limit to the number of records that can be included in this file. A range of ages is permitted through the use of a lower age bound and an upper age bound field. A single age can be specified by using the same value in both the upper and lower age bound.

Harvest Allocation List File Format :
CODE SITE LOWER_AGE_BOUND UPPER_AGE_BOUND
Where:
CODE : the working group species code
SITE : the working site code
LOWER_AGE_BOUND : the lowest age at which a stand will be matched
UPPER_AGE_BOUND: the highest age at which a stand will be matched

Harvest Allocation List File Example:

```
Pj X 100 120
Pj 1 100 120
Pj 2 110 130
Sb 1 120 130
Sb 2 120 130
Sb 3 130 140
Sw 2 155 155
```

10.2 Economic Modifications to HSG

Modifications were made to HSG to schedule stands for allocation of harvest and regeneration treatments from user supplied economic criteria. This section explains the use and format of these economic scheduling modifications.

As explained earlier, a fourth harvest priority rule has been added to HSG version 3.0. The new rule, Rule_3, ranks stands for harvest based upon the stand's opportunity cost of delaying harvest one year. This rule also applies regeneration treatments to all eligible clearcut stands based upon the stands' Soil Expectation Value (SEV). To operate, this rule requires an economic input file, an optional transportation cost file, an optional silvicultural treatment cost file and the discount rate.

Rule_3 consists of two main functions, the selection and harvesting of stands and the application of silviculture. Rule_3 first calculates the opportunity cost of harvest delay (refer to main text for the calculation) for all of the eligible stands, then ranks them highest to lowest. Harvesting commences from the top of the list until the harvest targets are reached or the list of stands exhausted. Rule_3 then applies regeneration treatments to all eligible clearcut stands in a manner similar to harvesting. There are four possible regeneration treatments in HSG; elite, intensive, basic and extensive. Rule_3 applies first the elite treatment, then the intensive treatment followed by the basic treatment. These three treatments are applied in the following manner. First, the list of clearcut stands in the step is run through the silvicultural treatment cost file. A list results from all stands which match the type described in the file for elite treatment. These stands will have a SEV calculated, then this list is ranked highest to lowest. Elite treatment is then applied up to the user defined limit for elite treatment beginning from the top of the list. The same procedure is then applied for intensive treatment to the step's remaining untreated clearcut stands, then repeated once more for basic treatment. The extensive treatment is the default, and it is applied to all the remaining untreated clearcut stands for the step. As with all the harvest rules, there is no user defined limit to the amount of extensive regeneration applied. (The only method to avoid extensive regeneration is by not listing it in the state table, which causes the silviculture default to be applied).

The rational behind Rule_3's regeneration allocation by SEV was removed from the body of the thesis and located here. The operational instructions continue with the section on the DISCOUNT command.

HSG Version 2.0 assigns regeneration treatments to clearcut stands according to a user-defined *treatment priority list*. Treatment is applied by stand working groups and treatment type. Trade-off decisions between distance, site and treatment intensity are not possible using this method. Stands furthest from the mill could receive an intensive regeneration treatment while closer stands could receive a less-intensive treatment. This would have the opposite effect of traditional forest economic regeneration strategies where profit should be maximised (Davis and Johnson 1987, Nautiyal 1988, Duerr 1993). A profit-maximising forest manager would assign the regeneration treatments to the stands that maximise return. In the boreal forest this is accomplished by locating the intensive regeneration treatments on the most productive sites closest to the mill. The goal of this behaviour is to increase <u>forest volumes</u> to desirable levels while maximising profits. To simulate this profit-maximising behaviour, the assignment of regeneration treatments to clearcut stands based upon SEV was added to Rule_3.

Most authors would define SEV as the value obtained when the optimum silvicultural treatment is applied. However, since SEV is the value of an infinite number of rotations of the same silvicultural treatment, it can be used to compare different treatments. The treatment which yields greater SEV is economically more efficient due to the higher return. This principle was used to assign regeneration treatments in earlier forest-level models (Zundel 1993).

For the forest manager to calculate the SEV, some assumptions need to be made. The regeneration treatment to be applied, the cost of the treatment, the resulting stand structure, and the age of the stand at harvest must be known. The first three are relatively easy to determine, but the age of a given stand type at harvest can vary widely throughout a simulation. When a forest is harvested at the maximum long-term sustained yield, some stands will be harvested as young as 40 years and others older than 120. For this study, an age of 70 or 60 years was used to represent an expected average harvest age, depending upon the working group. These ages were chosen because they are typical first eligible ages for harvest in northwestern Ontario's boreal forests.

The application of regeneration treatments by SEV operates much like the harvest function. All the clearcut stands for a single *STEP* are ranked according to their SEV's which are calculated using equation [3]. The economic input variables price, cost and transportation cost are calculated in the same manner as the opportunity cost. The additional information is retrieved from a regeneration treatment cost file. This new file contains a list of the eligible working groups and treatment types as well as a cost for each treatment and an expected harvest age.

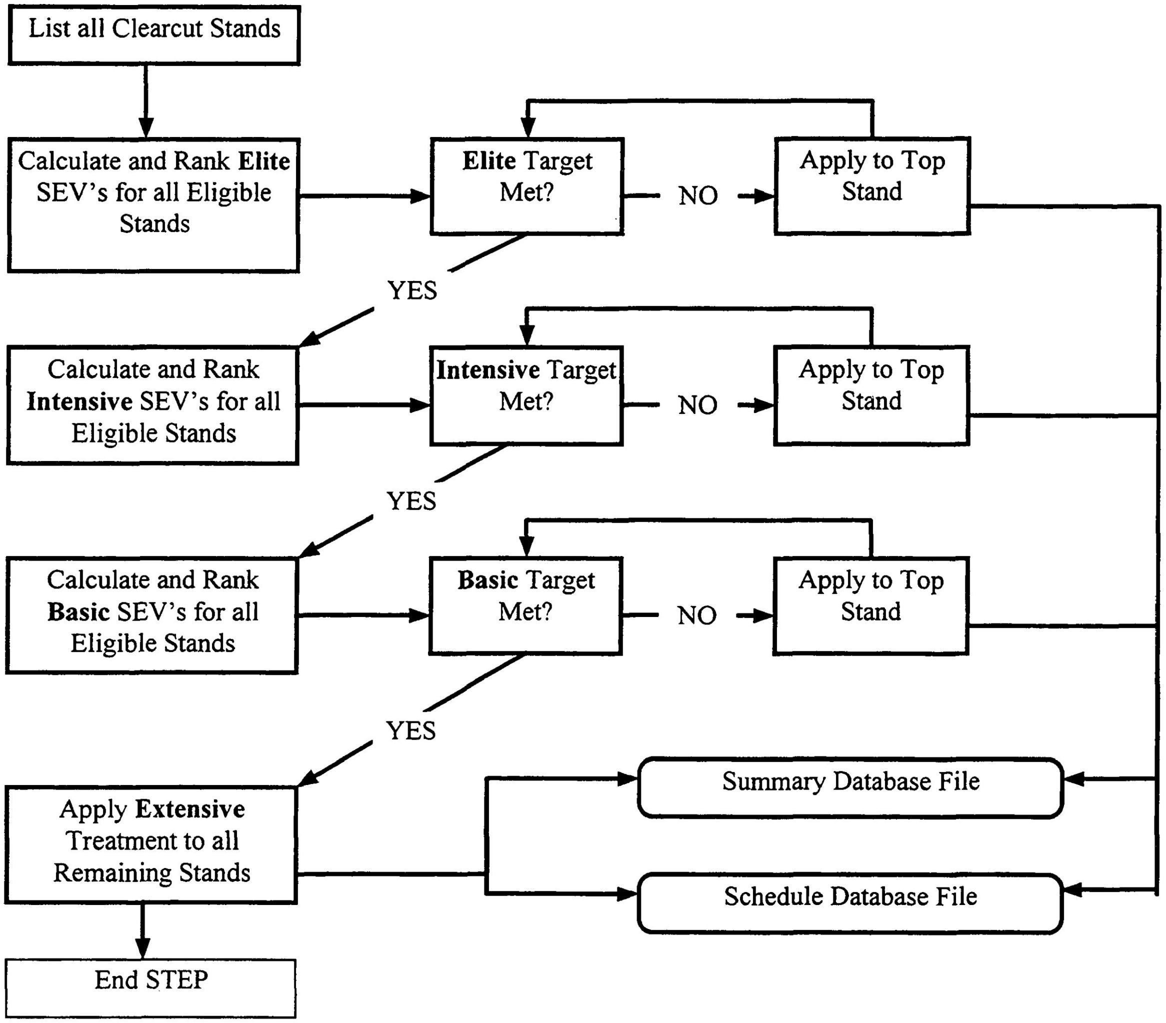

Figure II - 1. Flow chart of Rule_3 regeneration assignment to clearcut stands.

Up to this point, all of the clearcut stands for the entire *STEP* are only flagged as clearcut. No change in the stand composition occurred. Assigning regeneration to clearcut stands is the final process in the *STEP* command. A flow chart of the clearcut regeneration assignment process which was developed for HSG 3.0 is shown in Figure II - 1.

HSG has the capacity to assign and track 4 different regeneration treatments (elite, intensive, basic and extensive). Rule_3 was developed to apply regeneration treatments always in the following order: elite, intensive, basic and extensive. The first action in the regeneration function is to calculate an elite treatment SEV for all eligible clearcut stands, then rank the stands by the calculated SEV in the same manner as harvesting. Elite treatment is assigned to the stands with the greatest SEV in decreasing order until the elite target is met or the list of stands is exhausted. The same process is repeated for intensive treatment to the remaining untreated stands, and subsequently for basic treatment. The default regeneration treatment is extensive regeneration. This treatment is assigned to <u>all remaining untreated stands</u>, following the process of the other harvest priority rules.

The procedure above was designed to apply regeneration to maximise the return by treatment type. It does not maximise the return for all regeneration treatments. This exemplifies the forest manager's dilemma that inefficient stand-level actions may have to be taken to maximise the forest-level objectives. Using this procedure, regeneration treatments are applied to specified levels according to the user's specifications, but applied so that SEV is maximised.

Care must be exercised when mixing different harvest priority rules within a simulation. While it is possible to use all four rules, regeneration treatments will be applied using the Rule_3 method to all clearcut stands within a single STEP command if Rule_3 is used at least once in the step. If Rule_3 is not used in a step, silviculture will be applied using the HSG 2.0 treatment function even if the economic commands are used in the activity file.

The command DISCOUNT sets the discount rate for the simulation. It is included in the activity file in much the same manner as other commands, and must be located before the first STEP command. The discount rate is expressed as a real number, as in the following example:

```
#
DISCOUNT .05
#
```

10.2.1 Economic Yield Curve File Format

This file is used to input the economic variables into HSG. It is loaded using ECONOMIC command, shown in the following examples.

```
#
ECONOMIC <filename> <value1>
#
Where:
<filename>    : is the name and optional path of the economic yield file
<value1>      : the optional economic operability limit (in $/m3)
```

```
#
ECONOMIC ../basic/lowcost.eco 0.0
#
```

In the ECONOMIC command, full pathways are supported to the filename. Economic yield curve files <u>cannot</u> be loaded using the SOURCE command with a separate file to define file names and pathways. The optional economic operability limit is a real number. This limit is applied <u>in addition</u> to any of the other two volume based operability limits used. In the above case a stand's net value (P-C-M) must be positive or it will be ineligible for harvest.

An economic file record is required for each volume curve in the model. The format of the economic yield curves is similar to that used by the volume yield curves, in that records are loaded by species code, site and age. Each record consists of 7 fields which are (in order): species, site, age, price, clearcut cost, partial cost and release cost.

Economic File Format (*.eco)

CODE SITE AGE <value1> <value2> <value3> <value4>

Where:

CODE	: species code
SITE	: site code
AGE	: time-dependent age for species (in years)
<value1>	: the time-dependent price of the pure species (in $/m3)
<value2>	: the time-dependent clearcut harvest cost to roadside (in $/m3)
<value3>	: the time-dependent partial harvest cost to roadside (in $/m3)
<value4>	: the time-dependent release harvest cost to roadside (in $/m3)

Economic File Example

Pj	X	10	40	50	55	54
Pj	X	20	40	50	55	54
Pj	X	30	40	50	55	54
Pj	X	40	40	48	53	52

As with the HAL file, the fields are separated with one or more spaces or tabs and each species/site/age record must be on a separate line. And again, there is no header line and the format is fixed.

10.2.2 Transportation Cost File Format

This file contains the cost of transportation from each stand to a predetermined delivery point. It is this file that provides a spatial cost link from the inventory into the HSG model. This file is loaded using the TRANSPORT command. The name of the transportation file (and optional pathway) follows the command as shown in the following example. This command must be included in the activity file before the STEP commands.

\#
TRANSPORT <filename>
\#

Like the economic and HAL files, the format of this file is fixed with no header. It consists of a text file with two columns, one of stand number, and the transportation cost for that stand in real or integer format. A warning is sent to the screen if a record is not matched to the inventory when loading the transportation cost file. This file is optional when Rule_3 is used, the default is 0.

Transportation Cost File Format
STANDNUM TRANCOST

Transportation Cost File Example:
1234567890 1.234
1234567891 0.34

10.2.3 Regeneration Treatment Cost File Format

This optional file contains the necessary information for Rule_3 to define the working group for the four different silvicultural regeneration treatments, as well as the cost for each treatment. If this file is not included when Rule_3 is used, extensive treatment will be applied to all clearcut stands. This file is loaded through the use of the RULE3SILV command in the activity file. This command must be located before the STEP command to which it will be applied. The syntax for this command is shown below:

\#
RULE3SILV <filename> <value1> <value2> <value3>
\#
Where:
<filename> : is the name and optional path of the regeneration treatment cost file
<Value1> : the silvicultural limit for elite treatment (in $/year)
<Value2> : the silvicultural limit for intensive treatment (in $/year)
<Value3> : the silvicultural limit for basic treatment (in $/year)

As with all other commands this should be on one line with the variables separated by one or more spaces or tabs. The following is an example:

```
#
RULE3SILV ../basic/lowcost.sil 0 0 250000
#
```

The regeneration treatment cost file is an ASCII text file consisting of multiple records ,one record per line with the variables separated with one or more tabs or spaces. There is no header line in this file. Each record has 5 fields, which are (in order):

CODE SITE TREATMENT AGE COST

Where:
CODE : the working group species code
SITE : the working group site code
TREATMENT: the regeneration treatment to be applied (elite, intensive or basic)
AGE : the anticipated age of the working group at next harvest in years
COST : the cost of the regeneration treatment applied in \$/ha.

A match is found when the stand's species code and site code match exactly and the treatment matches the current regeneration treatment SEV's then being calculated. In other words, if the same species and site code is listed for all three treatments, that working group code is eligible for all three treatments. The age is required for the SEV calculation, and is the age of the working group when next harvested. The final field is cost of the regeneration treatment in dollars per year. An example of a regeneration treatment cost file is shown below:

Regeneration treatment cost file format:

Sb	**X**	**elite**	**70**	**800**	
Sb	**1**	**elite**	**75**	**800**	
Sb	**X**	**intensive**		**80**	**500**
Sb	**1**	**intensive**		**80**	**500**
Sb	**2**	**intensive**		**90**	**550**
Sb	**2**	**basic**	**100**	**300**	
Sb	**3**	**basic**	**120**	**300**	
Pj	**X**	**elite**	**60**	**700**	

10.3 Version 3.0 Output

Modifications were made in both the summary and schedule files that reflect the changes made in Version 3.0. Both files report on the partial and release harvesting activities in the same format as clearcutting. The exception is that the volume harvested by the partial and release functions is not reported in the schedule file. It contains only the results of these activities upon the stand.

Three additional fields were added to both the summary schedule and files. These new variables in these fields are Residual Timber Value (RTV), Wood_cost and Trans_cost. Each field is calculated by a summation of the appropriate species components from each stand for the particular activity being reported upon as follows:

RTV =P-C-M
Wood_cost = C+M
Tran_cost = M

Where:

P= The sum of the appropriate species products' value
C= The sum of the appropriate species harvest costs
M= The sum of the appropriate transportation cost

The list of species included from each stand used in the calculation of these variables depends upon the current activity. For inventory updates and clearcut harvesting all stand species are used in the calculation. For partial and release harvests only the species present in the rule and the current stand are used in the calculation. In the summary file, the results of the total value ($ or m^3) for each species in the stand are recorded in the same format used for volume in version 2.0. In the case of partial and release harvests these values are scaled by the percent harvested listed in the harvest rule. For the schedule file, the values are listed in m^3/ha or $/$m^3$/ha for the total eligible species in the stand, these are not scaled by the percent harvested as listed in the harvest rule for partial and release harvests. This format permits queries such as those that can produce a "draped" map of delivered wood cost for each harvested stand by period.

These changes in the summary and schedule file for partial and release harvesting are automatically produced whenever used, and the economic results are produced when the economic input files are loaded in the activity file.

Note: when partial or release harvesting is used, the MANDATORY command will no longer function as designed since it does not recognise different harvest treatments.

11 APPENDIX III: VOLUME AND ECONOMIC YIELD DATA

This section consists of one chart which contains all of the volume and economic yield data used to run the scenarios.

Species	Site	Age	Volume(m^3/ha)	Price(\$/m^3)	Clearcut cost(\$/m^3)	Partial cost	Release Cost
Ab	X	0	0	40.0	45.0	67.5	58.5
Ab	X	10	0	40.0	45.0	67.5	58.5
Ab	X	20	0	40.0	45.0	67.5	58.5
Ab	X	30	0	40.0	45.0	67.5	58.5
Ab	X	40	25	40.0	45.0	67.5	58.5
Ab	X	50	73	44.0	42.8	64.2	55.6
Ab	X	60	113	50.0	36.7	55.1	47.7
Ab	X	70	142	55.4	30.0	45.0	39.0
Ab	X	80	160	58.4	24.7	37.1	32.1
Ab	X	90	171	60.0	20.0	30.0	26.0
Ab	X	100	176	60.0	17.5	26.3	22.8
Ab	X	110	179	60.0	16.0	24.0	20.8
Ab	X	120	179	60.0	15.1	22.7	19.6
Ab	X	130	178	60.0	15.1	22.7	19.6
Ab	X	140	175	60.0	15.7	23.6	20.4
Ab	X	150	160	60.0	16.6	24.9	21.6
Ab	X	160	150	60.0	17.0	25.5	22.1
Ab	X	170	150	60.0	18.7	28.1	24.3
Ab	X	180	150	60.0	20.0	30.0	26.0
Ab	X	190	150	60.0	21.7	32.6	28.2
Ab	X	200	150	60.0	22.9	34.4	29.8
Ab	1	0	0	40.0	45.0	67.5	58.5
Ab	1	10	0	40.0	45.0	67.5	58.5
Ab	1	20	0	40.0	45.0	67.5	58.5
Ab	1	30	0	40.0	45.0	67.5	58.5
Ab	1	40	21	40.0	45.0	67.5	58.5
Ab	1	50	63	40.0	45.0	67.5	58.5
Ab	1	60	97	45.0	41.0	61.5	53.3
Ab	1	70	121	52.0	33.1	49.7	43.0
Ab	1	80	136	55.4	27.1	40.7	35.2
Ab	1	90	146	58.0	21.1	31.7	27.4
Ab	1	100	150	59.0	18.7	28.1	24.3
Ab	1	110	152	60.0	16.9	25.4	22.0
Ab	1	120	152	60.0	16.0	24.0	20.8
Ab	1	130	151	60.0	16.0	24.0	20.8
Ab	1	140	149	60.0	16.3	24.5	21.2
Ab	1	150	145	60.0	16.6	24.9	21.6
Ab	1	160	140	60.0	17.0	25.5	22.1
Ab	1	170	140	60.0	17.5	26.3	22.8
Ab	1	180	140	60.0	18.0	27.0	23.4
Ab	1	190	140	60.0	19.0	28.5	24.7
Ab	1	200	140	60.0	20.5	30.8	26.7
Ab	2	0	0	40.0	45.0	67.5	58.5
Ab	2	10	0	40.0	45.0	67.5	58.5
Ab	2	20	0	40.0	45.0	67.5	58.5
Ab	2	30	0	40.0	45.0	67.5	58.5
Ab	2	40	20	40.0	45.0	67.5	58.5
Ab	2	50	58	40.0	45.0	67.5	58.5
Ab	2	60	87	41.0	41.0	61.5	53.3
Ab	2	70	107	46.4	37.3	56.0	48.5

Species	Site	Age	Volume(m^3/ha)	Price(\$/m^3)	Clearcut cost(\$/m^3)	Partial cost	Release Cost
Ab	2	80	119	50.0	32.0	48.0	41.6
Ab	2	90	127	52.4	26.0	39.0	33.8
Ab	2	100	130	54.8	21.7	32.6	28.2
Ab	2	110	132	56.6	19.3	29.0	25.1
Ab	2	120	133	58.0	18.7	28.1	24.3
Ab	2	130	132	58.0	17.5	26.3	22.8
Ab	2	140	127	58.0	17.5	26.3	22.8
Ab	2	150	120	58.0	18.0	27.0	23.4
Ab	2	160	120	58.0	18.0	27.0	23.4
Ab	2	170	120	58.0	18.0	27.0	23.4
Ab	2	180	120	58.0	18.0	27.0	23.4
Ab	2	190	120	58.0	19.0	28.5	24.7
Ab	2	200	120	58.0	20.5	30.8	26.7
Ab	3	0	0	40.0	45.0	67.5	58.5
Ab	3	10	0	40.0	45.0	67.5	58.5
Ab	3	20	0	40.0	45.0	67.5	58.5
Ab	3	30	0	40.0	45.0	67.5	58.5
Ab	3	40	14	40.0	45.0	67.5	58.5
Ab	3	50	44	40.0	45.0	67.5	58.5
Ab	3	60	60	40.0	45.0	67.5	58.5
Ab	3	70	73	40.4	40.4	60.6	52.5
Ab	3	80	81	44.0	34.0	51.0	44.2
Ab	3	90	83	46.4	28.0	42.0	36.4
Ab	3	100	86	48.8	23.5	35.3	30.6
Ab	3	110	88	51.2	21.1	31.7	27.4
Ab	3	120	88	53.6	19.0	28.5	24.7
Ab	3	130	65	53.6	19.2	28.8	25.0
Ab	3	140	65	55.0	19.8	29.7	25.7
Ab	3	150	65	55.0	20.5	30.8	26.7
Ab	3	160	65	55.0	21.2	31.8	27.6
Ab	3	170	65	55.0	21.7	32.6	28.2
Ab	3	180	65	55.0	21.7	32.6	28.2
Ab	3	190	65	55.0	22.0	33.0	28.6
Ab	3	200	65	55.0	23.0	34.5	29.9
Ab	4	0	0	40.0	45.0	67.5	58.5
Ab	4	10	0	40.0	45.0	67.5	58.5
Ab	4	20	0	40.0	45.0	67.5	58.5
Ab	4	30	0	40.0	45.0	67.5	58.5
Ab	4	40	8	40.0	45.0	67.5	58.5
Ab	4	50	26	40.0	45.0	67.5	58.5
Ab	4	60	35	40.0	45.0	67.5	58.5
Ab	4	70	43	40.0	45.0	67.5	58.5
Ab	4	80	47	42.0	42.8	64.2	55.6
Ab	4	90	49	45.0	34.9	52.4	45.4
Ab	4	100	51	50.0	28.3	42.5	36.8
Ab	4	110	52	50.0	24.0	36.0	31.2
Ab	4	120	52	50.0	21.1	31.7	27.4
Ab	4	130	40	50.0	20.0	30.0	26.0
Ab	4	140	40	50.0	20.5	30.8	26.7
Ab	4	150	40	50.0	21.0	31.5	27.3
Ab	4	160	40	50.0	22.0	33.0	28.6
Ab	4	170	40	50.0	22.5	33.8	29.3
Ab	4	180	40	50.0	23.0	34.5	29.9
Ab	4	190	40	50.0	24.0	36.0	31.2
Ab	4	200	40	50.0	25.0	37.5	32.5
Ce	X	0	0.0	40.0	45.0	67.5	58.5
Ce	X	10	0.0	40.0	45.0	67.5	58.5
Ce	X	20	0.0	40.0	45.0	67.5	58.5
Ce	X	30	13.0	40.0	45.0	67.5	58.5
Ce	X	40	28.0	40.0	45.0	67.5	58.5
Ce	X	50	53.0	43.0	39.2	58.8	51.0
Ce	X	60	81.0	51.0	32.5	48.8	42.3

Species	Site	Age	Volume(m^3/ha)	Price($/$m^3$)	Clearcut cost($/$m^3$)	Partial cost	Release Cost
Ce	X	70	105.0	59.0	24.7	37.1	32.1
Ce	X	80	124.0	64.5	20.0	30.0	26.0
Ce	X	90	137.0	69.3	16.9	25.4	22.0
Ce	X	100	144.0	72.9	15.7	23.6	20.4
Ce	X	110	148.0	74.7	14.5	21.8	18.9
Ce	X	120	143.0	75.0	15.7	23.6	20.4
Ce	X	130	137.0	71.7	16.0	24.0	20.8
Ce	X	140	118.0	67.5	17.5	26.3	22.8
Ce	X	150	86.0	64.0	18.0	27.0	23.4
Ce	X	160	37.0	58.0	19.3	29.0	25.1
Ce	X	170	12.0	52.0	21.1	31.7	27.4
Ce	X	180	0.0	47.0	22.9	34.4	29.8
Ce	X	190	0.0	40.0	26.0	39.0	33.8
Ce	X	200	0.0	40.0	30.7	46.1	39.9
Ce	1	0	0.0	40.0	45.0	67.5	58.5
Ce	1	10	0.0	40.0	45.0	67.5	58.5
Ce	1	20	0.0	40.0	45.0	67.5	58.5
Ce	1	30	0.0	40.0	45.0	67.5	58.5
Ce	1	40	12.0	40.0	45.0	67.5	58.5
Ce	1	50	26.0	40.0	45.0	67.5	58.5
Ce	1	60	50.0	41.0	40.0	60.0	52.0
Ce	1	70	77.0	48.8	29.5	44.3	38.4
Ce	1	80	100.0	58.0	23.5	35.3	30.6
Ce	1	90	118.0	64.5	18.7	28.1	24.3
Ce	1	100	131.0	68.0	17.0	25.5	22.1
Ce	1	110	138.0	70.0	16.0	24.0	20.8
Ce	1	120	142.0	70.0	16.0	24.0	20.8
Ce	1	130	137.0	70.0	16.0	24.0	20.8
Ce	1	140	132.0	68.7	16.5	24.8	21.5
Ce	1	150	116.0	66.9	17.0	25.5	22.1
Ce	1	160	87.0	63.3	18.0	27.0	23.4
Ce	1	170	37.0	59.0	19.0	28.5	24.7
Ce	1	180	12.0	53.0	20.5	30.8	26.7
Ce	1	190	0.0	47.0	22.0	33.0	28.6
Ce	1	200	0.0	42.0	24.0	36.0	31.2
Ce	2	0	0.0	40.0	45.0	67.5	58.5
Ce	2	10	0.0	40.0	45.0	67.5	58.5
Ce	2	20	0.0	40.0	45.0	67.5	58.5
Ce	2	30	0.0	40.0	45.0	67.5	58.5
Ce	2	40	0.0	40.0	45.0	67.5	58.5
Ce	2	50	6.0	40.0	45.0	67.5	58.5
Ce	2	60	17.0	40.0	45.0	67.5	58.5
Ce	2	70	29.0	40.4	44.0	66.0	57.2
Ce	2	80	43.0	43.4	37.3	56.0	48.5
Ce	2	90	59.0	50.6	28.3	42.5	36.8
Ce	2	100	74.0	58.0	24.7	37.1	32.1
Ce	2	110	88.0	61.0	22.0	33.0	28.6
Ce	2	120	100.0	63.5	21.1	31.7	27.4
Ce	2	130	110.0	64.0	20.0	30.0	26.0
Ce	2	140	110.0	65.0	19.9	29.9	25.9
Ce	2	150	108.0	64.0	20.0	30.0	26.0
Ce	2	160	102.0	62.0	20.5	30.8	26.7
Ce	2	170	82.0	59.0	21.7	32.6	28.2
Ce	2	180	42.0	53.0	21.7	32.6	28.2
Ce	2	190	22.0	47.0	23.5	35.3	30.6
Ce	2	200	0.0	42.0	25.3	38.0	32.9
Ce	3	0	0.0	40.0	45.0	67.5	58.5
Ce	3	10	0.0	40.0	45.0	67.5	58.5
Ce	3	20	0.0	40.0	45.0	67.5	58.5
Ce	3	30	0.0	40.0	45.0	67.5	58.5
Ce	3	40	0.0	40.0	45.0	67.5	58.5
Ce	3	50	0.0	40.0	45.0	67.5	58.5

Species	Site	Age	Volume(m^3/ha)	Price($/$m^3$)	Clearcut cost($/$m^3$)	Partial cost	Release Cost
Ce	3	60	0.0	40.0	45.0	67.5	58.5
Ce	3	70	6.0	40.0	45.0	67.5	58.5
Ce	3	80	15.0	40.0	45.0	67.5	58.5
Ce	3	90	26.0	40.0	42.0	63.0	54.6
Ce	3	100	36.0	40.0	37.3	56.0	48.5
Ce	3	110	50.0	42.0	26.5	39.8	34.5
Ce	3	120	62.0	46.0	22.9	34.4	29.8
Ce	3	130	75.0	51.2	21.1	31.7	27.4
Ce	3	140	85.0	56.0	21.1	31.7	27.4
Ce	3	150	90.0	58.0	20.5	30.8	26.7
Ce	3	160	90.0	60.0	21.1	31.7	27.4
Ce	3	170	88.0	60.0	22.0	33.0	28.6
Ce	3	180	85.0	58.4	22.0	33.0	28.6
Ce	3	190	80.0	56.6	23.5	35.3	30.6
Ce	3	200	60.0	55.4	25.3	38.0	32.9
Ce	4	0	0.0	40.0	45.0	67.5	58.5
Ce	4	10	0.0	40.0	45.0	67.5	58.5
Ce	4	20	0.0	40.0	45.0	67.5	58.5
Ce	4	30	0.0	40.0	45.0	67.5	58.5
Ce	4	40	0.0	40.0	45.0	67.5	58.5
Ce	4	50	0.0	40.0	45.0	67.5	58.5
Ce	4	60	0.0	40.0	45.0	67.5	58.5
Ce	4	70	4.0	40.0	45.0	67.5	58.5
Ce	4	80	11.0	40.0	45.0	67.5	58.5
Ce	4	90	21.0	40.0	42.0	63.0	54.6
Ce	4	100	29.0	40.0	37.3	56.0	48.5
Ce	4	110	43.0	41.0	29.5	44.3	38.4
Ce	4	120	54.0	44.0	25.3	38.0	32.9
Ce	4	130	66.0	48.8	22.9	34.4	29.8
Ce	4	140	69.0	53.6	22.0	33.0	28.6
Ce	4	150	75.0	58.0	21.1	31.7	27.4
Ce	4	160	76.0	60.0	21.1	31.7	27.4
Ce	4	170	73.0	60.0	22.0	33.0	28.6
Ce	4	180	68.0	59.0	22.0	33.0	28.6
Ce	4	190	60.0	58.0	23.5	35.3	30.6
Ce	4	200	45.0	55.4	25.3	38.0	32.9
L	X	0	0.0	40.0	45.0	67.5	58.5
L	X	10	0.0	40.0	45.0	67.5	58.5
L	X	20	0.0	40.0	45.0	67.5	58.5
L	X	30	13.0	40.0	45.0	67.5	58.5
L	X	40	28.0	40.0	43.4	65.1	56.4
L	X	50	53.0	42.8	37.3	56.0	48.5
L	X	60	90.0	52.4	30.0	45.0	39.0
L	X	70	130.0	62.0	23.5	35.3	30.6
L	X	80	170.0	68.7	18.0	27.0	23.4
L	X	90	190.0	73.5	16.0	24.0	20.8
L	X	100	200.0	75.0	15.5	23.3	20.2
L	X	110	185.0	74.0	16.0	24.0	20.8
L	X	120	160.0	68.7	16.5	24.8	21.5
L	X	130	100.0	58.4	17.5	26.3	22.8
L	X	140	0.0	49.4	19.0	28.5	24.7
L	X	150	0.0	40.0	23.0	34.5	29.9
L	X	160	0.0	0.0	0.0	0.0	0.0
L	X	170	0.0	0.0	0.0	0.0	0.0
L	X	180	0.0	0.0	0.0	0.0	0.0
L	X	190	0.0	0.0	0.0	0.0	0.0
L	X	200	0.0	0.0	0.0	0.0	0.0
L	1	0	0.0	40.0	45.0	67.5	58.5
L	1	10	0.0	40.0	45.0	67.5	58.5
L	1	20	0.0	40.0	45.0	67.5	58.5
L	1	30	0.0	40.0	45.0	67.5	58.5
L	1	40	12.0	40.0	45.0	67.5	58.5

Species	Site	Age	Volume(m^3/ha)	Price($/$m^3$)	Clearcut cost($/$m^3$)	Partial cost	Release Cost
L	1	50	26.0	40.0	43.0	64.5	55.9
L	1	60	50.0	40.0	39.2	58.8	51.0
L	1	70	77.0	47.0	30.7	46.1	39.9
L	1	80	120.0	53.0	22.9	34.4	29.8
L	1	90	155.0	56.0	18.7	28.1	24.3
L	1	100	175.0	58.4	16.5	24.8	21.5
L	1	110	180.0	60.0	16.0	24.0	20.8
L	1	120	170.0	60.0	16.5	24.8	21.5
L	1	130	140.0	58.4	17.5	26.3	22.8
L	1	140	100.0	55.4	19.0	28.5	24.7
L	1	150	0.0	50.0	23.0	34.5	29.9
L	1	160	0.0	46.4	27.1	40.7	35.2
L	1	170	0.0	0.0	0.0	0.0	0.0
L	1	180	0.0	0.0	0.0	0.0	0.0
L	1	190	0.0	0.0	0.0	0.0	0.0
L	1	200	0.0	0.0	0.0	0.0	0.0
L	2	0	0.0	40.0	45.0	67.5	58.5
L	2	10	0.0	40.0	45.0	67.5	58.5
L	2	20	0.0	40.0	45.0	67.5	58.5
L	2	30	0.0	40.0	45.0	67.5	58.5
L	2	40	0.0	40.0	45.0	67.5	58.5
L	2	50	6.0	40.0	44.6	66.9	58.0
L	2	60	17.0	40.0	41.6	62.4	54.1
L	2	70	29.0	40.0	33.1	49.7	43.0
L	2	80	50.0	44.0	26.0	39.0	33.8
L	2	90	75.0	48.8	21.1	31.7	27.4
L	2	100	110.0	52.0	19.3	29.0	25.1
L	2	110	130.0	54.0	17.5	26.3	22.8
L	2	120	130.0	55.0	17.0	25.5	22.1
L	2	130	120.0	55.0	17.5	26.3	22.8
L	2	140	100.0	53.0	18.0	27.0	23.4
L	2	150	10.0	50.0	19.5	29.3	25.4
L	2	160	0.0	46.4	22.0	33.0	28.6
L	2	170	0.0	0.0	0.0	0.0	0.0
L	2	180	0.0	0.0	0.0	0.0	0.0
L	2	190	0.0	0.0	0.0	0.0	0.0
L	2	200	0.0	0.0	0.0	0.0	0.0
L	3	0	0.0	40.0	45.0	67.5	58.5
L	3	10	0.0	40.0	45.0	67.5	58.5
L	3	20	0.0	40.0	45.0	67.5	58.5
L	3	30	0.0	40.0	45.0	67.5	58.5
L	3	40	0.0	40.0	45.0	67.5	58.5
L	3	50	0.0	40.0	45.0	67.5	58.5
L	3	60	0.0	40.0	44.0	66.0	57.2
L	3	70	6.0	40.0	37.3	56.0	48.5
L	3	80	15.0	40.0	32.0	48.0	41.6
L	3	90	26.0	44.6	26.0	39.0	33.8
L	3	100	45.0	48.0	22.9	34.4	29.8
L	3	110	65.0	49.0	19.3	29.0	25.1
L	3	120	75.0	50.0	18.7	28.1	24.3
L	3	130	85.0	50.0	18.0	27.0	23.4
L	3	140	75.0	50.0	18.7	28.1	24.3
L	3	150	20.0	49.0	20.0	30.0	26.0
L	3	160	0.0	48.0	22.0	33.0	28.6
L	3	170	0.0	0.0	0.0	0.0	0.0
L	3	180	0.0	0.0	0.0	0.0	0.0
L	3	190	0.0	0.0	0.0	0.0	0.0
L	3	200	0.0	0.0	0.0	0.0	0.0
L	4	0	0.0	40.0	45.0	67.5	58.5
L	4	10	0.0	40.0	45.0	67.5	58.5
L	4	20	0.0	40.0	45.0	67.5	58.5
L	4	30	0.0	40.0	45.0	67.5	58.5

Species	Site	Age	Volume(m³/ha)	Price($/m³)	Clearcut cost($/m³)	Partial cost	Release Cost
L	4	40	0.0	40.0	45.0	67.5	58.5
L	4	50	0.0	40.0	45.0	67.5	58.5
L	4	60	0.0	40.0	45.0	67.5	58.5
L	4	70	4.0	40.0	45.0	67.5	58.5
L	4	80	11.0	40.0	44.0	66.0	57.2
L	4	90	20.0	40.0	36.7	55.1	47.7
L	4	100	29.0	45.2	26.0	39.0	33.8
L	4	110	43.0	49.0	21.1	31.7	27.4
L	4	120	54.0	50.0	20.5	30.8	26.7
L	4	130	66.0	50.0	20.0	30.0	26.0
L	4	140	69.0	50.0	19.3	29.0	25.1
L	4	150	55.0	49.0	20.0	30.0	26.0
L	4	160	10.0	48.0	21.7	32.6	28.2
L	4	170	0.0	0.0	0.0	0.0	0.0
L	4	180	0.0	0.0	0.0	0.0	0.0
L	4	190	0.0	0.0	0.0	0.0	0.0
L	4	200	0.0	0.0	0.0	0.0	0.0
Ms	X	0	0.0	40.0	45.0	67.5	58.5
Ms	X	10	0.0	40.0	45.0	67.5	58.5
Ms	X	20	0.0	40.0	45.0	67.5	58.5
Ms	X	30	0.0	40.0	45.0	67.5	58.5
Ms	X	40	25.0	40.0	45.0	67.5	58.5
Ms	X	50	73.0	44.0	42.8	64.2	55.6
Ms	X	60	113.0	50.0	36.7	55.1	47.7
Ms	X	70	142.0	55.4	30.0	45.0	39.0
Ms	X	80	160.0	58.4	24.7	37.1	32.1
Ms	X	90	171.0	60.0	20.0	30.0	26.0
Ms	X	100	176.0	60.0	17.5	26.3	22.8
Ms	X	110	179.0	60.0	16.0	24.0	20.8
Ms	X	120	179.0	60.0	15.1	22.7	19.6
Ms	X	130	178.0	60.0	15.1	22.7	19.6
Ms	X	140	175.0	60.0	15.7	23.6	20.4
Ms	X	150	160.0	60.0	16.6	24.9	21.6
Ms	X	160	150.0	60.0	17.0	25.5	22.1
Ms	X	170	150.0	60.0	18.7	28.1	24.3
Ms	X	180	150.0	60.0	20.0	30.0	26.0
Ms	X	190	150.0	60.0	21.7	32.6	28.2
Ms	X	200	150.0	60.0	22.9	34.4	29.8
Ms	1	0	0.0	40.0	45.0	67.5	58.5
Ms	1	10	0.0	40.0	45.0	67.5	58.5
Ms	1	20	0.0	40.0	45.0	67.5	58.5
Ms	1	30	0.0	40.0	45.0	67.5	58.5
Ms	1	40	21.0	40.0	45.0	67.5	58.5
Ms	1	50	63.0	40.0	45.0	67.5	58.5
Ms	1	60	97.0	45.0	41.0	61.5	53.3
Ms	1	70	121.0	52.0	33.1	49.7	43.0
Ms	1	80	136.0	55.4	27.1	40.7	35.2
Ms	1	90	146.0	58.0	21.1	31.7	27.4
Ms	1	100	150.0	59.0	18.7	28.1	24.3
Ms	1	110	152.0	60.0	16.9	25.4	22.0
Ms	1	120	152.0	60.0	16.0	24.0	20.8
Ms	1	130	151.0	60.0	16.0	24.0	20.8
Ms	1	140	149.0	60.0	16.3	24.5	21.2
Ms	1	150	145.0	60.0	16.6	24.9	21.6
Ms	1	160	140.0	60.0	17.0	25.5	22.1
Ms	1	170	140.0	60.0	17.5	26.3	22.8
Ms	1	180	140.0	60.0	18.0	27.0	23.4
Ms	1	190	140.0	60.0	19.0	28.5	24.7
Ms	1	200	140.0	60.0	20.5	30.8	26.7
Ms	2	0	0.0	40.0	45.0	67.5	58.5
Ms	2	10	0.0	40.0	45.0	67.5	58.5
Ms	2	20	0.0	40.0	45.0	67.5	58.5

Species	Site	Age	Volume(m^3/ha)	Price($/$m^3$)	Clearcut cost($/$m^3$)	Partial cost	Release Cost
Ms	2	30	0.0	40.0	45.0	67.5	58.5
Ms	2	40	20.0	40.0	45.0	67.5	58.5
Ms	2	50	58.0	40.0	45.0	67.5	58.5
Ms	2	60	87.0	41.0	41.0	61.5	53.3
Ms	2	70	107.0	46.4	37.3	56.0	48.5
Ms	2	80	119.0	50.0	32.0	48.0	41.6
Ms	2	90	127.0	52.4	26.0	39.0	33.8
Ms	2	100	130.0	54.8	21.7	32.6	28.2
Ms	2	110	132.0	56.6	19.3	29.0	25.1
Ms	2	120	133.0	58.0	18.7	28.1	24.3
Ms	2	130	132.0	58.0	17.5	26.3	22.8
Ms	2	140	127.0	58.0	17.5	26.3	22.8
Ms	2	150	120.0	58.0	18.0	27.0	23.4
Ms	2	160	120.0	58.0	18.0	27.0	23.4
Ms	2	170	120.0	58.0	18.0	27.0	23.4
Ms	2	180	120.0	58.0	18.0	27.0	23.4
Ms	2	190	120.0	58.0	19.0	28.5	24.7
Ms	2	200	120.0	58.0	20.5	30.8	26.7
Ms	3	0	0.0	40.0	45.0	67.5	58.5
Ms	3	10	0.0	40.0	45.0	67.5	58.5
Ms	3	20	0.0	40.0	45.0	67.5	58.5
Ms	3	30	0.0	40.0	45.0	67.5	58.5
Ms	3	40	14.0	40.0	45.0	67.5	58.5
Ms	3	50	44.0	40.0	45.0	67.5	58.5
Ms	3	60	60.0	40.0	45.0	67.5	58.5
Ms	3	70	73.0	40.4	40.4	60.6	52.5
Ms	3	80	81.0	44.0	34.0	51.0	44.2
Ms	3	90	83.0	46.4	28.0	42.0	36.4
Ms	3	100	86.0	48.8	23.5	35.3	30.6
Ms	3	110	88.0	51.2	21.1	31.7	27.4
Ms	3	120	88.0	53.6	19.0	28.5	24.7
Ms	3	130	65.0	53.6	19.2	28.8	25.0
Ms	3	140	65.0	55.0	19.8	29.7	25.7
Ms	3	150	65.0	55.0	20.5	30.8	26.7
Ms	3	160	65.0	55.0	21.2	31.8	27.6
Ms	3	170	65.0	55.0	21.7	32.6	28.2
Ms	3	180	65.0	55.0	21.7	32.6	28.2
Ms	3	190	65.0	55.0	22.0	33.0	28.6
Ms	3	200	65.0	55.0	23.0	34.5	29.9
Ms	4	0	0.0	40.0	45.0	67.5	58.5
Ms	4	10	0.0	40.0	45.0	67.5	58.5
Ms	4	20	0.0	40.0	45.0	67.5	58.5
Ms	4	30	0.0	40.0	45.0	67.5	58.5
Ms	4	40	8.0	40.0	45.0	67.5	58.5
Ms	4	50	26.0	40.0	45.0	67.5	58.5
Ms	4	60	35.0	40.0	45.0	67.5	58.5
Ms	4	70	43.0	40.0	45.0	67.5	58.5
Ms	4	80	47.0	42.0	42.8	64.2	55.6
Ms	4	90	49.0	45.0	34.9	52.4	45.4
Ms	4	100	51.0	50.0	28.3	42.5	36.8
Ms	4	110	52.0	50.0	24.0	36.0	31.2
Ms	4	120	52.0	50.0	21.1	31.7	27.4
Ms	4	130	40.0	50.0	20.0	30.0	26.0
Ms	4	140	40.0	50.0	20.5	30.8	26.7
Ms	4	150	40.0	50.0	21.0	31.5	27.3
Ms	4	160	40.0	50.0	22.0	33.0	28.6
Ms	4	170	40.0	50.0	22.5	33.8	29.3
Ms	4	180	40.0	50.0	23.0	34.5	29.9
Ms	4	190	40.0	50.0	24.0	36.0	31.2
Ms	4	200	40.0	50.0	25.0	37.5	32.5
Pr	X	0	0.0	40.0	45.0	67.5	58.5
Pr	X	10	0.0	40.0	45.0	67.5	58.5

Species	Site	Age	Volume(m^3/ha)	Price(\$/m^3)	Clearcut cost(\$/m^3)	Partial cost	Release Cost
Pr	X	20	58.0	40.0	45.0	67.5	58.5
Pr	X	30	145.0	40.0	45.0	67.5	58.5
Pr	X	40	234.0	44.0	43.0	64.5	55.9
Pr	X	50	291.0	52.0	36.0	54.0	46.8
Pr	X	60	333.0	59.6	30.0	45.0	39.0
Pr	X	70	365.0	67.5	25.3	38.0	32.9
Pr	X	80	387.0	74.0	22.9	34.4	29.8
Pr	X	90	406.0	78.9	21.7	32.6	28.2
Pr	X	100	420.0	83.1	21.1	31.7	27.4
Pr	X	110	432.0	86.0	20.0	30.0	26.0
Pr	X	120	442.0	90.0	19.3	29.0	25.1
Pr	X	130	451.0	92.8	19.0	28.5	24.7
Pr	X	140	458.0	94.1	18.5	27.8	24.1
Pr	X	150	464.0	95.0	18.8	28.2	24.4
Pr	X	160	470.0	94.6	19.3	29.0	25.1
Pr	X	170	470.0	92.8	20.0	30.0	26.0
Pr	X	180	470.0	89.2	20.5	30.8	26.7
Pr	X	190	470.0	86.0	21.0	31.5	27.3
Pr	X	200	470.0	81.3	23.5	35.3	30.6
Pr	1	0	0.0	40.0	45.0	67.5	58.5
Pr	1	10	0.0	40.0	45.0	67.5	58.5
Pr	1	20	0.0	40.0	45.0	67.5	58.5
Pr	1	30	82.0	40.0	45.0	67.5	58.5
Pr	1	40	156.0	40.0	43.0	64.5	55.9
Pr	1	50	209.0	44.6	39.2	58.8	51.0
Pr	1	60	248.0	53.0	32.5	48.8	42.3
Pr	1	70	276.0	59.6	27.0	40.5	35.1
Pr	1	80	299.0	66.0	25.0	37.5	32.5
Pr	1	90	317.0	71.1	23.0	34.5	29.9
Pr	1	100	331.0	76.0	21.7	32.6	28.2
Pr	1	110	342.0	80.7	20.5	30.8	26.7
Pr	1	120	351.0	84.9	20.0	30.0	26.0
Pr	1	130	359.0	88.0	19.5	29.3	25.4
Pr	1	140	365.0	89.2	19.0	28.5	24.7
Pr	1	150	371.0	90.0	19.0	28.5	24.7
Pr	1	160	375.0	88.6	19.5	29.3	25.4
Pr	1	170	375.0	88.0	20.0	30.0	26.0
Pr	1	180	375.0	86.0	20.5	30.8	26.7
Pr	1	190	375.0	84.0	21.0	31.5	27.3
Pr	1	200	375.0	79.5	22.0	33.0	28.6
Pr	2	0	0.0	40.0	45.0	67.5	58.5
Pr	2	10	0.0	40.0	45.0	67.5	58.5
Pr	2	20	0.0	40.0	45.0	67.5	58.5
Pr	2	30	55.0	40.0	45.0	67.5	58.5
Pr	2	40	110.0	40.0	45.0	67.5	58.5
Pr	2	50	147.0	42.0	40.4	60.6	52.5
Pr	2	60	180.0	47.6	34.0	51.0	44.2
Pr	2	70	205.0	54.8	29.5	44.3	38.4
Pr	2	80	220.0	60.8	26.5	39.8	34.5
Pr	2	90	235.0	65.1	25.3	38.0	32.9
Pr	2	100	248.0	70.0	24.7	37.1	32.1
Pr	2	110	257.0	74.0	23.5	35.3	30.6
Pr	2	120	265.0	78.9	23.0	34.5	29.9
Pr	2	130	273.0	81.3	21.8	32.7	28.3
Pr	2	140	280.0	84.0	20.8	31.2	27.0
Pr	2	150	287.0	85.0	20.3	30.5	26.4
Pr	2	160	290.0	84.3	20.0	30.0	26.0
Pr	2	170	290.0	84.0	20.5	30.8	26.7
Pr	2	180	290.0	83.1	21.2	31.8	27.6
Pr	2	190	288.0	81.3	22.3	33.5	29.0
Pr	2	200	285.0	79.5	25.0	37.5	32.5
Pr	3	0	0	40.0	45.0	67.5	58.5

Species	Site	Age	Volume(m^3/ha)	Price($/$m^3$)	Clearcut cost($/$m^3$)	Partial cost	Release Cost
Pr	3	10	0	40.0	45.0	67.5	58.5
Pr	3	20	0	40.0	45.0	67.5	58.5
Pr	3	30	20	40.0	45.0	67.5	58.5
Pr	3	40	68	40.0	45.0	67.5	58.5
Pr	3	50	114	41.0	42.8	64.2	55.6
Pr	3	60	151	42.8	36.7	55.1	47.7
Pr	3	70	175	47.6	32.0	48.0	41.6
Pr	3	80	194	54.8	29.5	44.3	38.4
Pr	3	90	207	61.4	27.1	40.7	35.2
Pr	3	100	218	65.7	26.0	39.0	33.8
Pr	3	110	227	69.3	24.0	36.0	31.2
Pr	3	120	235	72.9	24.0	36.0	31.2
Pr	3	130	240	73.5	22.9	34.4	29.8
Pr	3	140	245	74.2	22.0	33.0	28.6
Pr	3	150	249	75.0	21.0	31.5	27.3
Pr	3	160	251	74.5	21.5	32.3	28.0
Pr	3	170	251	74.0	22.0	33.0	28.6
Pr	3	180	250	73.0	22.6	33.9	29.4
Pr	3	190	245	72.0	23.9	35.9	31.1
Pr	3	200	240	70.8	25.5	38.3	33.2
Pr	4	0	0	40.0	45.0	67.5	58.5
Pr	4	10	0	40.0	45.0	67.5	58.5
Pr	4	20	0	40.0	45.0	67.5	58.5
Pr	4	30	10	40.0	45.0	67.5	58.5
Pr	4	40	50	40.0	45.0	67.5	58.5
Pr	4	50	90	40.0	42.8	64.2	55.6
Pr	4	60	125	40.0	39.2	58.8	51.0
Pr	4	70	150	40.4	35.5	53.3	46.2
Pr	4	80	170	44.6	31.3	47.0	40.7
Pr	4	90	182	49.4	28.9	43.4	37.6
Pr	4	100	192	53.0	27.1	40.7	35.2
Pr	4	110	200	55.4	25.3	38.0	32.9
Pr	4	120	210	58.0	24.7	37.1	32.1
Pr	4	130	215	59.6	24.0	36.0	31.2
Pr	4	140	220	61.4	24.0	36.0	31.2
Pr	4	150	225	63.3	24.0	36.0	31.2
Pr	4	160	226	64.5	22.9	34.4	29.8
Pr	4	170	226	65.0	24.7	37.1	32.1
Pr	4	180	225	64.0	25.3	38.0	32.9
Pr	4	190	222	63.0	26.0	39.0	33.8
Pr	4	200	215	62.0	28.0	42.0	36.4
Pw	X	0	0.0	40.0	45.0	67.5	58.5
Pw	X	10	0.0	40.0	45.0	67.5	58.5
Pw	X	20	0.0	40.0	45.0	67.5	58.5
Pw	X	30	76.0	40.0	45.0	67.5	58.5
Pw	X	40	157.0	40.0	42.8	64.2	55.6
Pw	X	50	237.0	43.4	38.6	57.9	50.2
Pw	X	60	290.0	49.4	33.1	49.7	43.0
Pw	X	70	325.0	58.4	28.0	42.0	36.4
Pw	X	80	358.0	66.9	24.8	37.2	32.2
Pw	X	90	382.0	71.7	22.0	33.0	28.6
Pw	X	100	403.0	76.5	20.5	30.8	26.7
Pw	X	110	420.0	80.7	19.5	29.3	25.4
Pw	X	120	440.0	84.9	19.0	28.5	24.7
Pw	X	130	457.0	89.2	18.7	28.1	24.3
Pw	X	140	468.0	91.6	18.5	27.8	24.1
Pw	X	150	476.0	94.0	19.0	28.5	24.7
Pw	X	160	480.0	95.0	19.5	29.3	25.4
Pw	X	170	481.0	94.0	20.0	30.0	26.0
Pw	X	180	485.0	92.8	21.0	31.5	27.3
Pw	X	190	488.0	90.0	22.2	33.3	28.9
Pw	X	200	488.0	86.7	23.5	35.3	30.6

Species	Site	Age	Volume(m^3/ha)	Price($/$m^3$)	Clearcut cost($/$m^3$)	Partial cost	Release Cost
Pw	1	0	0.0	40.0	45.0	67.5	58.5
Pw	1	10	0.0	40.0	45.0	67.5	58.5
Pw	1	20	0.0	40.0	45.0	67.5	58.5
Pw	1	30	0.0	40.0	45.0	67.5	58.5
Pw	1	40	77.0	40.0	45.2	67.8	58.8
Pw	1	50	134.0	40.0	41.6	62.4	54.1
Pw	1	60	190.0	40.0	34.9	52.4	45.4
Pw	1	70	238.0	43.0	28.9	43.4	37.6
Pw	1	80	277.0	50.6	26.0	39.0	33.8
Pw	1	90	310.0	57.2	24.0	36.0	31.2
Pw	1	100	338.0	63.3	22.0	33.0	28.6
Pw	1	110	362.0	68.7	20.5	30.8	26.7
Pw	1	120	382.0	72.0	20.0	30.0	26.0
Pw	1	130	398.0	77.1	19.5	29.3	25.4
Pw	1	140	410.0	80.0	19.0	28.5	24.7
Pw	1	150	420.0	84.0	19.0	28.5	24.7
Pw	1	160	427.0	86.0	19.5	29.3	25.4
Pw	1	170	432.0	88.0	20.0	30.0	26.0
Pw	1	180	436.0	90.0	20.5	30.8	26.7
Pw	1	190	439.0	89.0	21.0	31.5	27.3
Pw	1	200	439.0	88.7	22.0	33.0	28.6
Pw	2	0	0.0	40.0	45.0	67.5	58.5
Pw	2	10	0.0	40.0	45.0	67.5	58.5
Pw	2	20	0.0	40.0	45.0	67.5	58.5
Pw	2	30	0.0	40.0	45.0	67.5	58.5
Pw	2	40	20.0	40.0	45.2	67.8	58.8
Pw	2	50	70.0	40.0	44.6	66.9	58.0
Pw	2	60	120.0	40.0	42.8	64.2	55.6
Pw	2	70	160.0	40.4	38.6	57.9	50.2
Pw	2	80	205.0	44.0	33.1	49.7	43.0
Pw	2	90	235.0	49.4	28.0	42.0	36.4
Pw	2	100	260.0	58.0	25.3	38.0	32.9
Pw	2	110	290.0	64.0	23.5	35.3	30.6
Pw	2	120	307.0	70.0	22.9	34.4	29.8
Pw	2	130	320.0	74.7	22.9	34.4	29.8
Pw	2	140	330.0	78.3	21.6	32.4	28.1
Pw	2	150	335.0	81.0	20.9	31.4	27.2
Pw	2	160	340.0	82.5	20.4	30.6	26.5
Pw	2	170	345.0	84.0	20.0	30.0	26.0
Pw	2	180	350.0	85.0	20.0	30.0	26.0
Pw	2	190	353.0	84.3	21.0	31.5	27.3
Pw	2	200	355.0	84.0	22.0	33.0	28.6
Pw	3	0	0.0	40.0	45.0	67.5	58.5
Pw	3	10	0.0	40.0	45.0	67.5	58.5
Pw	3	20	0.0	40.0	45.0	67.5	58.5
Pw	3	30	0.0	40.0	45.0	67.5	58.5
Pw	3	40	0.0	40.0	45.0	67.5	58.5
Pw	3	50	38.0	40.0	45.0	67.5	58.5
Pw	3	60	69.0	40.0	45.2	67.8	58.8
Pw	3	70	102.0	40.0	41.0	61.5	53.3
Pw	3	80	133.0	41.0	34.0	51.0	44.2
Pw	3	90	160.0	46.0	29.5	44.3	38.4
Pw	3	100	185.0	53.0	27.1	40.7	35.2
Pw	3	110	205.0	59.0	26.0	39.0	33.8
Pw	3	120	223.0	65.7	24.7	37.1	32.1
Pw	3	130	236.0	71.1	23.4	35.1	30.4
Pw	3	140	247.0	73.3	22.6	33.9	29.4
Pw	3	150	254.0	76.0	21.8	32.7	28.3
Pw	3	160	259.0	77.5	21.3	32.0	27.7
Pw	3	170	261.0	79.0	21.0	31.5	27.3
Pw	3	180	262.0	80.0	21.0	31.5	27.3
Pw	3	190	263.0	79.4	22.0	33.0	28.6

Species	Site	Age	Volume(m^3/ha)	Price($/m^3)	Clearcut cost($/m^3)	Partial cost	Release Cost
Pw	3	200	263.0	79.1	23.0	34.5	29.9
Pw	4	0	0.0	40.0	45.0	67.5	58.5
Pw	4	10	0.0	40.0	45.0	67.5	58.5
Pw	4	20	0.0	40.0	45.0	67.5	58.5
Pw	4	30	0.0	40.0	45.0	67.5	58.5
Pw	4	40	0.0	40.0	45.0	67.5	58.5
Pw	4	50	18.0	40.0	45.0	67.5	58.5
Pw	4	60	40.0	40.0	45.0	67.5	58.5
Pw	4	70	65.0	40.0	43.0	64.5	55.9
Pw	4	80	88.0	40.0	39.0	58.5	50.7
Pw	4	90	115.0	40.0	34.3	51.5	44.6
Pw	4	100	140.0	42.0	29.5	44.3	38.4
Pw	4	110	160.0	46.0	27.1	40.7	35.2
Pw	4	120	180.0	50.0	25.3	38.0	32.9
Pw	4	130	192.0	54.8	24.2	36.3	31.5
Pw	4	140	210.0	56.6	23.2	34.8	30.2
Pw	4	150	225.0	58.0	22.5	33.8	29.3
Pw	4	160	235.0	59.0	22.2	33.3	28.9
Pw	4	170	240.0	59.6	22.0	33.0	28.6
Pw	4	180	242.0	60.0	22.0	33.0	28.6
Pw	4	190	243.0	60.8	22.0	33.0	28.6
Pw	4	200	243.0	61.0	23.0	34.5	29.9
Pj	X	0	0.0	45.0	45.0	67.5	58.5
Pj	X	10	0.0	45.0	45.0	67.5	58.5
Pj	X	20	10.0	45.0	45.0	67.5	58.5
Pj	X	30	65.0	46.7	40.6	60.9	52.8
Pj	X	40	120.0	50.9	34.0	51.0	44.2
Pj	X	50	190.0	61.2	27.3	41.0	35.5
Pj	X	60	235.0	76.0	23.0	34.5	29.9
Pj	X	70	251.0	81.2	21.5	32.3	28.0
Pj	X	80	255.0	85.0	20.5	30.8	26.7
Pj	X	90	230.0	83.0	20.0	30.0	26.0
Pj	X	100	190.0	76.0	20.5	30.8	26.7
Pj	X	110	100.0	68.5	21.5	32.3	28.0
Pj	X	120	0.0	59.4	23.8	35.7	30.9
Pj	X	130	0.0	0.0	0.0	0.0	0.0
Pj	X	140	0.0	0.0	0.0	0.0	0.0
Pj	X	150	0.0	0.0	0.0	0.0	0.0
Pj	X	160	0.0	0.0	0.0	0.0	0.0
Pj	X	170	0.0	0.0	0.0	0.0	0.0
Pj	X	180	0.0	0.0	0.0	0.0	0.0
Pj	X	190	0.0	0.0	0.0	0.0	0.0
Pj	X	200	0.0	0.0	0.0	0.0	0.0
Pj	1	0	0.0	45.0	45.0	67.5	58.5
Pj	1	10	0.0	45.0	45.0	67.5	58.5
Pj	1	20	0.0	45.0	45.0	67.5	58.5
Pj	1	30	42.0	45.0	44.0	66.0	57.2
Pj	1	40	90.0	46.7	37.6	56.4	48.9
Pj	1	50	150.0	53.3	29.1	43.7	37.8
Pj	1	60	190.0	63.0	25.5	38.3	33.2
Pj	1	70	220.0	74.0	23.0	34.5	29.9
Pj	1	80	230.0	78.0	21.7	32.6	28.2
Pj	1	90	235.0	80.0	21.0	31.5	27.3
Pj	1	100	210.0	80.0	20.5	30.8	26.7
Pj	1	110	140.0	74.5	21.5	32.3	28.0
Pj	1	120	0.0	70.0	23.0	34.5	29.9
Pj	1	130	0.0	0.0	0.0	0.0	0.0
Pj	1	140	0.0	0.0	0.0	0.0	0.0
Pj	1	150	0.0	0.0	0.0	0.0	0.0
Pj	1	160	0.0	0.0	0.0	0.0	0.0
Pj	1	170	0.0	0.0	0.0	0.0	0.0
Pj	1	180	0.0	0.0	0.0	0.0	0.0

Species	Site	Age	Volume(m^3/ha)	Price($/$m^3$)	Clearcut cost($/$m^3$)	Partial cost	Release Cost
Pj	1	190	0.0	0.0	0.0	0.0	0.0
Pj	1	200	0.0	0.0	0.0	0.0	0.0
Pj	2	0	0.0	45.0	45.0	67.5	58.5
Pj	2	10	0.0	45.0	45.0	67.5	58.5
Pj	2	20	0.0	45.0	45.0	67.5	58.5
Pj	2	30	15.0	45.0	45.0	67.5	58.5
Pj	2	40	60.0	45.0	44.0	66.0	57.2
Pj	2	50	100.0	52.7	39.0	58.5	50.7
Pj	2	60	135.0	61.2	33.0	49.5	42.9
Pj	2	70	165.0	68.9	28.5	42.8	37.1
Pj	2	80	180.0	72.0	26.0	39.0	33.8
Pj	2	90	185.0	74.4	24.0	36.0	31.2
Pj	2	100	170.0	74.5	25.0	37.5	32.5
Pj	2	110	120.0	72.6	26.6	39.9	34.6
Pj	2	120	20.0	65.5	27.0	40.5	35.1
Pj	2	130	0.0	0.0	0.0	0.0	0.0
Pj	2	140	0.0	0.0	0.0	0.0	0.0
Pj	2	150	0.0	0.0	0.0	0.0	0.0
Pj	2	160	0.0	0.0	0.0	0.0	0.0
Pj	2	170	0.0	0.0	0.0	0.0	0.0
Pj	2	180	0.0	0.0	0.0	0.0	0.0
Pj	2	190	0.0	0.0	0.0	0.0	0.0
Pj	2	200	0.0	0.0	0.0	0.0	0.0
Pj	3	0	0.0	45.0	45.0	67.5	58.5
Pj	3	10	0.0	45.0	45.0	67.5	58.5
Pj	3	20	0.0	45.0	45.0	67.5	58.5
Pj	3	30	0.0	45.0	45.0	67.5	58.5
Pj	3	40	20.0	45.0	45.0	67.5	58.5
Pj	3	50	55.0	46.0	42.0	63.0	54.6
Pj	3	60	80.0	55.0	35.0	52.5	45.5
Pj	3	70	100.0	61.0	31.0	46.5	40.3
Pj	3	80	120.0	66.0	28.0	42.0	36.4
Pj	3	90	130.0	69.1	26.0	39.0	33.8
Pj	3	100	135.0	70.0	25.0	37.5	32.5
Pj	3	110	105.0	70.0	27.0	40.5	35.1
Pj	3	120	45.0	63.0	29.0	43.5	37.7
Pj	3	130	0.0	56.0	31.0	46.5	40.3
Pj	3	140	0.0	0.0	0.0	0.0	0.0
Pj	3	150	0.0	0.0	0.0	0.0	0.0
Pj	3	160	0.0	0.0	0.0	0.0	0.0
Pj	3	170	0.0	0.0	0.0	0.0	0.0
Pj	3	180	0.0	0.0	0.0	0.0	0.0
Pj	3	190	0.0	0.0	0.0	0.0	0.0
Pj	3	200	0.0	0.0	0.0	0.0	0.0
Pj	4	0	0.0	45.0	45.0	67.5	58.5
Pj	4	10	0.0	45.0	45.0	67.5	58.5
Pj	4	20	0.0	45.0	45.0	67.5	58.5
Pj	4	30	0.0	45.0	45.0	67.5	58.5
Pj	4	40	5.0	45.0	45.0	67.5	58.5
Pj	4	50	35.0	45.0	45.0	67.5	58.5
Pj	4	60	60.0	45.0	43.0	64.5	55.9
Pj	4	70	85.0	47.0	37.0	55.5	48.1
Pj	4	80	103.0	52.0	32.0	48.0	41.6
Pj	4	90	118.0	56.7	29.0	43.5	37.7
Pj	4	100	125.0	61.0	28.0	42.0	36.4
Pj	4	110	115.0	62.0	27.0	40.5	35.1
Pj	4	120	80.0	58.0	28.5	42.8	37.1
Pj	4	130	10.0	50.0	31.0	46.5	40.3
Pj	4	140	0.0	0.0	0.0	0.0	0.0
Pj	4	150	0.0	0.0	0.0	0.0	0.0
Pj	4	160	0.0	0.0	0.0	0.0	0.0
Pj	4	170	0.0	0.0	0.0	0.0	0.0

Species	Site	Age	Volume(m^3/ha)	Price($/$m^3$)	Clearcut cost($/$m^3$)	Partial cost	Release Cost
Pj	4	180	0.0	0.0	0.0	0.0	0.0
Pj	4	190	0.0	0.0	0.0	0.0	0.0
Pj	4	200	0.0	0.0	0.0	0.0	0.0
Po	X	0	0.0	45.0	45.0	67.5	58.5
Po	X	10	0.0	45.0	45.0	67.5	58.5
Po	X	20	30.0	45.0	41.6	62.4	54.1
Po	X	30	110.0	45.0	28.9	43.4	37.6
Po	X	40	200.0	47.0	21.7	32.6	28.2
Po	X	50	260.0	49.4	18.0	27.0	23.4
Po	X	60	295.0	56.0	15.7	23.6	20.4
Po	X	70	320.0	65.1	14.5	21.8	18.9
Po	X	80	330.0	70.5	14.5	21.8	18.9
Po	X	90	333.0	74.7	14.5	21.8	18.9
Po	X	100	300.0	74.7	15.0	22.5	19.5
Po	X	110	200.0	71.7	15.5	23.3	20.2
Po	X	120	20.0	65.7	16.0	24.0	20.8
Po	X	130	0.0	58.4	17.5	26.3	22.8
Po	X	140	0.0	0.0	0.0	0.0	0.0
Po	X	150	0.0	0.0	0.0	0.0	0.0
Po	X	160	0.0	0.0	0.0	0.0	0.0
Po	X	170	0.0	0.0	0.0	0.0	0.0
Po	X	180	0.0	0.0	0.0	0.0	0.0
Po	X	190	0.0	0.0	0.0	0.0	0.0
Po	X	200	0.0	0.0	0.0	0.0	0.0
Po	1	0	0.0	45.0	45.0	67.5	58.5
Po	1	10	0.0	45.0	45.0	67.5	58.5
Po	1	20	25.0	45.0	45.0	67.5	58.5
Po	1	30	80.0	45.0	33.0	49.5	42.9
Po	1	40	155.0	45.0	24.7	37.1	32.1
Po	1	50	220.0	45.0	20.5	30.8	26.7
Po	1	60	265.0	51.2	18.0	27.0	23.4
Po	1	70	290.0	60.8	16.3	24.5	21.2
Po	1	80	300.0	67.5	15.5	23.3	20.2
Po	1	90	305.0	70.0	15.0	22.5	19.5
Po	1	100	290.0	70.0	15.0	22.5	19.5
Po	1	110	240.0	68.5	15.5	23.3	20.2
Po	1	120	30.0	65.7	16.0	24.0	20.8
Po	1	130	0.0	62.7	17.5	26.3	22.8
Po	1	140	0.0	0.0	0.0	0.0	0.0
Po	1	150	0.0	0.0	0.0	0.0	0.0
Po	1	160	0.0	0.0	0.0	0.0	0.0
Po	1	170	0.0	0.0	0.0	0.0	0.0
Po	1	180	0.0	0.0	0.0	0.0	0.0
Po	1	190	0.0	0.0	0.0	0.0	0.0
Po	1	200	0.0	0.0	0.0	0.0	0.0
Po	2	0	0.0	45.0	45.0	67.5	58.5
Po	2	10	0.0	45.0	45.0	67.5	58.5
Po	2	20	10.0	45.0	45.0	67.5	58.5
Po	2	30	40.0	45.0	43.4	65.1	56.4
Po	2	40	115.0	45.0	36.7	55.1	47.7
Po	2	50	175.0	45.0	26.5	39.8	34.5
Po	2	60	220.0	45.2	19.3	29.0	25.1
Po	2	70	245.0	51.2	17.5	26.3	22.8
Po	2	80	250.0	60.0	16.0	24.0	20.8
Po	2	90	245.0	65.0	16.0	24.0	20.8
Po	2	100	230.0	65.0	16.0	24.0	20.8
Po	2	110	180.0	63.5	17.0	25.5	22.1
Po	2	120	90.0	61.4	18.5	27.8	24.1
Po	2	130	0.0	56.6	20.0	30.0	26.0
Po	2	140	0.0	0.0	0.0	0.0	0.0
Po	2	150	0.0	0.0	0.0	0.0	0.0
Po	2	160	0.0	0.0	0.0	0.0	0.0

Species	Site	Age	Volume(m^3/ha)	Price($/$m^3$)	Clearcut cost($/$m^3$)	Partial cost	Release Cost
Po	2	170	0.0	0.0	0.0	0.0	0.0
Po	2	180	0.0	0.0	0.0	0.0	0.0
Po	2	190	0.0	0.0	0.0	0.0	0.0
Po	2	200	0.0	0.0	0.0	0.0	0.0
Po	3	0	0.0	45.0	45.0	67.5	58.5
Po	3	10	0.0	45.0	45.0	67.5	58.5
Po	3	20	0.0	45.0	45.0	67.5	58.5
Po	3	30	15.0	45.0	44.6	66.9	58.0
Po	3	40	55.0	45.0	42.0	63.0	54.6
Po	3	50	110.0	45.0	31.3	47.0	40.7
Po	3	60	160.0	45.0	22.9	34.4	29.8
Po	3	70	190.0	45.2	20.0	30.0	26.0
Po	3	80	203.0	52.0	18.0	27.0	23.4
Po	3	90	205.0	55.0	17.0	25.5	22.1
Po	3	100	190.0	55.0	17.0	25.5	22.1
Po	3	110	140.0	54.8	17.0	25.5	22.1
Po	3	120	90.0	52.4	18.5	27.8	24.1
Po	3	130	35.0	50.0	20.0	30.0	26.0
Po	3	140	0.0	47.5	22.0	33.0	28.6
Po	3	150	0.0	0.0	0.0	0.0	0.0
Po	3	160	0.0	0.0	0.0	0.0	0.0
Po	3	170	0.0	0.0	0.0	0.0	0.0
Po	3	180	0.0	0.0	0.0	0.0	0.0
Po	3	190	0.0	0.0	0.0	0.0	0.0
Po	3	200	0.0	0.0	0.0	0.0	0.0
Po	4	0	0.0	45.0	45.0	67.5	58.5
Po	4	10	0.0	45.0	45.0	67.5	58.5
Po	4	20	0.0	45.0	45.0	67.5	58.5
Po	4	30	10.0	45.0	44.6	66.9	58.0
Po	4	40	33.0	45.0	44.6	66.9	58.0
Po	4	50	70.0	45.0	38.6	57.9	50.2
Po	4	60	110.0	45.0	28.3	42.5	36.8
Po	4	70	130.0	45.0	22.9	34.4	29.8
Po	4	80	140.0	45.0	19.3	29.0	25.1
Po	4	90	130.0	45.0	18.7	28.1	24.3
Po	4	100	105.0	45.0	18.0	27.0	23.4
Po	4	110	80.0	45.0	18.0	27.0	23.4
Po	4	120	30.0	45.0	18.5	27.8	24.1
Po	4	130	5.0	45.0	20.0	30.0	26.0
Po	4	140	0.0	45.0	22.0	33.0	28.6
Po	4	150	0.0	0.0	0.0	0.0	0.0
Po	4	160	0.0	0.0	0.0	0.0	0.0
Po	4	170	0.0	0.0	0.0	0.0	0.0
Po	4	180	0.0	0.0	0.0	0.0	0.0
Po	4	190	0.0	0.0	0.0	0.0	0.0
Po	4	200	0.0	0.0	0.0	0.0	0.0
Sb	X	0	0.0	50.0	45.0	67.5	58.5
Sb	X	10	0.0	50.0	45.0	67.5	58.5
Sb	X	20	0.0	50.0	45.0	67.5	58.5
Sb	X	30	34.0	50.0	44.6	66.9	58.0
Sb	X	40	78.0	52.0	38.6	57.9	50.2
Sb	X	50	118.0	54.0	32.5	48.8	42.3
Sb	X	60	160.0	57.2	27.1	40.7	35.2
Sb	X	70	200.0	62.0	22.0	33.0	28.6
Sb	X	80	228.0	70.0	20.5	30.8	26.7
Sb	X	90	250.0	78.9	19.8	29.7	25.7
Sb	X	100	263.0	84.1	19.3	29.0	25.1
Sb	X	110	265.0	85.0	19.0	28.5	24.7
Sb	X	120	255.0	85.0	19.7	29.6	25.6
Sb	X	130	200.0	80.0	20.5	30.8	26.7
Sb	X	140	0.0	72.9	21.1	31.7	27.4
Sb	X	150	0.0	65.7	22.9	34.4	29.8

Species	Site	Age	Volume(m³/ha)	Price($/m³)	Clearcut cost($/m³)	Partial cost	Release Cost
Sb	X	160	0.0	59.6	24.7	37.1	32.1
Sb	X	170	0.0	0.0	0.0	0.0	0.0
Sb	X	180	0.0	0.0	0.0	0.0	0.0
Sb	X	190	0.0	0.0	0.0	0.0	0.0
Sb	X	200	0.0	0.0	0.0	0.0	0.0
Sb	1	0	0.0	50.0	45.0	67.5	58.5
Sb	1	10	0.0	50.0	45.0	67.5	58.5
Sb	1	20	0.0	50.0	45.0	67.5	58.5
Sb	1	30	0.0	50.0	44.6	66.9	58.0
Sb	1	40	39.0	50.0	41.0	61.5	53.3
Sb	1	50	75.0	50.0	34.9	52.4	45.4
Sb	1	60	111.0	51.2	29.5	44.3	38.4
Sb	1	70	146.0	54.8	26.0	39.0	33.8
Sb	1	80	179.0	59.6	22.9	34.4	29.8
Sb	1	90	205.0	67.5	21.1	31.7	27.4
Sb	1	100	230.0	74.7	20.5	30.8	26.7
Sb	1	110	240.0	78.9	20.0	30.0	26.0
Sb	1	120	242.0	80.0	20.0	30.0	26.0
Sb	1	130	230.0	80.0	20.0	30.0	26.0
Sb	1	140	170.0	78.0	20.5	30.8	26.7
Sb	1	150	100.0	74.7	21.2	31.8	27.6
Sb	1	160	0.0	68.7	22.0	33.0	28.6
Sb	1	170	0.0	0.0	0.0	0.0	0.0
Sb	1	180	0.0	0.0	0.0	0.0	0.0
Sb	1	190	0.0	0.0	0.0	0.0	0.0
Sb	1	200	0.0	0.0	0.0	0.0	0.0
Sb	2	0	0.0	50.0	45.0	67.5	58.5
Sb	2	10	0.0	50.0	45.0	67.5	58.5
Sb	2	20	0.0	50.0	45.0	67.5	58.5
Sb	2	30	0.0	50.0	44.6	66.9	58.0
Sb	2	40	0.0	50.0	44.6	66.9	58.0
Sb	2	50	0.0	50.0	44.6	66.9	58.0
Sb	2	60	21.0	50.0	41.6	62.4	54.1
Sb	2	70	53.0	50.0	36.0	54.0	46.8
Sb	2	80	88.0	52.0	32.5	48.8	42.3
Sb	2	90	119.0	55.4	28.3	42.5	36.8
Sb	2	100	146.0	61.4	25.5	38.3	33.2
Sb	2	110	169.0	66.9	23.5	35.3	30.6
Sb	2	120	187.0	70.5	22.5	33.8	29.3
Sb	2	130	200.0	74.0	21.7	32.6	28.2
Sb	2	140	205.0	75.0	21.0	31.5	27.3
Sb	2	150	190.0	75.0	21.0	31.5	27.3
Sb	2	160	170.0	72.0	21.0	31.5	27.3
Sb	2	170	115.0	68.7	22.0	33.0	28.6
Sb	2	180	50.0	65.1	23.0	34.5	29.9
Sb	2	190	0.0	0.0	0.0	0.0	0.0
Sb	2	200	0.0	0.0	0.0	0.0	0.0
Sb	3	0	0.0	50.0	45.0	67.5	58.5
Sb	3	10	0.0	50.0	45.0	67.5	58.5
Sb	3	20	0.0	50.0	45.0	67.5	58.5
Sb	3	30	0.0	50.0	44.6	66.9	58.0
Sb	3	40	0.0	50.0	44.6	66.9	58.0
Sb	3	50	0.0	50.0	44.6	66.9	58.0
Sb	3	60	0.0	50.0	44.6	66.9	58.0
Sb	3	70	0.0	50.0	43.4	65.1	56.4
Sb	3	80	25.0	50.0	40.4	60.6	52.5
Sb	3	90	50.0	50.0	34.9	52.4	45.4
Sb	3	100	74.0	51.5	30.7	46.1	39.9
Sb	3	110	94.0	53.6	27.1	40.7	35.2
Sb	3	120	111.0	59.0	23.5	35.3	30.6
Sb	3	130	124.0	61.4	22.9	34.4	29.8
Sb	3	140	133.0	64.0	22.2	33.3	28.9

Species	Site	Age	Volume(m^3/ha)	Price($\$/m^3$)	Clearcut cost($\$/m^3$)	Partial cost	Release Cost
Sb	3	150	140.0	65.0	22.0	33.0	28.6
Sb	3	160	130.0	65.0	22.0	33.0	28.6
Sb	3	170	110.0	65.0	22.0	33.0	28.6
Sb	3	180	90.0	64.0	23.0	34.5	29.9
Sb	3	190	50.0	62.8	24.0	36.0	31.2
Sb	3	200	0.0	59.0	25.5	38.3	33.2
Sb	4	0	0.0	50.0	45.0	67.5	58.5
Sb	4	10	0.0	50.0	45.0	67.5	58.5
Sb	4	20	0.0	50.0	45.0	67.5	58.5
Sb	4	30	0.0	50.0	45.0	67.5	58.5
Sb	4	40	0.0	50.0	45.0	67.5	58.5
Sb	4	50	0.0	50.0	45.0	67.5	58.5
Sb	4	60	0.0	50.0	45.0	67.5	58.5
Sb	4	70	0.0	50.0	45.0	67.5	58.5
Sb	4	80	0.0	50.0	45.0	67.5	58.5
Sb	4	90	15.0	50.0	44.0	66.0	57.2
Sb	4	100	35.0	51.5	42.0	63.0	54.6
Sb	4	110	55.0	53.0	39.2	58.8	51.0
Sb	4	120	70.0	54.5	35.5	53.3	46.2
Sb	4	130	80.0	56.6	30.7	46.1	39.9
Sb	4	140	93.0	58.4	27.1	40.7	35.2
Sb	4	150	99.0	60.0	25.3	38.0	32.9
Sb	4	160	100.0	60.0	24.0	36.0	31.2
Sb	4	170	97.0	60.0	24.0	36.0	31.2
Sb	4	180	92.0	60.0	24.0	36.0	31.2
Sb	4	190	80.0	60.0	25.0	37.5	32.5
Sb	4	200	60.0	59.0	26.0	39.0	33.8
Sw	X	0	0.0	50.0	45.0	67.5	58.5
Sw	X	10	0.0	50.0	45.0	67.5	58.5
Sw	X	20	0.0	50.0	45.0	67.5	58.5
Sw	X	30	39.0	51.2	45.0	67.5	58.5
Sw	X	40	120.0	54.8	41.6	62.4	54.1
Sw	X	50	192.0	59.6	36.0	54.0	46.8
Sw	X	60	250.0	65.7	32.5	48.8	42.3
Sw	X	70	285.0	71.1	28.0	42.0	36.4
Sw	X	80	315.0	78.0	25.3	38.0	32.9
Sw	X	90	332.0	80.7	23.5	35.3	30.6
Sw	X	100	345.0	85.5	22.0	33.0	28.6
Sw	X	110	350.0	88.0	20.5	30.8	26.7
Sw	X	120	353.0	89.3	20.0	30.0	26.0
Sw	X	130	350.0	90.0	18.7	28.1	24.3
Sw	X	140	345.0	90.0	19.3	29.0	25.1
Sw	X	150	340.0	87.3	19.3	29.0	25.1
Sw	X	160	330.0	84.9	20.2	30.3	26.3
Sw	X	170	315.0	81.3	20.5	30.8	26.7
Sw	X	180	295.0	78.0	21.0	31.5	27.3
Sw	X	190	275.0	74.0	21.8	32.7	28.3
Sw	X	200	250.0	71.1	22.5	33.8	29.3
Sw	1	0	0.0	50.0	45.0	67.5	58.5
Sw	1	10	0.0	50.0	45.0	67.5	58.5
Sw	1	20	0.0	50.0	45.0	67.5	58.5
Sw	1	30	15.0	50.0	45.0	67.5	58.5
Sw	1	40	60.0	51.2	42.8	64.2	55.6
Sw	1	50	115.0	54.0	38.0	57.0	49.4
Sw	1	60	160.0	60.0	34.0	51.0	44.2
Sw	1	70	195.0	67.5	29.5	44.3	38.4
Sw	1	80	225.0	72.9	27.1	40.7	35.2
Sw	1	90	245.0	76.5	24.7	37.1	32.1
Sw	1	100	260.0	79.5	22.8	34.2	29.6
Sw	1	110	272.0	82.0	21.6	32.4	28.1
Sw	1	120	285.0	82.5	20.7	31.1	26.9
Sw	1	130	300.0	84.0	20.0	30.0	26.0

Species	Site	Age	Volume(m^3/ha)	Price(\$/m^3)	Clearcut cost(\$/m^3)	Partial cost	Release Cost
Sw	1	140	300.0	85.0	20.0	30.0	26.0
Sw	1	150	300.0	85.0	20.0	30.0	26.0
Sw	1	160	295.0	85.0	20.2	30.3	26.3
Sw	1	170	290.0	83.1	20.5	30.8	26.7
Sw	1	180	280.0	81.3	21.0	31.5	27.3
Sw	1	190	265.0	78.3	21.8	32.7	28.3
Sw	1	200	245.0	75.0	22.5	33.8	29.3
Sw	2	0	0.0	50.0	45.0	67.5	58.5
Sw	2	10	0.0	50.0	45.0	67.5	58.5
Sw	2	20	0.0	50.0	45.0	67.5	58.5
Sw	2	30	0.0	50.0	45.0	67.5	58.5
Sw	2	40	0.0	50.0	45.0	67.5	58.5
Sw	2	50	25.0	50.0	44.0	66.0	57.2
Sw	2	60	62.0	52.4	40.4	60.6	52.5
Sw	2	70	95.0	58.4	36.0	54.0	46.8
Sw	2	80	130.0	64.0	29.5	44.3	38.4
Sw	2	90	165.0	70.5	25.3	38.0	32.9
Sw	2	100	190.0	76.5	23.5	35.3	30.6
Sw	2	110	215.0	78.9	22.6	33.9	29.4
Sw	2	120	230.0	82.5	22.0	33.0	28.6
Sw	2	130	240.0	84.0	21.5	32.3	28.0
Sw	2	140	243.0	85.0	21.2	31.8	27.6
Sw	2	150	243.0	85.0	21.0	31.5	27.3
Sw	2	160	240.0	85.0	21.0	31.5	27.3
Sw	2	170	235.0	84.3	21.7	32.6	28.2
Sw	2	180	225.0	82.0	22.5	33.8	29.3
Sw	2	190	213.0	79.5	23.5	35.3	30.6
Sw	2	200	200.0	76.5	24.5	36.8	31.9
Sw	3	0	0.0	50.0	45.0	67.5	58.5
Sw	3	10	0.0	50.0	45.0	67.5	58.5
Sw	3	20	0.0	50.0	45.0	67.5	58.5
Sw	3	30	0.0	50.0	45.0	67.5	58.5
Sw	3	40	0.0	50.0	45.0	67.5	58.5
Sw	3	50	0.0	50.0	45.0	67.5	58.5
Sw	3	60	0.0	50.0	44.0	66.0	57.2
Sw	3	70	25.0	50.0	41.0	61.5	53.3
Sw	3	80	57.0	52.4	36.0	54.0	46.8
Sw	3	90	85.0	55.4	30.0	45.0	39.0
Sw	3	100	105.0	60.0	27.1	40.7	35.2
Sw	3	110	125.0	66.0	25.0	37.5	32.5
Sw	3	120	145.0	70.0	23.9	35.9	31.1
Sw	3	130	160.0	71.7	23.3	35.0	30.3
Sw	3	140	170.0	72.9	22.7	34.1	29.5
Sw	3	150	175.0	75.0	22.3	33.5	29.0
Sw	3	160	180.0	75.0	22.0	33.0	28.6
Sw	3	170	175.0	75.0	22.0	33.0	28.6
Sw	3	180	170.0	72.9	22.5	33.8	29.3
Sw	3	190	160.0	70.5	23.0	34.5	29.9
Sw	3	200	150.0	68.7	23.7	35.6	30.8
Sw	4	0	0.0	50.0	45.0	67.5	58.5
Sw	4	10	0.0	50.0	45.0	67.5	58.5
Sw	4	20	0.0	50.0	45.0	67.5	58.5
Sw	4	30	0.0	50.0	45.0	67.5	58.5
Sw	4	40	0.0	50.0	45.0	67.5	58.5
Sw	4	50	0.0	50.0	45.0	67.5	58.5
Sw	4	60	0.0	50.0	45.0	67.5	58.5
Sw	4	70	0.0	50.0	45.0	67.5	58.5
Sw	4	80	10.0	50.0	45.0	67.5	58.5
Sw	4	90	35.0	50.0	43.4	65.1	56.4
Sw	4	100	55.0	50.0	39.2	58.8	51.0
Sw	4	110	70.0	53.0	33.1	49.7	43.0
Sw	4	120	85.0	57.2	29.5	44.3	38.4

Species	Site	Age	Volume(m^3/ha)	Price($/$m^3$)	Clearcut cost($/$m^3$)	Partial cost	Release Cost
Sw	4	130	94.0	60.0	26.5	39.8	34.5
Sw	4	140	100.0	62.0	24.8	37.2	32.2
Sw	4	150	100.0	64.5	23.6	35.4	30.7
Sw	4	160	100.0	65.0	23.0	34.5	29.9
Sw	4	170	97.0	65.0	23.0	34.5	29.9
Sw	4	180	92.0	64.0	23.0	34.5	29.9
Sw	4	190	89.0	62.7	23.0	34.5	29.9
Sw	4	200	86.0	60.8	23.5	35.3	30.6
Bw	X	0	0.0	40.0	45.0	67.5	58.5
Bw	X	10	0.0	40.0	45.0	67.5	58.5
Bw	X	20	0.0	40.0	45.0	67.5	58.5
Bw	X	30	40.0	40.0	43.4	65.1	56.4
Bw	X	40	80.0	42.0	32.0	48.0	41.6
Bw	X	50	130.0	48.0	23.5	35.3	30.6
Bw	X	60	170.0	55.4	18.7	28.1	24.3
Bw	X	70	190.0	61.4	16.9	25.4	22.0
Bw	X	80	188.0	63.3	16.5	24.8	21.5
Bw	X	90	160.0	59.0	17.0	25.5	22.1
Bw	X	100	80.0	53.6	20.0	30.0	26.0
Bw	X	110	0.0	40.0	23.5	35.3	30.6
Bw	X	120	0.0	40.0	26.0	39.0	33.8
Bw	X	130	0.0	0.0	0.0	0.0	0.0
Bw	X	140	0.0	0.0	0.0	0.0	0.0
Bw	X	150	0.0	0.0	0.0	0.0	0.0
Bw	X	160	0.0	0.0	0.0	0.0	0.0
Bw	X	170	0.0	0.0	0.0	0.0	0.0
Bw	X	180	0.0	0.0	0.0	0.0	0.0
Bw	X	190	0.0	0.0	0.0	0.0	0.0
Bw	X	200	0.0	0.0	0.0	0.0	0.0
Bw	1	0	0.0	40.0	45.0	67.5	58.5
Bw	1	10	0.0	40.0	45.0	67.5	58.5
Bw	1	20	2.0	40.0	45.0	67.5	58.5
Bw	1	30	30.0	40.0	45.0	67.5	58.5
Bw	1	40	70.0	40.0	33.1	49.7	43.0
Bw	1	50	110.0	41.0	25.3	38.0	32.9
Bw	1	60	150.0	47.6	20.5	30.8	26.7
Bw	1	70	168.0	54.8	18.0	27.0	23.4
Bw	1	80	175.0	58.4	17.0	25.5	22.1
Bw	1	90	165.0	60.0	17.0	25.5	22.1
Bw	1	100	130.0	58.0	18.0	27.0	23.4
Bw	1	110	0.0	40.0	20.5	30.8	26.7
Bw	1	120	0.0	40.0	24.0	36.0	31.2
Bw	1	130	0.0	0.0	0.0	0.0	0.0
Bw	1	140	0.0	0.0	0.0	0.0	0.0
Bw	1	150	0.0	0.0	0.0	0.0	0.0
Bw	1	160	0.0	0.0	0.0	0.0	0.0
Bw	1	170	0.0	0.0	0.0	0.0	0.0
Bw	1	180	0.0	0.0	0.0	0.0	0.0
Bw	1	190	0.0	0.0	0.0	0.0	0.0
Bw	1	200	0.0	0.0	0.0	0.0	0.0
Bw	2	0	0.0	40.0	45.0	67.5	58.5
Bw	2	10	0.0	40.0	45.0	67.5	58.5
Bw	2	20	0.0	40.0	45.0	67.5	58.5
Bw	2	30	18.0	40.0	45.0	67.5	58.5
Bw	2	40	54.0	40.0	45.0	67.5	58.5
Bw	2	50	86.0	40.0	32.0	48.0	41.6
Bw	2	60	110.0	43.4	24.0	36.0	31.2
Bw	2	70	124.0	50.0	20.5	30.8	26.7
Bw	2	80	131.0	54.0	19.0	28.5	24.7
Bw	2	90	133.0	55.4	18.0	27.0	23.4
Bw	2	100	120.0	53.6	19.0	28.5	24.7
Bw	2	110	20.0	45.2	20.5	30.8	26.7

Species	Site	Age	Volume(m^3/ha)	Price($/$m^3$)	Clearcut cost($/$m^3$)	Partial cost	Release Cost
Bw	2	120	0.0	40.0	24.0	36.0	31.2
Bw	2	130	0.0	40.0	28.0	42.0	36.4
Bw	2	140	0.0	0.0	0.0	0.0	0.0
Bw	2	150	0.0	0.0	0.0	0.0	0.0
Bw	2	160	0.0	0.0	0.0	0.0	0.0
Bw	2	170	0.0	0.0	0.0	0.0	0.0
Bw	2	180	0.0	0.0	0.0	0.0	0.0
Bw	2	190	0.0	0.0	0.0	0.0	0.0
Bw	2	200	0.0	0.0	0.0	0.0	0.0
Bw	3	0	0.0	40.0	45.0	67.5	58.5
Bw	3	10	0.0	40.0	45.0	67.5	58.5
Bw	3	20	0.0	40.0	45.0	67.5	58.5
Bw	3	30	4.0	40.0	45.0	67.5	58.5
Bw	3	40	34.0	40.0	45.0	67.5	58.5
Bw	3	50	59.0	40.0	41.6	62.4	54.1
Bw	3	60	77.0	40.0	28.3	42.5	36.8
Bw	3	70	88.0	40.0	22.9	34.4	29.8
Bw	3	80	93.0	40.0	20.0	30.0	26.0
Bw	3	90	94.0	40.0	19.0	28.5	24.7
Bw	3	100	80.0	40.0	20.0	30.0	26.0
Bw	3	110	0.0	40.0	22.0	33.0	28.6
Bw	3	120	0.0	40.0	26.0	39.0	33.8
Bw	3	130	0.0	40.0	28.9	43.4	37.6
Bw	3	140	0.0	40.0	30.0	45.0	39.0
Bw	3	150	0.0	0.0	0.0	0.0	0.0
Bw	3	160	0.0	0.0	0.0	0.0	0.0
Bw	3	170	0.0	0.0	0.0	0.0	0.0
Bw	3	180	0.0	0.0	0.0	0.0	0.0
Bw	3	190	0.0	0.0	0.0	0.0	0.0
Bw	3	200	0.0	0.0	0.0	0.0	0.0
Bw	4	0	0.0	40.0	45.0	67.5	58.5
Bw	4	10	0.0	40.0	45.0	67.5	58.5
Bw	4	20	0.0	40.0	45.0	67.5	58.5
Bw	4	30	0.0	40.0	45.0	67.5	58.5
Bw	4	40	30.0	40.0	45.0	67.5	58.5
Bw	4	50	55.0	40.0	45.0	67.5	58.5
Bw	4	60	70.0	40.0	31.3	47.0	40.7
Bw	4	70	80.0	40.0	22.9	34.4	29.8
Bw	4	80	85.0	40.0	21.0	31.5	27.3
Bw	4	90	80.0	40.0	22.0	33.0	28.6
Bw	4	100	70.0	40.0	23.5	35.3	30.6
Bw	4	110	0.0	40.0	24.7	37.1	32.1
Bw	4	120	0.0	40.0	28.3	42.5	36.8
Bw	4	130	0.0	40.0	30.7	46.1	39.9
Bw	4	140	0.0	0.0	0.0	0.0	0.0
Bw	4	150	0.0	0.0	0.0	0.0	0.0
Bw	4	160	0.0	0.0	0.0	0.0	0.0
Bw	4	170	0.0	0.0	0.0	0.0	0.0
Bw	4	180	0.0	0.0	0.0	0.0	0.0
Bw	4	190	0.0	0.0	0.0	0.0	0.0
Bw	4	200	0.0	0.0	0.0	0.0	0.0
B	X	0	0.0	40.0	45.0	67.5	58.5
B	X	10	0.0	40.0	45.0	67.5	58.5
B	X	20	14.0	40.0	45.0	67.5	58.5
B	X	30	43.0	42.8	42.8	64.2	55.6
B	X	40	75.0	59.0	33.1	49.7	43.0
B	X	50	105.0	71.7	24.0	36.0	31.2
B	X	60	100.0	75.0	20.0	30.0	26.0
B	X	70	34.0	68.0	21.0	31.5	27.3
B	X	80	6.0	59.6	23.5	35.3	30.6
B	X	90	0.0	46.4	26.0	39.0	33.8
B	X	100	0.0	40.0	28.3	42.5	36.8

Species	Site	Age	Volume(m^3/ha)	Price($/$m^3$)	Clearcut cost($/$m^3$)	Partial cost	Release Cost
B	X	110	0.0	40.0	31.3	47.0	40.7
B	X	120	0.0	40.0	33.1	49.7	43.0
B	X	130	0.0	0.0	0.0	0.0	0.0
B	X	140	0.0	0.0	0.0	0.0	0.0
B	X	150	0.0	0.0	0.0	0.0	0.0
B	X	160	0.0	0.0	0.0	0.0	0.0
B	X	170	0.0	0.0	0.0	0.0	0.0
B	X	180	0.0	0.0	0.0	0.0	0.0
B	X	190	0.0	0.0	0.0	0.0	0.0
B	X	200	0.0	0.0	0.0	0.0	0.0
B	1	0	0.0	40.0	45.0	67.5	58.5
B	1	10	0.0	40.0	45.0	67.5	58.5
B	1	20	0.0	40.0	45.0	67.5	58.5
B	1	30	12.0	40.0	45.0	67.5	58.5
B	1	40	31.0	43.4	45.0	67.5	58.5
B	1	50	68.0	55.0	30.7	46.1	39.9
B	1	60	90.0	65.0	24.0	36.0	31.2
B	1	70	86.0	70.0	21.0	31.5	27.3
B	1	80	34.0	62.7	21.5	32.3	28.0
B	1	90	6.0	53.0	23.0	34.5	29.9
B	1	100	0.0	40.0	26.0	39.0	33.8
B	1	110	0.0	40.0	29.5	44.3	38.4
B	1	120	0.0	40.0	33.1	49.7	43.0
B	1	130	0.0	0.0	0.0	0.0	0.0
B	1	140	0.0	0.0	0.0	0.0	0.0
B	1	150	0.0	0.0	0.0	0.0	0.0
B	1	160	0.0	0.0	0.0	0.0	0.0
B	1	170	0.0	0.0	0.0	0.0	0.0
B	1	180	0.0	0.0	0.0	0.0	0.0
B	1	190	0.0	0.0	0.0	0.0	0.0
B	1	200	0.0	0.0	0.0	0.0	0.0
B	2	0	0.0	40.0	45.0	67.5	58.5
B	2	10	0.0	40.0	45.0	67.5	58.5
B	2	20	0.0	40.0	45.0	67.5	58.5
B	2	30	6.0	40.0	45.0	67.5	58.5
B	2	40	21.0	39.2	45.0	67.5	58.5
B	2	50	52.0	50.0	45.0	67.5	58.5
B	2	60	68.0	59.0	28.3	42.5	36.8
B	2	70	62.0	65.0	22.0	33.0	28.6
B	2	80	50.0	64.0	22.0	33.0	28.6
B	2	90	12.0	55.4	24.0	36.0	31.2
B	2	100	0.0	40.0	26.0	39.0	33.8
B	2	110	0.0	40.0	29.5	44.3	38.4
B	2	120	0.0	40.0	33.1	49.7	43.0
B	2	130	0.0	0.0	0.0	0.0	0.0
B	2	140	0.0	0.0	0.0	0.0	0.0
B	2	150	0.0	0.0	0.0	0.0	0.0
B	2	160	0.0	0.0	0.0	0.0	0.0
B	2	170	0.0	0.0	0.0	0.0	0.0
B	2	180	0.0	0.0	0.0	0.0	0.0
B	2	190	0.0	0.0	0.0	0.0	0.0
B	2	200	0.0	0.0	0.0	0.0	0.0
B	3	0	0.0	40.0	45.0	67.5	58.5
B	3	10	0.0	40.0	45.0	67.5	58.5
B	3	20	0.0	40.0	45.0	67.5	58.5
B	3	30	0.0	40.0	45.0	67.5	58.5
B	3	40	6.0	40.0	45.0	67.5	58.5
B	3	50	21.0	40.0	45.0	67.5	58.5
B	3	60	52.0	40.0	44.6	66.9	58.0
B	3	70	68.0	40.0	28.3	42.5	36.8
B	3	80	63.0	40.0	23.0	34.5	29.9
B	3	90	50.0	40.0	24.0	36.0	31.2

Species	Site	Age	Volume(m^3/ha)	Price(\$/m^3)	Clearcut cost(\$/m^3)	Partial cost	Release Cost
B	3	100	12.0	40.0	26.0	39.0	33.8
B	3	110	0.0	40.0	29.5	44.3	38.4
B	3	120	0.0	40.0	33.1	49.7	43.0
B	3	130	0.0	0.0	0.0	0.0	0.0
B	3	140	0.0	0.0	0.0	0.0	0.0
B	3	150	0.0	0.0	0.0	0.0	0.0
B	3	160	0.0	0.0	0.0	0.0	0.0
B	3	170	0.0	0.0	0.0	0.0	0.0
B	3	180	0.0	0.0	0.0	0.0	0.0
B	3	190	0.0	0.0	0.0	0.0	0.0
B	3	200	0.0	0.0	0.0	0.0	0.0
B	4	0	0.0	40.0	45.0	67.5	58.5
B	4	10	0.0	40.0	45.0	67.5	58.5
B	4	20	0.0	40.0	45.0	67.5	58.5
B	4	30	0.0	40.0	45.0	67.5	58.5
B	4	40	5.0	40.0	45.0	67.5	58.5
B	4	50	19.0	40.0	45.0	67.5	58.5
B	4	60	48.0	40.0	45.0	67.5	58.5
B	4	70	56.0	40.0	32.0	48.0	41.6
B	4	80	55.0	40.0	26.0	39.0	33.8
B	4	90	46.0	40.0	26.0	39.0	33.8
B	4	100	9.0	40.0	26.5	39.8	34.5
B	4	110	0.0	40.0	29.5	44.3	38.4
B	4	120	0.0	40.0	33.1	49.7	43.0
B	4	130	0.0	0.0	0.0	0.0	0.0
B	4	140	0.0	0.0	0.0	0.0	0.0
B	4	150	0.0	0.0	0.0	0.0	0.0
B	4	160	0.0	0.0	0.0	0.0	0.0
B	4	170	0.0	0.0	0.0	0.0	0.0
B	4	180	0.0	0.0	0.0	0.0	0.0
B	4	190	0.0	0.0	0.0	0.0	0.0
B	4	200	0.0	0.0	0.0	0.0	0.0

12 APPENDIX IV

12.1 Clearcut Management Activity File

This file is an HSG activity file used to simulate the clearcut management scenario.

File <sr_80.act>

```
#
LOG sr_80.log
#
# HSG run for the Seine River Forest. Only Clearcutting!!
# =375000 m3/yr 380,000 too high! 375,000 OK step=5, silva=3,000,000
#
 INVENTORY /thesis/seine/inventor/seine.inv
#
SOURCE /thesis/seine/data/yield/yield.inc
#
 STATES /thesis/seine/data/state12.dat
#
 TREATMENT basic_80.trt
#
OPMIN 50
#
SILVA 3000000
#
 TRANSPORT /thesis/data.dev/costs/trancst2.dat
 ECONOMIC /thesis/seine/data/yield/basic.eco 0.0
 DISCOUNT 0.05
 RULE3SILV basic.rtc 0 0 3000000
#
BEGIN 1995
#
 SCHEDULE sr_80.sch
#
 SNAPSHOT 80_1995.inv
#       step to 2000
STEP 5 : Pj/Sb/Sw/Po/B/Bw=375000: Rule_2-Pj/Sb/Sw/Po/B/Bw=375000(50)
#       step to 2005
STEP 5 : Pj/Sb/Sw/Po/B/Bw=375000: Rule_2-Pj/Sb/Sw/Po/B/Bw=375000(50)
#       step to 2010
STEP 5 : Pj/Sb/Sw/Po/B/Bw=375000: Rule_2-Pj/Sb/Sw/Po/B/Bw=375000(50)
#       step to 2015
STEP 5 : Pj/Sb/Sw/Po/B/Bw=375000: Rule_2-Pj/Sb/Sw/Po/B/Bw=375000(50)
#       step to 2020
STEP 5 : Pj/Sb/Sw/Po/B/Bw=375000: Rule_2-Pj/Sb/Sw/Po/B/Bw=375000(50)
#       step to 2025
STEP 5 : Pj/Sb/Sw/Po/B/Bw=375000: Rule_2-Pj/Sb/Sw/Po/B/Bw=375000(50)
#       step to 2030
STEP 5 : Pj/Sb/Sw/Po/B/Bw=375000: Rule_2-Pj/Sb/Sw/Po/B/Bw=375000(50)
#       step to 2035
STEP 5 : Pj/Sb/Sw/Po/B/Bw=375000: Rule_2-Pj/Sb/Sw/Po/B/Bw=375000(50)
```

```
#          step to 2040
STEP 5 : Pj/Sb/Sw/Po/B/Bw=375000:  Rule_2-Pj/Sb/Sw/Po/B/Bw=375000(50)
#          step to 2045
STEP 5 : Pj/Sb/Sw/Po/B/Bw=375000:  Rule_2-Pj/Sb/Sw/Po/B/Bw=375000(50)
#          step to 2050
STEP 5 : Pj/Sb/Sw/Po/B/Bw=375000:  Rule_2-Pj/Sb/Sw/Po/B/Bw=375000(50)
#          step to 2055
STEP 5 : Pj/Sb/Sw/Po/B/Bw=375000:  Rule_2-Pj/Sb/Sw/Po/B/Bw=375000(50)
#          step to 2060
STEP 5 : Pj/Sb/Sw/Po/B/Bw=375000:  Rule_2-Pj/Sb/Sw/Po/B/Bw=375000(50)
#          step to 2065
STEP 5 : Pj/Sb/Sw/Po/B/Bw=375000:  Rule_2-Pj/Sb/Sw/Po/B/Bw=375000(50)
#          step to 2070
STEP 5 : Pj/Sb/Sw/Po/B/Bw=375000:  Rule_2-Pj/Sb/Sw/Po/B/Bw=375000(50)
#          step to 2075
STEP 5 : Pj/Sb/Sw/Po/B/Bw=375000:  Rule_2-Pj/Sb/Sw/Po/B/Bw=375000(50)
#          step to 2080
STEP 5 : Pj/Sb/Sw/Po/B/Bw=375000:  Rule_2-Pj/Sb/Sw/Po/B/Bw=375000(50)
#          step to 2085
STEP 5 : Pj/Sb/Sw/Po/B/Bw=375000:  Rule_2-Pj/Sb/Sw/Po/B/Bw=375000(50)
#          step to 2090
STEP 5 : Pj/Sb/Sw/Po/B/Bw=375000:  Rule_2-Pj/Sb/Sw/Po/B/Bw=375000(50)
#          step to 2095
STEP 5 : Pj/Sb/Sw/Po/B/Bw=375000:  Rule_2-Pj/Sb/Sw/Po/B/Bw=375000(50)
#          step to 2100
STEP 5 : Pj/Sb/Sw/Po/B/Bw=375000:  Rule_2-Pj/Sb/Sw/Po/B/Bw=375000(50)
#          step to 2105
STEP 5 : Pj/Sb/Sw/Po/B/Bw=375000:  Rule_2-Pj/Sb/Sw/Po/B/Bw=375000(50)
#          step to 2110
STEP 5 : Pj/Sb/Sw/Po/B/Bw=375000:  Rule_2-Pj/Sb/Sw/Po/B/Bw=375000(50)
#          step to 2115
STEP 5 : Pj/Sb/Sw/Po/B/Bw=375000:  Rule_2-Pj/Sb/Sw/Po/B/Bw=375000(50)
#          step to 2120
STEP 5 : Pj/Sb/Sw/Po/B/Bw=375000:  Rule_2-Pj/Sb/Sw/Po/B/Bw=375000(50)
#          step to 2125
STEP 5 : Pj/Sb/Sw/Po/B/Bw=375000:  Rule_2-Pj/Sb/Sw/Po/B/Bw=375000(50)
#          step to 2130
STEP 5 : Pj/Sb/Sw/Po/B/Bw=375000:  Rule_2-Pj/Sb/Sw/Po/B/Bw=375000(50)
#          step to 2135
STEP 5 : Pj/Sb/Sw/Po/B/Bw=375000:  Rule_2-Pj/Sb/Sw/Po/B/Bw=375000(50)
#          step to 2140
STEP 5 : Pj/Sb/Sw/Po/B/Bw=375000:  Rule_2-Pj/Sb/Sw/Po/B/Bw=375000(50)
#          step to 2145
STEP 5 : Pj/Sb/Sw/Po/B/Bw=375000:  Rule_2-Pj/Sb/Sw/Po/B/Bw=375000(50)
#          step to 2150
STEP 5 : Pj/Sb/Sw/Po/B/Bw=375000:  Rule_2-Pj/Sb/Sw/Po/B/Bw=375000(50)
#          step to 2155
STEP 5 : Pj/Sb/Sw/Po/B/Bw=375000:  Rule_2-Pj/Sb/Sw/Po/B/Bw=375000(50)
#          step to 2160
STEP 5 : Pj/Sb/Sw/Po/B/Bw=375000:  Rule_2-Pj/Sb/Sw/Po/B/Bw=375000(50)
#          step to 2165
STEP 5 : Pj/Sb/Sw/Po/B/Bw=375000:  Rule_2-Pj/Sb/Sw/Po/B/Bw=375000(50)
#          step to 2170
STEP 5 : Pj/Sb/Sw/Po/B/Bw=375000:  Rule_2-Pj/Sb/Sw/Po/B/Bw=375000(50)
#          step to 2175
```

```
STEP 5 : Pj/Sb/Sw/Po/B/Bw=375000:  Rule_2-Pj/Sb/Sw/Po/B/Bw=375000(50)
#          step to 2180
STEP 5 : Pj/Sb/Sw/Po/B/Bw=375000:  Rule_2-Pj/Sb/Sw/Po/B/Bw=375000(50)
#          step to 2185
STEP 5 : Pj/Sb/Sw/Po/B/Bw=375000:  Rule_2-Pj/Sb/Sw/Po/B/Bw=375000(50)
#          step to 2190
STEP 5 : Pj/Sb/Sw/Po/B/Bw=375000:  Rule_2-Pj/Sb/Sw/Po/B/Bw=375000(50)
#          step to 2195
STEP 5 : Pj/Sb/Sw/Po/B/Bw=375000:  Rule_2-Pj/Sb/Sw/Po/B/Bw=375000(50)
#
 SCHEDULE
#
ERRORS
QUIT
```

12.2 Combined Management Scenario Activity File Log

This file is actually the HSG screen output produced from the LOG command. Included is all the activity file information as well as the screen output. The activity file used to produce this is from an combined management scenario simulation, with the opportunity cost of harvest delay rule (Rule_3).

File <sr_alt1e.log>

```
>NOTICE Logging output to sr_alte1.log
HSG> #
HSG> #  HSG run for the Seine River Forest.   Clearcut Version - Economic Rule
HSG> #  Vol=235000 m3/yr  ?240,000 too high!  235,000 ok  $0, 5, step5, $3000000
HSG> #
HSG> INVENTORY /thesis/seine/inventor/seine.inv
>INFORM Estimated file size = 7100 records
>NOTICE stands read 7093
HSG> # SOURCE /thesis/seine/data/stk_cat.dat
HSG> #
HSG> SOURCE /thesis/seine/data/yield/yield.inc
HSG> YIELD /thesis/seine/data/yield/ab.yld
HSG> YIELD /thesis/seine/data/yield/b.yld
HSG> YIELD /thesis/seine/data/yield/bw.yld
HSG> YIELD /thesis/seine/data/yield/ce.yld
HSG> YIELD /thesis/seine/data/yield/l.yld
HSG> YIELD /thesis/seine/data/yield/ms.yld
HSG> YIELD /thesis/seine/data/yield/pb.yld
HSG> YIELD /thesis/seine/data/yield/pj.yld
HSG> YIELD /thesis/seine/data/yield/po.yld
HSG> YIELD /thesis/seine/data/yield/pr.yld
HSG> YIELD /thesis/seine/data/yield/pw.yld
HSG> YIELD /thesis/seine/data/yield/sb.yld
HSG> YIELD /thesis/seine/data/yield/sw.yld
HSG> RETURN
```

```
HSG> #
HSG> STATES /thesis/seine/data/state12.dat
HSG> #
HSG> # TRANSPORT /thesis/seine/theory/flat_1.dat
HSG> TRANSPORT /thesis/data.dev/costs/trancst2.dat
>INFORM 6085 transport cost records loaded from /thesis/data.dev/costs/trancst2.dat
HSG> ECONOMIC /thesis/seine/data/yield/basic.eco 0.0
>INFORM 1260 economic records loaded from /thesis/seine/data/yield/basic.eco
>INFORM Rule_3 minimum is 0.000000
HSG> DISCOUNT 0.05
HSG> RULE3SILV basic.rtc 0 0 3000000
>INFORM 23 rule 3 silviculture records loaded from basic.rtc
>INFORM silv limits: elite 0.00 intensive 0.00 basic 3000000.00
HSG> TREATMENT basic_80.trt
HSG> #
HSG> OPMIN 50
HSG> #
HSG> # SILVA 10000
HSG> #
HSG> BEGIN 1995
>NOTICE Total area of harvest
HSG> #
HSG> SCHEDULE sr_alte1.sch
HSG> #
HSG> # SNAPSHOT alt_1995.inv
HSG> #          step to 2000
HSG> STEP 5 : Pj/Sb/Sw/Po/B/Bw=235000: Rule_3-{Release-100}[pj_rel.hal]-
Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-{Partial-30}[bas_hold.hal;30]-Pj/Sb/Sw/Po/B/Bw=235000(50),
Rule_3-Pj/Sb/Sw/Po/B/Bw=235000(50)
>NOTICE Rule 1 tally is 4479.50
>NOTICE Rule 2 tally is 912604.81
>NOTICE Rule 3 tally is 263654.19
>NOTICE Total area of harvest       25443
HSG> #          step to 2005
HSG> STEP 5 : Pj/Sb/Sw/Po/B/Bw=235000: Rule_3-{Release-100}[pj_rel.hal]-
Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-{Partial-30}[bas_hold.hal;30]-Pj/Sb/Sw/Po/B/Bw=235000(50),
Rule_3-Pj/Sb/Sw/Po/B/Bw=235000(50)
>NOTICE Rule 1 tally is 10226.91
>NOTICE Rule 2 tally is 465668.56
>NOTICE Rule 3 tally is 702078.31
>NOTICE Total area of harvest       16167
HSG> #          step to 2010
HSG> STEP 5 : Pj/Sb/Sw/Po/B/Bw=235000: Rule_3-{Release-100}[pj_rel.hal]-
Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-{Partial-30}[bas_hold.hal;30]-Pj/Sb/Sw/Po/B/Bw=235000(50),
Rule_3-Pj/Sb/Sw/Po/B/Bw=235000(50)
>NOTICE Rule 1 tally is 5088.99
>NOTICE Rule 2 tally is 386032.06
>NOTICE Rule 3 tally is 785398.81
>NOTICE Total area of harvest       13719
HSG> #          step to 2015
HSG> STEP 5 : Pj/Sb/Sw/Po/B/Bw=235000: Rule_3-{Release-100}[pj_rel.hal]-
Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-{Partial-30}[bas_hold.hal;30]-Pj/Sb/Sw/Po/B/Bw=235000(50),
Rule_3-Pj/Sb/Sw/Po/B/Bw=235000(50)
>NOTICE Rule 1 tally is 4322.64
>NOTICE Rule 2 tally is 553367.19
```

>NOTICE Rule 3 tally is 643523.69
>NOTICE Total area of harvest 16977
HSG> # step to 2020
HSG> STEP 5 : Pj/Sb/Sw/Po/B/Bw=235000: Rule_3-{Release-100}[pj_rel.hal]-Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-{Partial-30}[bas_hold.hal;30]-Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-Pj/Sb/Sw/Po/B/Bw=235000(50)
>NOTICE Rule 1 tally is 10912.33
>NOTICE Rule 2 tally is 374088.81
>NOTICE Rule 3 tally is 795165.00
>NOTICE Total area of harvest 14595
HSG> # step to 2025
HSG> STEP 5 : Pj/Sb/Sw/Po/B/Bw=235000: Rule_3-{Release-100}[pj_rel.hal]-Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-{Partial-30}[bas_hold.hal;30]-Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-Pj/Sb/Sw/Po/B/Bw=235000(50)
>NOTICE Rule 1 tally is 680.00
>NOTICE Rule 2 tally is 290370.16
>NOTICE Rule 3 tally is 899868.19
>NOTICE Total area of harvest 12505
HSG> # step to 2030
HSG> STEP 5 : Pj/Sb/Sw/Po/B/Bw=235000: Rule_3-{Release-100}[pj_rel.hal]-Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-{Partial-30}[bas_hold.hal;30]-Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-Pj/Sb/Sw/Po/B/Bw=235000(50)
>NOTICE Rule 1 tally is 15940.17
>NOTICE Rule 2 tally is 895270.69
>NOTICE Rule 3 tally is 264485.75
>NOTICE Total area of harvest 28175
HSG> # step to 2035
HSG> STEP 5 : Pj/Sb/Sw/Po/B/Bw=235000: Rule_3-{Release-100}[pj_rel.hal]-Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-{Partial-30}[bas_hold.hal;30]-Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-Pj/Sb/Sw/Po/B/Bw=235000(50)
>NOTICE Rule 1 tally is 33937.57
>NOTICE Rule 2 tally is 499441.62
>NOTICE Rule 3 tally is 645035.06
>NOTICE Total area of harvest 19732
HSG> # step to 2040
HSG> STEP 5 : Pj/Sb/Sw/Po/B/Bw=235000: Rule_3-{Release-100}[pj_rel.hal]-Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-{Partial-30}[bas_hold.hal;30]-Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-Pj/Sb/Sw/Po/B/Bw=235000(50)
>NOTICE Rule 1 tally is 180840.69
>NOTICE Rule 2 tally is 342212.47
>NOTICE Rule 3 tally is 652094.62
>NOTICE Total area of harvest 17005
HSG> # step to 2045
HSG> STEP 5 : Pj/Sb/Sw/Po/B/Bw=235000: Rule_3-{Release-100}[pj_rel.hal]-Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-{Partial-30}[bas_hold.hal;30]-Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-Pj/Sb/Sw/Po/B/Bw=235000(50)
>NOTICE Rule 1 tally is 190723.39
>NOTICE Rule 2 tally is 407372.31
>NOTICE Rule 3 tally is 587038.19
>NOTICE Total area of harvest 19450
HSG> # step to 2050
HSG> STEP 5 : Pj/Sb/Sw/Po/B/Bw=235000: Rule_3-{Release-100}[pj_rel.hal]-Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-{Partial-30}[bas_hold.hal;30]-Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-Pj/Sb/Sw/Po/B/Bw=235000(50)
>NOTICE Rule 1 tally is 0.00

```
>NOTICE Rule 2 tally is 291026.12
>NOTICE Rule 3 tally is 884065.75
>NOTICE Total area of harvest      16313
HSG> #          step to 2055
HSG> STEP 5 : Pj/Sb/Sw/Po/B/Bw=235000: Rule_3-{Release-100}[pj_rel.hal]-
Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-{Partial-30}[bas_hold.hal;30]-Pj/Sb/Sw/Po/B/Bw=235000(50),
Rule_3-Pj/Sb/Sw/Po/B/Bw=235000(50)
>NOTICE Rule 1 tally is 11170.50
>NOTICE Rule 2 tally is 210846.09
>NOTICE Rule 3 tally is 956450.00
>NOTICE Total area of harvest      13986
HSG> #          step to 2060
HSG> STEP 5 : Pj/Sb/Sw/Po/B/Bw=235000: Rule_3-{Release-100}[pj_rel.hal]-
Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-{Partial-30}[bas_hold.hal;30]-Pj/Sb/Sw/Po/B/Bw=235000(50),
Rule_3-Pj/Sb/Sw/Po/B/Bw=235000(50)
>NOTICE Rule 1 tally is 103945.50
>NOTICE Rule 2 tally is 884567.88
>NOTICE Rule 3 tally is 189390.53
>NOTICE Total area of harvest      27835
HSG> #          step to 2065
HSG> STEP 5 : Pj/Sb/Sw/Po/B/Bw=235000: Rule_3-{Release-100}[pj_rel.hal]-
Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-{Partial-30}[bas_hold.hal;30]-Pj/Sb/Sw/Po/B/Bw=235000(50),
Rule_3-Pj/Sb/Sw/Po/B/Bw=235000(50)
>NOTICE Rule 1 tally is 55126.00
>NOTICE Rule 2 tally is 497552.25
>NOTICE Rule 3 tally is 627218.94
>NOTICE Total area of harvest      19401
HSG> #          step to 2070
HSG> STEP 5 : Pj/Sb/Sw/Po/B/Bw=235000: Rule_3-{Release-100}[pj_rel.hal]-
Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-{Partial-30}[bas_hold.hal;30]-Pj/Sb/Sw/Po/B/Bw=235000(50),
Rule_3-Pj/Sb/Sw/Po/B/Bw=235000(50)
>NOTICE Rule 1 tally is 15852.25
>NOTICE Rule 2 tally is 336060.84
>NOTICE Rule 3 tally is 826700.44
>NOTICE Total area of harvest      16107
HSG> #          step to 2075
HSG> STEP 5 : Pj/Sb/Sw/Po/B/Bw=235000: Rule_3-{Release-100}[pj_rel.hal]-
Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-{Partial-30}[bas_hold.hal;30]-Pj/Sb/Sw/Po/B/Bw=235000(50),
Rule_3-Pj/Sb/Sw/Po/B/Bw=235000(50)
>NOTICE Rule 1 tally is 17912.75
>NOTICE Rule 2 tally is 409292.19
>NOTICE Rule 3 tally is 748699.50
>NOTICE Total area of harvest      17472
HSG> #          step to 2080
HSG> STEP 5 : Pj/Sb/Sw/Po/B/Bw=235000: Rule_3-{Release-100}[pj_rel.hal]-
Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-{Partial-30}[bas_hold.hal;30]-Pj/Sb/Sw/Po/B/Bw=235000(50),
Rule_3-Pj/Sb/Sw/Po/B/Bw=235000(50)
>NOTICE Rule 1 tally is 0.00
>NOTICE Rule 2 tally is 291090.09
>NOTICE Rule 3 tally is 888387.94
>NOTICE Total area of harvest      15664
HSG> #          step to 2085
HSG> STEP 5 : Pj/Sb/Sw/Po/B/Bw=235000: Rule_3-{Release-100}[pj_rel.hal]-
Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-{Partial-30}[bas_hold.hal;30]-Pj/Sb/Sw/Po/B/Bw=235000(50),
Rule_3-Pj/Sb/Sw/Po/B/Bw=235000(50)
```

>NOTICE Rule 1 tally is 0.00
>NOTICE Rule 2 tally is 211137.61
>NOTICE Rule 3 tally is 968591.50
>NOTICE Total area of harvest 13338
HSG> # step to 2090
HSG> STEP 5 : Pj/Sb/Sw/Po/B/Bw=235000: Rule_3-{Release-100}[pj_rel.hal]-Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-{Partial-30}[bas_hold.hal;30]-Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-Pj/Sb/Sw/Po/B/Bw=235000(50)
>NOTICE Rule 1 tally is 0.00
>NOTICE Rule 2 tally is 884672.19
>NOTICE Rule 3 tally is 293779.09
>NOTICE Total area of harvest 28259
HSG> # step to 2095
HSG> STEP 5 : Pj/Sb/Sw/Po/B/Bw=235000: Rule_3-{Release-100}[pj_rel.hal]-Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-{Partial-30}[bas_hold.hal;30]-Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-Pj/Sb/Sw/Po/B/Bw=235000(50)
>NOTICE Rule 1 tally is 0.00
>NOTICE Rule 2 tally is 497720.53
>NOTICE Rule 3 tally is 683690.38
>NOTICE Total area of harvest 19414
HSG> # step to 2100
HSG> STEP 5 : Pj/Sb/Sw/Po/B/Bw=235000: Rule_3-{Release-100}[pj_rel.hal]-Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-{Partial-30}[bas_hold.hal;30]-Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-Pj/Sb/Sw/Po/B/Bw=235000(50)
>NOTICE Rule 1 tally is 4770.00
>NOTICE Rule 2 tally is 336127.19
>NOTICE Rule 3 tally is 844338.25
>NOTICE Total area of harvest 15804
HSG> # step to 2105
HSG> STEP 5 : Pj/Sb/Sw/Po/B/Bw=235000: Rule_3-{Release-100}[pj_rel.hal]-Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-{Partial-30}[bas_hold.hal;30]-Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-Pj/Sb/Sw/Po/B/Bw=235000(50)
>NOTICE Rule 1 tally is 648.00
>NOTICE Rule 2 tally is 409292.19
>NOTICE Rule 3 tally is 767677.38
>NOTICE Total area of harvest 17515
HSG> # step to 2110
HSG> STEP 5 : Pj/Sb/Sw/Po/B/Bw=235000: Rule_3-{Release-100}[pj_rel.hal]-Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-{Partial-30}[bas_hold.hal;30]-Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-Pj/Sb/Sw/Po/B/Bw=235000(50)
>NOTICE Rule 1 tally is 3888.00
>NOTICE Rule 2 tally is 291090.09
>NOTICE Rule 3 tally is 880563.25
>NOTICE Total area of harvest 16064
HSG> # step to 2115
HSG> STEP 5 : Pj/Sb/Sw/Po/B/Bw=235000: Rule_3-{Release-100}[pj_rel.hal]-Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-{Partial-30}[bas_hold.hal;30]-Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-Pj/Sb/Sw/Po/B/Bw=235000(50)
>NOTICE Rule 1 tally is 0.00
>NOTICE Rule 2 tally is 211137.61
>NOTICE Rule 3 tally is 969661.75
>NOTICE Total area of harvest 13731
HSG> # step to 2120

HSG> STEP 5 : Pj/Sb/Sw/Po/B/Bw=235000: Rule_3-{Release-100}[pj_rel.hal]-Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-{Partial-30}[bas_hold.hal;30]-Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-Pj/Sb/Sw/Po/B/Bw=235000(50)
>NOTICE Rule 1 tally is 0.00
>NOTICE Rule 2 tally is 884672.19
>NOTICE Rule 3 tally is 293683.50
>NOTICE Total area of harvest 27865
HSG> # step to 2125
HSG> STEP 5 : Pj/Sb/Sw/Po/B/Bw=235000: Rule_3-{Release-100}[pj_rel.hal]-Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-{Partial-30}[bas_hold.hal;30]-Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-Pj/Sb/Sw/Po/B/Bw=235000(50)
>NOTICE Rule 1 tally is 0.00
>NOTICE Rule 2 tally is 497720.53
>NOTICE Rule 3 tally is 679409.00
>NOTICE Total area of harvest 18265
HSG> # step to 2130
HSG> STEP 5 : Pj/Sb/Sw/Po/B/Bw=235000: Rule_3-{Release-100}[pj_rel.hal]-Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-{Partial-30}[bas_hold.hal;30]-Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-Pj/Sb/Sw/Po/B/Bw=235000(50)
>NOTICE Rule 1 tally is 0.00
>NOTICE Rule 2 tally is 336127.19
>NOTICE Rule 3 tally is 841332.81
>NOTICE Total area of harvest 16245
HSG> # step to 2135
HSG> STEP 5 : Pj/Sb/Sw/Po/B/Bw=235000: Rule_3-{Release-100}[pj_rel.hal]-Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-{Partial-30}[bas_hold.hal;30]-Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-Pj/Sb/Sw/Po/B/Bw=235000(50)
>NOTICE Rule 1 tally is 0.00
>NOTICE Rule 2 tally is 409292.19
>NOTICE Rule 3 tally is 774031.50
>NOTICE Total area of harvest 18303
HSG> # step to 2140
HSG> STEP 5 : Pj/Sb/Sw/Po/B/Bw=235000: Rule_3-{Release-100}[pj_rel.hal]-Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-{Partial-30}[bas_hold.hal;30]-Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-Pj/Sb/Sw/Po/B/Bw=235000(50)
>NOTICE Rule 1 tally is 0.00
>NOTICE Rule 2 tally is 291090.09
>NOTICE Rule 3 tally is 883994.69
>NOTICE Total area of harvest 14541
HSG> # step to 2145
HSG> STEP 5 : Pj/Sb/Sw/Po/B/Bw=235000: Rule_3-{Release-100}[pj_rel.hal]-Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-{Partial-30}[bas_hold.hal;30]-Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-Pj/Sb/Sw/Po/B/Bw=235000(50)
>NOTICE Rule 1 tally is 0.00
>NOTICE Rule 2 tally is 211137.61
>NOTICE Rule 3 tally is 975691.00
>NOTICE Total area of harvest 12804
HSG> # step to 2150
HSG> STEP 5 : Pj/Sb/Sw/Po/B/Bw=235000: Rule_3-{Release-100}[pj_rel.hal]-Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-{Partial-30}[bas_hold.hal;30]-Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-Pj/Sb/Sw/Po/B/Bw=235000(50)
>NOTICE Rule 1 tally is 0.00
>NOTICE Rule 2 tally is 884672.19
>NOTICE Rule 3 tally is 293257.69
>NOTICE Total area of harvest 27967

HSG> # step to 2155
HSG> STEP 5 : Pj/Sb/Sw/Po/B/Bw=235000: Rule_3-{Release-100}[pj_rel.hal]-Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-{Partial-30}[bas_hold.hal;30]-Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-Pj/Sb/Sw/Po/B/Bw=235000(50)
>NOTICE Rule 1 tally is 0.00
>NOTICE Rule 2 tally is 497720.53
>NOTICE Rule 3 tally is 685122.44
>NOTICE Total area of harvest 18236
HSG> # step to 2160
HSG> STEP 5 : Pj/Sb/Sw/Po/B/Bw=235000: Rule_3-{Release-100}[pj_rel.hal]-Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-{Partial-30}[bas_hold.hal;30]-Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-Pj/Sb/Sw/Po/B/Bw=235000(50)
>NOTICE Rule 1 tally is 0.00
>NOTICE Rule 2 tally is 336127.19
>NOTICE Rule 3 tally is 843858.62
>NOTICE Total area of harvest 14703
HSG> # step to 2165
HSG> STEP 5 : Pj/Sb/Sw/Po/B/Bw=235000: Rule_3-{Release-100}[pj_rel.hal]-Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-{Partial-30}[bas_hold.hal;30]-Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-Pj/Sb/Sw/Po/B/Bw=235000(50)
>NOTICE Rule 1 tally is 0.00
>NOTICE Rule 2 tally is 409292.19
>NOTICE Rule 3 tally is 767603.50
>NOTICE Total area of harvest 16922
HSG> # step to 2170
HSG> STEP 5 : Pj/Sb/Sw/Po/B/Bw=235000: Rule_3-{Release-100}[pj_rel.hal]-Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-{Partial-30}[bas_hold.hal;30]-Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-Pj/Sb/Sw/Po/B/Bw=235000(50)
>NOTICE Rule 1 tally is 0.00
>NOTICE Rule 2 tally is 291090.09
>NOTICE Rule 3 tally is 885438.25
>NOTICE Total area of harvest 14466
HSG> # step to 2175
HSG> STEP 5 : Pj/Sb/Sw/Po/B/Bw=235000: Rule_3-{Release-100}[pj_rel.hal]-Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-{Partial-30}[bas_hold.hal;30]-Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-Pj/Sb/Sw/Po/B/Bw=235000(50)
>NOTICE Rule 1 tally is 0.00
>NOTICE Rule 2 tally is 211137.61
>NOTICE Rule 3 tally is 964464.81
>NOTICE Total area of harvest 11496
HSG> # step to 2180
HSG> STEP 5 : Pj/Sb/Sw/Po/B/Bw=235000: Rule_3-{Release-100}[pj_rel.hal]-Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-{Partial-30}[bas_hold.hal;30]-Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-Pj/Sb/Sw/Po/B/Bw=235000(50)
>NOTICE Rule 1 tally is 0.00
>NOTICE Rule 2 tally is 884672.19
>NOTICE Rule 3 tally is 294656.56
>NOTICE Total area of harvest 27502
HSG> # step to 2185
HSG> STEP 5 : Pj/Sb/Sw/Po/B/Bw=235000: Rule_3-{Release-100}[pj_rel.hal]-Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-{Partial-30}[bas_hold.hal;30]-Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-Pj/Sb/Sw/Po/B/Bw=235000(50)
>NOTICE Rule 1 tally is 0.00
>NOTICE Rule 2 tally is 497720.53
>NOTICE Rule 3 tally is 682349.12

>NOTICE Total area of harvest 17752
HSG> # step to 2190
HSG> STEP 5 : Pj/Sb/Sw/Po/B/Bw=235000: Rule_3-{Release-100}[pj_rel.hal]-Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-{Partial-30}[bas_hold.hal;30]-Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-Pj/Sb/Sw/Po/B/Bw=235000(50)
>NOTICE Rule 1 tally is 0.00
>NOTICE Rule 2 tally is 336127.19
>NOTICE Rule 3 tally is 840140.81
>NOTICE Total area of harvest 14208
HSG> # step to 2195
HSG> STEP 5 : Pj/Sb/Sw/Po/B/Bw=235000: Rule_3-{Release-100}[pj_rel.hal]-Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-{Partial-30}[bas_hold.hal;30]-Pj/Sb/Sw/Po/B/Bw=235000(50), Rule_3-Pj/Sb/Sw/Po/B/Bw=235000(50)
>NOTICE Rule 1 tally is 0.00
>NOTICE Rule 2 tally is 410183.34
>NOTICE Rule 3 tally is 768337.44
>NOTICE Total area of harvest 16060
HSG> #
HSG> SCHEDULE
>INFORM Schedule file closed
HSG> #
HSG> ERRORS
Errors detected:
HSG> QUIT
>NOTICE Normal end of HSG

13 APPENDIX V

13.1 Silvicultural Treatment File : BASIC_80.TRT

This file was used to assign regeneration treatments to clearcut areas in all runs where Rule_2 was used. This file is in HSG Version 2.0 format.

```
VAR CODE SITE TREATMENT
DATA Pj X basic
DATA Pj 1 basic
DATA Pj 2 basic
DATA Pj 3 basic
DATA Sb X basic
DATA Sb 1 basic
DATA Sb 2 basic
DATA Sw X basic
DATA Sw 1 basic
DATA Sw 2 basic
DATA Sw 3 basic
DATA B X basic
DATA B 1 basic
DATA B 2 basic
DATA Pr X basic
DATA Pr 1 basic
DATA Pr 2 basic
DATA Bw X basic
DATA Bw 1 basic
DATA Bw 2 basic
DATA L X basic
DATA L 1 basic
DATA L 2 basic
```

13.2 Regeneration Treatment Cost File : BASIC.RTC

This file is used to load the information required by Rule_3 regeneration to calculate the SEV's and to determine the eligibility of specific working groups for regeneration treatments. This is the file used by all the Rule_3 simulation runs. The header line is not present in the actual file, it is included here for information only.

```
Species Site Harvest_age Regeneration_cost
Pj X basic 70 600
Pj 1 basic 70 600
Pj 2 basic 70 600
Pj 3 basic 70 600
```

Sb X basic 70 600
Sb 1 basic 70 600
Sb 2 basic 70 600
Sw X basic 70 600
Sw 1 basic 70 600
Sw 2 basic 70 600
Sw 3 basic 70 600
B X basic 60 700
B 1 basic 60 700
B 2 basic 60 700
Bw X basic 70 650
Bw 1 basic 70 650
Bw 2 basic 70 650
Pr X basic 70 600
Pr 1 basic 70 600
Pr 2 basic 70 600
L X basic 70 600
L 1 basic 70 600
L 2 basic 70 600

14 APPENDIX VI

14.1 Harvest Allocation List : BAS_HOLD.HAL

This file was used by all the simulation runs to determine the eligibility of the "hold on the stump" "partial harvest" alternative silvicultural treatment. The header line is for information only.

Species Site Lower_age_bound Upper_age_bound
Sb X 100 120
Sb 1 120 130
Sb 2 140 160
Sb 3 160 180
Sb 4 170 190
Pj X 80 110
Pj 1 90 110
Pj 2 90 110
Pj 3 100 115
Po X 90 110
Po 1 90 110
Po 2 90 115
Po 3 90 115
Sw X 130 190
Sw 1 150 195
Sw 2 150 195
Sw 3 160 195
Sw 4 160 195
Bw X 80 100
Bw 1 80 100
Bw 2 90 100
Bw 3 90 100
B X 60 90
B 1 60 90
B 2 70 90
B 3 80 100
B 4 80 100

14.2 Harvest Allocation List : PJ_REL.HAL

This file was used by all the "release" alternative silvicultural treatments to determine the eligibility of jack pine stands to release a spruce under story.

Species Site Lower_age _bound Upper_age_bound
Pj X 40 59
Pj 1 40 59
Pj 2 40 59
Pj 3 40 59

15 APPENDIX VII: SRF STATE TABLE

This is the state table describing natural forest dynamics and response to treatments.

CODE	SITE	AGE	P_STKG(Po)	TYPE	TREATMENT	/	Sp1	St1	Age1	Stk1	Sp2	St2	Age2	Stk2	Sp3	St3	Age3	Stk3	Sp4	St4	Age4	Stk4	Sp5	St5	Age5	Stk5
Ab	1	*	>.30	silv	extensive	/	Po	X	0	0.45	Ab	X	0	0.4	Sb	1	0	0.1	Ab	2	0	0.1				
Ab	1	*	*	silv	extensive	/	Ab	X	0	0.5	Sb	X	0	0.2	Po	X	0	0.2								
Ab	X	>195	>.30	invt	none	/	Ab	X	70	0.3	B	X	20	0.15	Sw	X	60	0.1	Sb	X	60	0.1	Po	X	20	0
Ab	X	>195	*	invt	none	/	Ab	X	70	0.3	Sb	X	90	0.3	B	X	20	0.1	Sw	X	60	0.1				
Ab	X	>195	*	invt	none	/	Ab	X	70	0.35	B	X	20	0.15	Sw	X	60	0.15	Sb	X	60	0.1				
Ab	1	*	>.30	silv	extensive	/	Ab	1	0	0.4	Sb	1	0	0.1	Po	1	0	0.35	Ab	2	0	0.1				
Ab	1	*	*	silv	extensive	/	Ab	1	0	0.5	Sb	1	0	0.2	Po	1	0	0.2								
Ab	1	>195	>.30	invt	none	/	Ab	1	70	0.3	B	1	20	0.15	Sw	1	60	0.1	Sb	1	60	0.1	Po			
Ab	1	>195	*	invt	none	/	Ab	1	70	0.3	Sb	1	90	0.3	B	1	20	0.1	Sw	1	60	0.1				
Ab	2	*	>.30	silv	extensive	/	Ab	2	0	0.4	Sb	2	0	0.1	Po	2	0	0.35	Ab	2	0	0.1				
Ab	2	*	*	silv	extensive	/	Ab	2	0	0.5	Sb	2	0	0.2	Po	2	0	0.2								
Ab	2	>195	>.30	invt	none	/	Ab	2	70	0.3	B	2	20	0.15	Sw	2	60	0.1	Sb	2	60	0.1	Po			
Ab	2	>195	*	invt	none	/	Ab	2	70	0.4	Sb	2	90	0.2	B	2	20	0.1	Sw	2	60	0.1				
Ab	3	*	>.30	silv	extensive	/	Ab	3	0	0.4	Sb	3	0	0.1	Po	3	0	0.35	Ab	2	0	0.1				
Ab	3	*	*	silv	extensive	/	Ab	3	0	0.5	Sb	3	0	0.2	Po	3	0	0.2								
Ab	3	>195	>.30	invt	none	/	Ab	3	70	0.3	B	3	30	0.15	Sw	3	70	0.1	Sb	3	70	0.1	Po			
Ab	3	>195	*	invt	none	/	Ab	3	70	0.4	Sb	3	90	0.2	B	3	40	0.05	Sw	3	70	0.1				
Ab	4	*	*	silv	extensive	/	Ab	4	0	0.4	Sb	4	0	0.1	Po	4	0	0.1								
Ab	4	>195	*	invt	none	/	Ab	4	70	0.3	Sw	4	90	0.2	Sb	3	90	0.1								
B	X	*	*	silv	basic	/	Sb	X	0	0.9	Sw	X	0	0.1												
B	X	*	>.30	silv	extensive	/	Po	X	0	0.9	Sb	X	0	0.1												
B	X	*	>.09	silv	extensive	/	Po	X	0	0.7	Sb	X	0	0.1	B	X	0	0.1								
B	X	*	*	silv	extensive	/	Sb	X	0	0.3	Po	X	0	0.3	B	X	0	0.2								
B	X	>59	>.30	hrvt	partial	/	B	X	30	0.3	Sb	X	60	0.1	Sw	X	60	0.1	Po							
B	X	>59	*	hrvt	partial	/	B	X	30	0.35	Sb	X	60	0.15	Sw	X	60	0.2								
B	X	>80	*	invt	none	/	B	X	20	0.9	Sw	X	40	0.1												
B	1	*	*	silv	basic	/	Sb	1	0	0.9	Sw	1	0	0.1												
B	1	*	>.30	silv	extensive	/	Po	1	0	0.85	Sb	1	0	0.1												
B	1	*	>.09	silv	extensive	/	Po	1	0	0.7	Sb	1	0	0.1	B	1	0	0.1								
B	1	*	*	silv	extensive	/	Sb	1	0	0.3	Po	1	0	0.3	B	1	0	0.2								
B	1	>59	>.30	hrvt	partial	/	B	1	30	0.3	Sb	1	80	0.1	Sw	1	80	0.1	F							
B	1	>59	*	hrvt	partial	/	B	1	30	0.35	Sb	1	80	0.15	Sw	1	80	0.2								
B	1	>85	*	invt	none	/	B	1	25	0.8	Sw	1	40	0.2												
B	2	*	*	silv	basic	/	Sb	2	0	0.9	Sw	3	0	0.1												
B	2	*	>.30	silv	extensive	/	Po	2	0	0.8	Sb	2	0	0.1												
B	2	*	>.09	silv	extensive	/	Po	2	0	0.5	Sb	2	0	0.15	B	2	0	0.15								
B	2	*	*	silv	extensive	/	Sb	2	0	0.25	Po	2	0	0.2	B	2	0	0.2								
B	2	>69	>.30	hrvt	partial	/	B	2	40	0.3	Sb	2	80	0.1	Sw	2	80	0.1	Po	2	60	0.				
B	2	>69	*	hrvt	partial	/	B	2	40	0.35	Sb	2	80	0.15	Sw	2	80	0.2								
B	2	>90	*	invt	none	/	B	2	25	0.7	Sb	2	50	0.1	Sw	2	45	0.1								
B	3	*	>.30	silv	extensive	/	Po	3	0	0.6	Sb	3	0	0.8	B	3	0	0.8								

B	3		>.09	silv	extensive	/	Po	3	0	0.4	Sb	3	0	0.15	B	3	0	0.2					
B	3	*	*	silv	extensive	/	Sb	3	0	0.25	Po	3	0	0.1	B	3	0	0.2	Sw	3	0	0.05	
B	3	>79	>.30	hrvt	partial	/	B	3	50	0.3	Sb	3	80	0.1	Sw	3	80	0.1	Po	3	70	0.1	
B	3	>79	*	hrvt	partial	/	B	3	50	0.3	Sb	3	80	0.15	Sw	3	80	0.2					
B	3	>100	*	invt	none	/	B	3	25	0.7	Sb	3	75	0.2	Sw	3	65	0.1					
B	4	*	*	silv	extensive	/	Po	4	0	0.4	Sb	3	10	0.2	B	4	0	0.1					
B	4	>79		hrvt	partial	/	B	4	50	0.3	Sb	4	80	0.15	Sw	3	80	0.2					
B	4	>100	*	invt	none	/	B	4	25	0.6	Sb	4	85	0.3									
Bw	X	*	*	silv	basic	/	Sb	X	0	1.0													
Bw	X	*	>.30	silv	extensive	/	Po	X	0	0.4	Bw	X	0	0.4	Sb	X	0	0.1	B	X	0	0.1	
Bw	X	*	>.05	silv	extensive	/	Bw	X	0	0.5	Po	X	0	0.2	Sb	X	0	0.2	B	X	0	0.1	
Bw	X	*	*	silv	extensive	/	Bw	X	0	0.6	Sb	X	0	0.15	Po	X	0	0.1	B	X	0	0.15	
Bw	X	>79	>.30	hrvt	partial	/	Sw	X	50	0.3	Sb	X	50	0.1	Bw	X	50	0.1	Po	X	50	0.2	
Bw	X	>79	*	hrvt	partial	/	Sw	X	50	0.3	Sb	X	50	0.1	Bw	X	50	0.15	B	X	30	0.05	
Bw	X	>105	>.30	invt	none	/	Bw	X	25	0.3	B	X	20	0.25	Sw	X	20	0.1	Sb	X	20	0.1	Po
Bw	X	>105	*	invt	none	/	Sb	X	105	0.3	B	X	20	0.2	Sw	X	50	0.1	Bw	X	20	0.1	
Bw	1	*	*	silv	basic	/	Sb	1	0	0.9	Sw	1	0	0.1									
Bw	1	*	>.30	silv	extensive	/	Po	1	0	0.4	Bw	1	0	0.4	Sb	1	0	0.1	B	1	0	0.1	
Bw	1	*	>.10	silv	extensive	/	Bw	1	0	0.5	Po	1	0	0.2	Sb	1	0	0.1	B	1	0	0.1	
Bw	1	*	*	silv	extensive	/	Bw	1	0	0.6	Sb	1	0	0.15	Po	1	0	0.1	B	1	0	0.15	
Bw	1	>79	>.30	hrvt	partial	/	Sw	1	50	0.3	Sb	1	50	0.1	Bw	1	50	0.1	Po	1	50	0.15	
Bw	1	>79	*	hrvt	partial	/	Sw	1	50	0.3	Sb	1	50	0.1	Bw	1	50	0.15	B	1	30	0.05	
Bw	1	>105	>.30	invt	none	/	Bw	1	25	0.3	B	1	20	0.2	Sw	1	20	0.1	Sb	1	20	0.1	Po
Bw	1	>105	*	invt	none	/	Sb	1	105	0.3	B	1	20	0.2	Sw	1	60	0.1	Bw	1	20	0.1	
Bw	2	*	*	silv	basic	/	Sb	2	0	0.9	Sw	2	0	0.1									
Bw	2	*	>.30	silv	extensive	/	Po	2	0	0.4	Bw	2	0	0.3	Sb	2	0	0.1	B	2	0	0.05	
Bw	2	*	>.10	silv	extensive	/	Bw	2	0	0.4	Po	2	0	0.2	Sb	2	0	0.1	B	2	0	0.1	
Bw	2	*	*	silv	extensive	/	Bw	2	0	0.5	Sb	2	0	0.1	Po	2	0	0.1	B	2	0	0.15	
Bw	2	>89	>.30	hrvt	partial	/	Sw	2	60	0.3	Sb	2	60	0.1	Bw	2	60	0.1	Po	2	60	0.15	
Bw	2	>89	*	hrvt	partial	/	Sw	2	60	0.3	Sb	2	60	0.1	Bw	2	60	0.15	B	2	40	0.05	
Bw	2	>110	>.30	invt	none	/	Bw	2	25	0.25	B	2	20	0.2	Sw	2	40	0.1	Sb	2	45	0.1	Po
Bw	2	>110	*	invt	none	/	Sb	2	110	0.3	B	2	20	0.2	Sw	2	80	0.1	Bw	2	25	0.1	
Bw	3	*	>.30	silv	extensive	/	Po	3	0	0.4	Bw	3	0	0.2	Sb	3	0	0.1	B	3	0	0.05	
Bw	3	*	>.10	silv	extensive	/	Bw	3	0	0.4	Po	3	0	0.2	Sb	3	0	0.1	B	3	0	0.05	
Bw	3	*	*	silv	extensive	/	Bw	3	0	0.5	Sb	3	0	0.1	B	3	0	0.15					
Bw	3	>89	>.30	hrvt	partial	/	Sw	3	60	0.2	Sb	3	60	0.2	Bw	3	60	0.1	Po	3	60	0.1	
Bw	3	>89	*	hrvt	partial	/	Sb	3	60	0.3	Sw	3	60	0.1	Bw	3	60	0.15	B	3	40	0.05	
Bw	3	>110	*	invt	none	/	Bw	3	30	0.2	B	3	20	0.2	Sw	3	50	0.5	Sb	3	70	0.13	
Bw	4	*	*	silv	extensive	/	Bw	4	0	0.4	Sb	4	10	0.1	B	4	0	0.1					
Bw	4	>110	*	invt	none	/	B	3	40	0.25	Bw	4	20	0.2	Sb	3	70	0.1					
Ce	X	*	*	silv	basic	/	Sb	X	0	0.8	Ce	1	0	0.1									
Ce	X	*	>.25	silv	extensive	/	Po	2	0	0.3	Ce	X	0	0.3	Sb	X	0	0.2					
Ce	X	*	*	silv	extensive	/	Ce	X	0	0.4	Sb	X	0	0.3	B	X	0	0.1					
Ce	X	>160	*	invt	none	/	Ce	X	50	0.8	Sb	X	25	0.1									
Ce	1	*	*	silv	basic	/	Sb	1	0	0.9	Ce	1	0	0.1									
Ce	1	*	>.25	silv	extensive	/	Po	2	0	0.3	Ce	1	0	0.25	Sb	1	0	0.2					
Ce	1	*	*	silv	extensive	/	Ce	1	0	0.4	Sb	1	0	0.25	B	1	0	0.1					
Ce	1	>170	*	invt	none	/	Ce	1	50	0.7	Sb	1	35	0.2									
Ce	2	*	*	silv	basic	/	Sb	2	0	0.9	Ce	2	0	0.1									
Ce	2	*	>.25	silv	extensive	/	Ce	2	0	0.3	Po	3	0	0.3	Sb	2							

Ce	2	*		silv	extensive	/	Ce	2	0	0.4	Sb	2	0	0.25												
Ce	2	>178		invt	none	/	Ce	2	60	0.6	Sb	2	55	0.2												
Ce	3	*		silv	extensive	/	Ce	3	0	0.4	Sb	3	0	0.2												
Ce	3	>190		invt	none	/	Ce	3	90	0.6	Sb	3	80	0.2												
Ce	4	*		silv	extensive	/	Ce	4	0	0.35	Sb	4	0	0.2												
Ce	4	>190	*	invt	none	/	Ce	4	90	0.5	Sb	4	100	0.2												
L	X	*	*	silv	basic	/	Sb	X	0	0.8	Pj	1	0	0.2												
L	X	*	>.25	silv	extensive	/	Po	X	0	0.45	Sb	X	0	0.15	B	X	0	0.15	L							
L	X	*	*	silv	extensive	/	Sb	X	0	0.4	B	X	0	0.2	L	X	0	0.15								
L	X	>120	>.25	invt	none	/	Sb	X	50	0.5	Po	X	20	0.15	Sw	X	30	0.1								
L	X	>120	*	invt	none	/	Sb	X	50	0.55	Sw	X	30	0.15	B	X	20	0.1								
L	1	*	*	silv	basic	/	Sb	1	0	0.8	Pj	2	0	0.2												
L	1	*	>.25	silv	extensive	/	Po	1	0	0.4	Sb	1	0	0.1	B	1	0	0.1								
L	1	*	*	silv	extensive	/	Sb	1	0	0.45	B	1	0	0.25	B	1	0	0.1								
L	1	>120	>.25	invt	none	/	Sb	1	50	0.5	Po	1	20	0.15	Sw	1	30	0.1								
L	1	>120	*	invt	none	/	Sb	1	50	0.55	Sw	1	30	0.15	B	1	20	0.1								
L	2	*	*	silv	basic	/	Sb	2	0	0.8	Pj	3	0	0.2												
L	2	*	>.25	silv	extensive	/	Po	2	0	0.4	Sb	2	0	0.1	B	2	0	0.1								
L	2	*	*	silv	extensive	/	Sb	2	0	0.45	B	2	0	0.25	B	2	0	0.1								
L	2	>120	>.25	invt	none	/	Sb	2	60	0.45	Po	2	20	0.1	Sw	2	50	0.1								
L	2	>120	*	invt	none	/	Sb	2	60	0.5	Sw	2	50	0.15	B	2	30	0.1								
L	3	*	>.25	silv	extensive	/	Po	3	0	0.3	Sb	3	0	0.1	B	3	0	0.1								
L	3	*	*	silv	extensive	/	Sb	3	0	0.4	B	3	0	0.1	B	3	0	0.1								
L	3	>120	>.25	invt	none	/	Sb	3	80	0.4	Po	3	30	0.1	Sw	3	70	0.1								
L	3	>120	*	invt	none	/	Sb	3	80	0.45	Sw	3	70	0.15	B	3	40	0.1								
L	4	*	>.25	silv	extensive	/	Sb	4	0	0.3	Po	4	0	0.15	B	4	0	0.1								
L	4	*	*	silv	extensive	/	Sb	4	0	0.4	B	4	0	0.1	B	4	0	0.1								
L	4	>120	*	invt	none	/	Sb	4	90	0.5	B	4	40	0.1												
Ms	X	*	>.30	silv	extensive	/	Po	X	0	0.65	Bw	X	0	0.1	B	X	0	0.1	Ms	X	0	0.1				
Ms	X	*	*	silv	extensive	/	Bw	X	0	0.3	Po	X	0	0.25	B	X	0	0.1	Ms	X	0	0.1				
Ms	X	>195	>.30	invt	none	/	Ms	X	70	0.3	B	X	20	0.15	Sw	X	60	0.1	Sb	X	60	0.1	Po			
Ms	X	>195	*	invt	none	/	Ms	X	70	0.35	B	X	20	0.15	Sw	X	60	0.15	Sb	X	60	0.1				
Ms	1	*	>.30	silv	extensive	/	Po	1	0	0.65	Bw	1	0	0.1	B	1	0	0.1	Ms	1	0	0.1				
Ms	1	*	*	silv	extensive	/	Bw	1	0	0.3	Po	1	0	0.25	B	1	0	0.1	Ms	1	0	0.1				
Ms	1	>195	>.30	invt	none	/	Ms	1	70	0.3	B	1	20	0.15	Sw	1	60	0.1	Sb	1	60	0.1	Po	1	20	0.
Ms	1	>195	*	invt	none	/	Ms	1	70	0.35	B	1	20	0.15	Sw	1	60	0.15	Sb	1	60	0.1				
Ms	2	*	>.30	silv	extensive	/	Po	2	0	0.65	Bw	2	0	0.1	B	2	0	0.1	Ms	2	0	0.1				
Ms	2	*	*	silv	extensive	/	Bw	2	0	0.3	Po	2	0	0.25	B	2	0	0.1	Ms	2	0	0.1				
Ms	2	>195	>.30	invt	none	/	Ms	2	70	0.3	B	2	20	0.15	Sw	2	60	0.1	Sb	2	60	0.1	Po			
Ms	2	>195	*	invt	none	/	Ms	2	70	0.35	B	2	20	0.15	Sw	2	60	0.15	Sb	2	60	0.1				
Ms	3	*	>.30	silv	extensive	/	Po	3	0	0.65	Bw	3	0	0.1	B	3	0	0.1	Ms	3	0	0.1				
Ms	3	*	*	silv	extensive	/	Bw	3	0	0.3	Po	3	0	0.25	B	3	0	0.1	Ms	3	0	0.1				
Ms	3	>195	>.30	invt	none	/	Ms	3	70	0.3	B	3	30	0.15	Sw	3	70	0.1	Sb	3	70	0.1	Po			
Ms	3	>195	*	invt	none	/	Ms	3	70	0.35	B	3	30	0.15	Sw	3	70	0.15	Sb	3	70	0.1				
Ms	4	*	*	silv	extensive	/	Bw	4	0	0.3	Po	4	0	0.25	Sb	4	0	0.1	B	4	0	0.1				
Ms	4	>195	*	invt	none	/	Ms	4	70	0.3	Sw	4	90	0.2	Sb	3	90	0.1								
Pj	X	*	*	silv	basic	/	Pj	X	0	1.0																
Pj	X	*	>.25	silv	extensive	/	Po	1	0	0.8	Pj	X	0	0.1	B	1	0	0.1								
Pj	X	*	>.01	silv	extensive	/	Po	1	0	0.3	Pj	X	0	0.1	Sb	1	0	0.1								
Pj	X		*	silv	extensive	/	Pj	X	0	0.4	Po	1	0	0.1	Sb	1	0	0.1								

Pj	X	>39&<60	*	hrvt	release	/	Sb	1	5	0.5	B	1	5	0.1									
Pj	X	>79	>.30	hrvt	partial	/	Sb	X	60	0.25	Pj	X	50	0.2	Po	X	50	0.1					
Pj	X	>79	*	hrvt	partial	/	Pj	X	50	0.25	Sb	X	70	0.2	Sw	X	70	0.1					
Pj	X	>110	<.20	invt	none	/	Sb	1	40	0.5	Pj	X	20	0.2	Sw	1	30	0.05	B	1	20	0.05	
Pj	X	>110	>.25	invt	none	/	Sb	1	40	0.45	Pj	X	20	0.1	Po	1	20	0.2	Sw	1	30	0.05	B
Pj	X	>110	*	invt	none	/	Sb	1	40	0.6	Sw	1	30	0.1	Pj	X	20	0.1					
Pj	1	*	*	silv	basic	/	Pj	1	0	0.9	Po	2	0	0.1									
Pj	1	*	>.25	silv	extensive	/	Po	2	0	0.8	Pj	1	0	0.1	B	2	0	0.1					
Pj	1	*	>.10	silv	extensive	/	Po	2	0	0.3	Pj	1	0	0.1	Sb	2	0	0.1					
Pj	1	*	*	silv	extensive	/	Pj	1	0	0.3	Po	2	0	0.1	Sb	2	0	0.1					
Pj	1	>39&<60	*	hrvt	release	/	Sb	1	5	0.5	B	1	5	0.1									
Pj	1	>89	>.30	hrvt	partial	/	Sb	1	60	0.25	Pj	1	60	0.2	Po	1	60	0.1					
Pj	1	>89	*	hrvt	partial	/	Pj	1	60	0.25	Sb	1	70	0.2	Sw	1	70	0.1					
Pj	1	>110	>.25	invt	none	/	Sb	1	45	0.45	Pj	1	25	0.1	Po	2	20	0.2	S		0	0.05	B
Pj	1	>110	*	invt	none	/	Sb	1	45	0.5	Pj	1	25	0.1	Sw	1	30	0.1					
Pj	2	*	*	silv	basic	/	Pj	2	0	0.9	Po	3	0	0.1									
Pj	2	*	>.25	silv	extensive	/	Po	3	0	0.5	Pj	2	0	0.1	B	3	0	0.1					
Pj	2	*	>.10	silv	extensive	/	Po	3	0	0.25	Pj	2	0	0.1	Sb	3	0	0.1	B	3	0	0.1	
Pj	2	*	*	silv	extensive	/	Pj	2	0	0.25	Po	3	0	0.1	Sb	3	0	0.1	B	3	0	0.1	
Pj	2	>39&<60	*	hrvt	release	/	Sb	2	5	0.4	B	2	5	0.1									
Pj	2	>89	>.30	hrvt	partial	/	Sb	2	60	0.25	Pj	2	60	0.2	Po	1	60	0.1					
Pj	2	>89	*	hrvt	partial	/	Pj	2	60	0.25	Sb	2	70	0.2	Sw	1	70	0.1					
Pj	2	>115	>.25	invt	none	/	Sb	2	55	0.4	Pj	2	30	0.1	Po	3	40	0.2	Sw	2	50	0.05	B
Pj	2	>115	*	invt	none	/	Sb	2	55	0.5	Pj	2	30	0.1	Sw	2	50	0.2					
Pj	3	*	>.20	silv	basic	/	Pj	3	0	1.0													
Pj	3	*	*	silv	basic	/	Pj	3	0	0.8	Po	3	0	0.2									
Pj	3	*	>.25	silv	extensive	/	Po	4	0	0.4	Pj	3	0	0.1	B	4	0	0.1					
Pj	3	*	>.10	silv	extensive	/	Po	4	0	0.25	Pj	3	0	0.1	Sb	3	0	0.1	B	4	0	0.1	
Pj	3	*	*	silv	extensive	/	Pj	3	0	0.2	Po	4	0	0.1	Sb	3	0	0.1	B	4	0	0.1	
Pj	3	>39&<60	*	hrvt	release	/	Sb	3	5	0.4													
Pj	3	>89	>.30	hrvt	partial	/	Sb	3	70	0.25	Pj	3	70	0.2	Po	1	70	0.1					
Pj	3	>89	*	hrvt	partial	/	Pj	3	70	0.25	Sb	3	80	0.25	Sw	1	80	0.1					
Pj	3	>120	>.30	invt	none	/	Sb	3	80	0.4	Pj	3	40	0.1	Po	3	40	0.1	Sw	3	70	0.05	B
Pj	3	>120	*	invt	none	/	Sb	3	80	0.45	Sw	3	70	0.2									
Pj	4	*	>.25	silv	extensive	/	Po	4	0	0.3	Pj	4	0	0.1	Sb	3	0	0.1					
Pj	4	*	*	silv	extensive	/	Sb	3	0	0.2	Pj	4	0	0.1	B	4	0	0.1					
Pj	4	>120	*	invt	none	/	Sb	4	90	0.4	Sw	4	90	0.2	B	4	30	0.05					
Po	X	*	*	silv	extensive	/	Po	X	0	0.85	Sw	X	0	0.05	B	X	0	0.1					
Po	X	*	*	silv	basic	/	Sb	X	0	0.9	Po	X	0	0.1									
Po	X	>90	*	hrvt	partial	/	Sb	X	80	0.3	Po	X	60	0.25	B	X	20	0.1	Sw	X	40	0.15	
Po	X	>110	>.70	invt	none	/	Po	X	20	0.25	Sb	X	30	0.2	Sw	X	30	0.15	B	X	20	0.15	
Po	X	>110	*	invt	none	/	Sb	X	30	0.5	Po	X	20	0.1	Sw	X	30	0.15	B	X	20	0.1	
Po	1	*	*	silv	basic	/	Sb	1	0	0.9	Po	1	0	0.1									
Po	1	*	*	silv	extensive	/	Po	1	0	0.9	Sb	1	0	0.1									
Po	1	>89	*	hrvt	partial	/	Po	1	60	0.3	Sb	1	90	0.2	Sw	1	110	0.1	B	1	25	0.1	
Po	1	>115	>.70	invt	none	/	Po	1	25	0.25	Sb	1	35	0.2	Sw	1	30	0.15	B	1	20	0.15	
Po	1	>115	*	invt	none	/	Sb	1	35	0.4	Po	1	20	0.1	Sw	1	30	0.15	B	1	20	0.15	
Po	2	*	*	silv	basic	/	Sb	2	0	0.9	Po	2	0	0.1									
Po	2	*		silv	extensive	/	Po	2	0	0.9	Sb	2	0	0.1									
Po	2	>89		hrvt	partial	/	Po	2	60	0.25	Sb	2	110	0.2	Sw	2	110	0.15	B	?	30	0	

Po	2	>125	'0	invt	none	/	Po	2	25	0.2	Sb	2	60	0.2	Sw	2	50	0.1	B	2	25	0.15				
Po	2	>125		invt	none	/	Sb	2	60	0.4	Po	2	25	0.1	Sw	2	50	0.15	B	2	25	0.1				
Po	3	*		silv	extensive	/	Po	3	0	0.9	Sb	3	0	0.1												
Po	3	>89		hrvt	partial	/	Po	3	60	0.25	Sb	3	110	0.2	Sw	2	110	0.15	B	2	30	0.1				
Po	3	>130		invt	none	/	Sb	3	80	0.3	Po	3	30	0.1	Sw	3	70	0.1	B	3	35	0.1				
Po	4	*		silv	extensive	/	Po	4	0	0.9																
Po	4	>135		invt	none	/	Sb	4	90	0.3	Sw	3	80	0.1	B	3	35	0.1								
Pr	X	*		silv	basic	/	Pr	X	0	1.0																
Pr	X	*		silv	extensive	/	Po	2	0	0.4	Bw	2	0	0.2	B	1	0	0.1								
Pr	X	>195		invt	none	/	Pr	X	60	0.5	Sw	1	60	0.1	B	1	25	0.2								
Pr	1	*		silv	basic	/	Pr	1	0	1.0																
Pr	1	*		silv	extensive	/	Po	2	0	0.4	Bw	2	0	0.2	B	1	0	0.1								
Pr	1	>195		invt	none	/	Pr	1	60	0.5	Sw	2	60	0.1	B	1	25	0.2								
Pr	2	*		silv	basic	/	Pr	2	0	1.0																
Pr	2	*		silv	extensive	/	Po	3	0	0.4	Bw	3	0	0.2	B	2	0	0.1								
Pr	2	>195		invt	none	/	Pr	2	60	0.4	Sw	3	70	0.1	Sb	3	60	0.1	B	2	30	0.1				
Pr	3	*		silv	extensive	/	Po	2	0	0.35	Bw	2	0	0.2	B	3	0	0.1								
Pr	3	>195		invt	none	/	Pr	3	60	0.3	B	3	30	0.3	Sw	3	70	0.1	Sb	3	70	0.2				
Pr	4	*		silv	extensive	/	Po	4	0	0.35	Bw	2	0	0.2	B	4	0	0.1								
Pr	4	>195	*	invt	none	/	Pr	4	70	0.2	B	4	35	0.3	Sw	4	80	0.1	Sb	4	80	0.2				
Pw	X	*	*	silv	extensive	/	Pw	X	10	0.2	Po	2	0	0.2	Bw	1	0	0.2	Sb	1	0	0.05	B	1	0	0.2
Pw	X	>195	>.20	invt	none	/	Pw	X	100	0.3	Sw	1	100	0.1	Sb	1	30	0.1	B	1	30	0.2	Po	2	30	0.1
Pw	X	>195	*	invt	none	/	Pw	X	100	0.4	Sw	1	100	0.1	Sb	1	30	0.1	B	1	30	0.2				
Pw	1	*	*	silv	extensive	/	Po	2	0	0.3	Pw	1	10	0.1	Bw	2	0	0.2	Sb	2	0	0.05	B	1	0	0.2
Pw	1	>195	>.20	invt	none	/	Pw	1	100	0.3	Sw	2	100	0.1	Sb	2	30	0.1	B	2	30	0.2	Po	2	30	0.1
Pw	1	>195	*	invt	none	/	Pw	1	100	0.4	Sw	2	100	0.1	Sb	2	30	0.1	B	2	30	0.2				
Pw	2	*	*	silv	extensive	/	Po	3	0	0.3	Pw	2	10	0.1	Bw	3	0	0.15	Sb	3	0	0.05	B	2	0	0.15
Pw	2	>195	>.20	invt	none	/	Pw	2	100	0.3	Sw	3	100	0.1	Sb	3	30	0.1	B	2	30	0.2	Po	3	30	0.1
Pw	2	>195	*	invt	none	/	Pw	2	100	0.4	Sw	3	100	0.1	Sb	3	30	0.1	B	2	30	0.2				
Pw	3	*	*	silv	extensive	/	Po	4	0	0.2	Pw	3	10	0.2	Bw	3	0	0.15	Sb	3	0	0.05	B	2	0	0.1
Pw	3	>195	>.20	invt	none	/	Pw	3	100	0.2	Sw	3	100	0.1	Sb	3	80	0.1	B	3	30	0.2	Po	3	30	0.1
Pw	3	>195	*	invt	none	/	Pw	3	100	0.3	Sw	3	100	0.1	Sb	3	80	0.1	B	3	30	0.2				
Pw	4	*	*	silv	extensive	/	Po	4	0	0.2	Pw	4	10	0.2	Bw	4	0	0.05	Sb	4	0	0.2	B	2	0	0.1
Pw	4	>195	>.20	invt	none	/	Pw	4	100	0.15	Sw	4	100	0.1	Sb	3	100	0.1	B	4	30	0.15	Po	4	30	0.1
Sb	X	*	*	silv	basic	/	Sb	X	0	1.0																
Sb	X	*	>.30	silv	extensive	/	Po	1	0	1.0	Sb	X	0	0.1												
Sb	X	*	=0	silv	extensive	/	Sb	X	0	0.35	B	X	0	0.1	Pj	2	0	0.05								
Sb	X	*	*	silv	extensive	/	Po	1	0	0.7	Sb	X	0	0.2	B	X	0	0.1								
Sb	X	>99	>.30	hrvt	partial	/	Sb	X	70	0.4	Po	1	70	0.2	Sw	X	70	0.1								
Sb	X	>99	*	hrvt	partial	/	Sb	X	70	0.4	Sw	X	70	0.1	Po	1	70	0.1								
Sb	X	>130	=0	invt	none	/	Sb	X	35	0.9	Sw	X	30	0.1												
Sb	X	>130	>.30	invt	none	/	Sb	X	35	0.7	Po	1	20	0.15												
Sb	X	>130	*	invt	none	/	Sb	X	35	0.8	Sw	X	30	0.1												
Sb	1	*	*	silv	basic	/	Sb	1	0	0.95	Po	2	0	0.05												
Sb	1	*	>.30	silv	extensive	/	Po	2	0	1.0																
Sb	1	*	=0	silv	extensive	/	Sb	1	0	0.35	B	1	0	0.1	Pj	[illegible]	0	0.05								
Sb	1	*	*	silv	extensive	/	Po	2	0	0.7	Sb	1	0	0.05												
Sb	1	>119	>.30	hrvt	partial	/	Sb	1	90	0.35	Po	2	80	0.2	Sw	1	90	0.1								
Sb	1	>119	*	hrvt	partial	/	Sb	1	90	0.35	Sw	1	90	0.1	Po	2	80	0.1								
Sb	1	>140	>.30	invt	none	/	Sb	1	40	0.7	Po	2	20	0.15												

Sb	1	>140	*	invt	none	/	Sb	1	40	0.8	Sw	1	35	0.1								
Sb	2	*	*	silv	basic	/	Sb	2	0	0.95	Po	3	0	0.05								
Sb	2	*	>.30	silv	extensive	/	Po	3	0	0.9												
Sb	2	*	=0	silv	extensive	/	Sb	2	0	0.3	B	2	0	0.1	Sw	2	0	0.05				
Sb	2	*	*	silv	extensive	/	Po	3	0	0.7	Sb	2	0	0.05								
Sb	2	>139	>.30	hrvt	partial	/	Sb	2	110	0.35	Po	2	80	0.15	Sw	2	110	0.1				
Sb	2	>139	*	hrvt	partial	/	Sb	2	110	0.3	Sw	2	110	0.1	Po	2	80	0.1				
Sb	2	>150	>.30	invt	none	/	Sb	2	60	0.65	Po	3	25	0.1								
Sb	2	>150	*	invt	none	/	Sb	2	60	0.7	Sw	2	50	0.1								
Sb	3	*	*	silv	basic	/	Sb	3	0	0.9												
Sb	3	*	*	silv	extensive	/	Sb	3	0	0.8												
Sb	3	>159	*	hrvt	partial	/	Sb	3	130	0.35	Sw	3	130	0.1								
Sb	3	>160	>.30	invt	none	/	Sb	3	80	0.5	Po	3	30	0.1								
Sb	3	>160	*	invt	none	/	Sb	3	80	0.6												
Sb	4	*	*	silv	extensive	/	Sb	4	0	0.65												
Sb	4	>169	*	hrvt	partial	/	Sb	4	140	0.4												
Sb	4	>190	*	invt	none	/	Sb	4	90	0.7												
Sw	X	*	*	silv	basic	/	Sb	X	0	0.7	Sw	X	0	0.2	Po	1	0	0.1				
Sw	X	*	>.30	silv	extensive	/	Po	1	0	1.0												
Sw	X	*	=0	silv	extensive	/	Sw	X	0	0.35	B	X	0	0.1	Pj	2	0	0.05				
Sw	X	*	*	silv	extensive	/	Po	1	0	0.7	Sw	X	0	0.05								
Sw	X	>129	>.30	hrvt	partial	/	Sw	X	100	0.25	Po	1	70	0.25	Sb	X	90	0.1	B	X	25	0.1
Sw	X	>129	*	hrvt	partial	/	Sw	X	100	0.3	Sb	X	90	0.15	Po	1	70	0.05	B	X	25	0.1
Sw	X	>195	=0	invt	none	/	Sw	X	60	0.5	Sb	X	50	0.3								
Sw	X	>195	>.30	invt	none	/	Sw	X	60	0.4	Sb	X	50	0.1	Po	1	20	0.2				
Sw	X	>195	*	invt	none	/	Sw	X	60	0.3	Sb	X	50	0.2	Po	1	20	0.1	Pw	2	60	0.
Sw	1	*	*	silv	basic	/	Sb	1	0	0.7	Sw	1	0	0.2	Po	2	0	0.1				
Sw	1	*	>.30	silv	extensive	/	Po	2	0	1.0												
Sw	1	*	=0	silv	extensive	/	Sw	1	0	0.35	B	1	0	0.1	Sb	1	0	0.1				
Sw	1	*	*	silv	extensive	/	Po	2	0	0.6	Sw	1	0	0.1	Sb	1	0	0.1				
Sw	1	>149	>.30	hrvt	partial	/	Sw	1	120	0.25	Po	2	75	0.2	Sb	1	100	0.1	B	1	30	0.1
Sw	1	>149	*	hrvt	partial	/	Sw	1	120	0.3	Sb	1	100	0.15	Po	2	75	0.05	B	1	30	0.1
Sw	1	>195	=0	invt	none	/	Sw	1	60	0.7	Sb	1	50	0.1								
Sw	1	>195	>.30	invt	none	/	Sw	1	60	0.4	Sb	1	50	0.1	Po	2	20	0.2				
Sw	1	>195	*	invt	none	/	Sw	1	60	0.3	Sb	1	50	0.2	Po	2	20	0.1				
Sw	2	*	*	silv	basic	/	Sb	2	0	0.7	Sw	2	0	0.2	Po	2	0	0.1				
Sw	2	*	>.30	silv	extensive	/	Po	3	0	0.8	B	2	0	0.1								
Sw	2	*	=0	silv	extensive	/	Sw	2	0	0.3	B	2	0	0.1	Sb	2	0	0.05				
Sw	2	*	*	silv	extensive	/	Po	3	0	0.7	Sb	2	0	0.1	Sw	2	0	0.05				
Sw	2	>149	>.30	hrvt	partial	/	Sw	2	120	0.25	Po	3	80	0.15	Sb	2	120	0.1	B	2	30	0.05
Sw	2	>149	*	hrvt	partial	/	Sw	2	120	0.3	Sb	2	120	0.15	Po	3	80	0.05	B	2	30	0.1
Sw	2	>195	=0	invt	none	/	Sw	2	60	0.7	Sb	2	50	0.1								
Sw	2	>195	>.30	invt	none	/	Sw	2	60	0.4	Sb	2	50	0.1	Po	3	20	0.2				
Sw	2	>195	*	invt	none	/	Sw	2	60	0.3	Sb	2	50	0.2	Po	3	20	0.1				
Sw	3	*	*	silv	basic	/	Sb	3	0	0.7	Sw	3	0	0.2	Po	4	0	0.1				
Sw	3	*	*	silv	extensive	/	Sb	3	0	0.7	Sw	3	0	0.05								
Sw	3	>159	*	hrvt	partial	/	Sw	3	130	0.3	Sb	3	130	0.2	Po	4	80	0.05	B			
Sw	3	>195	=0	invt	none	/	Sw	3	80	0.7	Sb	3	80	0.15								
Sw	3	>195	>.30	invt	none	/	Sw	3	80	0.35	Sb	3	80	0.1	Po	3	30	0.15				
Sw	3	>195	*	invt	none	/	Sw	3	80	0.25	Sb	3	80	0.15	Po	3	30	0.1				

Sw	4	*		silv	extensive	/	Sb	4	0	0.65									
Sw	4	>159	*	hrvt	partial	/	Sw	4	130	0.3	Sb	4	130	0.2	B	4	60	0.05
Sw	4	>195	>.30	invt	none	/	Sw	4	80	0.2	Sb	4	80	0.3	Po	4	50	0.1
Sw	4	>195	*	invt	none	/	Sw	4	80	0.2	Sb	4	80	0.4				

16 APPENDIX VIII: TABLE OF SUMMARY RESULTS

Table VIII-1 Predicted results, 200 year totals, of the Seine River Forest comparing three management strategies and 7 response variables. Both RTV with actual regeneration costs and RTV without actual regeneration costs are included. Average annual results are enclosed with { } and results per m3 are enclosed with [ ].

Mgmt Strategy	**Clearcut Management**			**Combined Management**		**No-clearcut Management**	
Harvest Rule	volume	economic	economic	volume	economic	volume	economic
Activity File	SR_80	SR_80E	**SR_80E4**	SR_ALT1	**SR_ALTE1**	SR_ALT2	SR_ALTE2
LTSY -target	375,000	310,000	235,000	230,000	235,000	150,000	115,000
LTSY -actual (m3) {/yr}	75,889,210 {379,000}	62,597,566 {313,000}	47,634,268 {238,000}	46,391,325 {232,000}	47,371,246 {237,000}	30,046,263 {150,000}	23,064,114 {115,000}
Harvest Area (ha) {/yr}	588,069 { 2,940}	455,985 { 2,280}	308,769 { 1,544}	892,760 { 4,464}	722,006 { 3,610}	801,944 { 4,010}	624,589 { 3,122}
Wood Cost ($) [/m^3]	5,286,836,522 [69.67]	2,771,037,985 [44.27]	1,910,502,375 [40.11]	3,381,980,807 [72.90]	2,234,194,743 [47.16]	2,226,775,217 [74.11]	1,108,341,791 [48.05]
Transport Cost ($)	3,271,907,007 [43.11]	1,171,892,733 [18.72]	864,327,964 [18.15]	2,026,640,629 [43.69]	911,534,510 [19.24]	1,270,389,273 [42.28]	379,586,422 [16.46]
RTV-no regen ($)	-944,980,761 [-12.45]	1,055,729,238 [16.87]	1,477,344,107 [31.01]	-280,151,800 [-6.04]	873,804,873 [18.45]	-27,478,563 [-0.92]	607,490,089 [26.34]
Regeneration Cost ($)	270,781,000 [3.57]	216,265,850 [3.45]	151,359,650 [3.18]	72,888,150 [1.57]	108,080,800 [2.28]	3,570,600 [0.12]	948,000 [0.04]
RTV-& regen ($)	-1,215,761,761 [-16.20]	839,463,388 [13.41]	1,325,984,457 [27.84]	-353,039,950 [-7.61]	765,724,073 [16.16]	-31,049,163 [-1.03]	606,542,089 [26.30]