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Relative error transmission and detection in Strategic Forest Management Model

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RELATIVE ERROR TRANSMISSION AND DETECTION IN STRATEGIC FOREST MANAGEMENT MODEL

MASTER DEGREE THESIS

Submitted to committee

By

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ABSTRACT

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The relative error (term error in the thesis always stands for relative error) transmission from Forest Resource Inventory (FRI) data to Strategic Forest Management Model (SFMM) outputs based on different FRI data to SFMM outputs bases on FRI survey factors such as age, stocking, height, and their combination, and species was studied. A basic input file from the Fort William Forest Management Unit was used to produce different experimental data sets which were entered into SFMMTOOL kit to generate SFMM input files. Each experimental data set was produced through modifying the basic data to make a given error rate inherent within. Through running SFMM input files of the experimental data sets, various SFMM outputs inherent error were produced, and were compared using statistical analysis technology and other analysis. It was concluded that FRI data errors such as the errors of species, age, stock, and combined errors of them could be transformed into SFMM outputs at different rates depending on the different survey factors.

The results from the study indicated that species errors caused large and various SFMM output errors, depending on the original forest conditions. Age errors could cause small SFMM output errors except for the case with the age error of more than 15%. Stock errors can be transmitted into SFMM outputs at the same rate as the stock error value. Combination error can be transmitted to SFMM outputs at the same rate as the combination errors, but with a sharp increase of the rate when the combination error surpassed 20%. Age had an additive effect and interacting effect on the SFMM output errors when the combination error was equal to or greater than 20%.

Based on the study, some suggestions to deal with the problems associated with FRI and SFMM application were made.

Keywords: SFMMTOOL, SFMM, error transmission, basic data file, SFMM outputs, total forest area error, harvested volume error, stumpage revenue error, silviculture error, Shannon-Weiner error, wildlife habitat error, and two-factor analysis.

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1.0 Introduction

It is axiomatic that sound management of our renewable but limited forest resources must be based on a "good" or "precise" inventory of the resources, on "accurate" interpretations of inventory results, and on "scientific" decision-making. The accuracy of the inventory has a large effect on the application of the inventory results in various forest sectors. Without up-to-date and accurate data, one can not make wise decisions on simple activities or on more complex forestry activities. As a renewable and dynamic resource database, a forest inventory varies over time, both in the technology used in data collecting and in the accuracy of surveying. Forest resource inventory (FRI) therefore has been a dynamic task that involves not only advanced technologies such as computers, Geographic Information Systems (GIS), Global Positioning Systems (GPS) and so on, but the growth of the forest and its utilization by man. Although it is impossible to obtain very precise data for the resource, professional personnel in the field have been trying to gain the exact nature of the resource by applying every available advance in technology. On the other hand, much work has been done on efforts to avoid inaccuracies of resources data and to try to manage the resource in a more controlled and expected way. In forest resources management, regular inventorying of the resource at intervals of 20 years was mandated as a general task in forest management in Ontario (Dixon 1965). It is the regular surveying that provides dynamic and relatively precise databases for the managers, policy makers and other decision makers in the forest sector and related sectors.

Compared to the first three FRI (1946-1959, 1959-1978, 1978-1997) in Ontario (Dixon 1965; Rosehart 1987), computer technology and GIS have improved recent inventories. Although the updating of the FRI data is now easier, the amount and type of data are more varied and complex. Who knows what kind of data will be required in the field in the future? Although remote sensing, prediction models and improved sampling designs are usually used in recent inventories to improve the quality, there is still some trepidation when dealing with the accuracy of the data. In fact, some of the errors are inherent in the surveying and are impossible to avoid, for example, the misuse of yield tables (those tables were produced from given locations, therefore can be applied only in those regions with a minimum error, but a large error when applied in other regions). Another source of error is imprecise interpretation of the available data such as aerial photos, misinterpretation by operators, and others. Before a better database can be produced, foresters and interested people and groups need to use current FRI in forest management and related activities. The problems foresters are having are how to use the existing FRI, with its defects, wisely and scientifically.

The FRI was designed to provide basic data at the forest management planning level without any supplementary information. When it is used for forest management at the operating level, the FRI cannot provide data of sufficient quality or accuracy. For example, the FRI provides statistically suitable data with few problems for intolerant and slow-growth trees, but with more problems for fast-growth trees, that is especially so when trying to use the data on an individual stand (Mogford 1986). To provide more timely estimates and adaptability to emerging issues, the FRI must be improved and updated frequently. A few studies have attempted to identify the errors existing in the FRI and to make the use of the data more accurate and correct.

Rosehart and his group (1987) made an assessment of Ontario's FRI system. They found the following differences existed between FRI and operational cruise (OPC) based on the OPC estimated.

21% for basal area per hectare,

3% for species composition,

71% for Gross Total Volume, and

7% for height.

Raymond (1976) conducted similar research and pointed out the area-weighted difference between operational cruising data and FRI data was about ±30%, a result similar to Rosehart's (1987). Although there is no further published data dealing with the problem, these differences must still exist.

Another use of the FRI data is to provide a base for decision and policy making. More and more decision-making support tools are created and used in forestry for forest management planning. Most of them require accurate and updated data. Some examples of current computer models used at the forest management planning level are FORMAN (Wang *et. al.* 1987), FORPLAN, SPECTRUM, RELM, WOODSTOCK (Hopper 1999), and SFMM. They are precise models and can produce more accurate output than ever before in forest planning if the source data is reliable.

Designers of these software analytical tools declare that their products are aimed at helping people make decisions. Unfortunately, more and more managers and policy makers are becoming dependent on these tools. Features that makes them attractive include their visual appearance, seemingly accurate figures, mega memory ability, and fast calculating speeds. SFMM (Davis 1995, 1999) was created in 1995, and is one of those models that are becoming popular in Ontario. Since 1995, most of forest management plans have applied this model either as a supplementary tool or as a major planning tool, i.e. in Forest Management Plan for the Lakehead Forest, 1997; Forest Management Plan for Bowater Forest, 1999; Forest Management Plan for Thunder Bay District, 1996. Updated several times, the model has gotten a more user-friendly interface, and more convenient with multiple functions ranging from wood supply analysis, and dynamic emulation of forest succession to financial analysis reporting.

Even very precise models cannot produce exact outcomes without reliable and precise data as the base for running the models. Unfortunately, it is impossible to be free of inherent errors in data because the surveyed forest is so vast and complicated that no one can confidently declare that their data are 100 % accurate. Error must be limited to an allowable level so that the data can be applied effectively and timely in forest activities. As a rule of thumb in forest resource management and inventory, a 5% of difference from the "real value" is allowable for forest management planning and other forest uses that focus on macro management of the forest. When we apply the inherent errors of the data into SFMM to make a forest management plan, how do the errors behave? Are they retained or lost? Amplified or minimized? Is it possible for us to find general principles governing the error transmission in SFMM? What are the effects of the errors on the final outputs of forest management planning, or other functions related to the application of SFMM?

In order to answer these questions, I designed my research project, *Error transmission and detection in SFMM.* In my research, I proposed to answer these questions based on a theoretical data set and to provide some useful suggestions on the use of the SFMM, at the same time, aimed at finding error factors in forest management planning tool. The results from the research should be of value to both the users and the developers of SFMM.

2.0 Review of Previous Research

2.1 Forest management and forest management models

2.1.1 Forest Management

Forest management has become a dynamic evolving profession and has a complexity that is difficult to grasp and understand not only for the public, but also among many professional practitioners (Gillis 1990). Forest management includes the use of forests to meet the objectives of landowners and society (Davis and Johnson 1987). Therefore, forest management is actually the process of taking skillful actions to produce desired outcomes. On the other hand, the desired outcomes may change significantly over time. For example, the management of forests has moved from timber production before the 1970's to multiple-purpose resource management during the 1970's, to integrated resource management in 1980's, to ecological or sustainable forest management in the 1990's (Hopper 1999). The movement was from an economic emphasized to a non monetary value emphasized planning. In these situations, the strategies applied in forest management are updated or upgraded year by year, sometimes even month by month.

Before ecosystem management became prevalent, the determination of an annual allowable cut (AAC), which was based on the area distribution of actual forests, was the primary standard to manage forests and the main concern to forest resource managers. Thereafter, the differences of site quality brought volume control technology into forest management tasks. When people think more about environmental benefits rather than economical profit from forest, forest management becomes more sophisticated and harder to execute. For this reason, people tend to create models to describe, outline, and determine the activities in forest management.

Paralleling the developments in forest management, advancements in computing enhanced the development of modeling technology. Corresponding to different management strategies at different times, various models were produced, from the Simple Area Method (SAM), to Long Term Sustained Yield (LTSY) until today's SFMM. Similar to SAM, LTSY was a spreadsheet or program (Benson 1986) that provides age class and volume distributions over a long term (Clutter *et al.* 1983). The weighted average age of the existing forest was used to "accelerate" or "decelerate" the time to reach a normal forest (Kloss and Oatway 1992). All of these models only focused on the adjustment to the annual allowable cut and can be classified as early models. Management Area Distribution Calculation (MADCALC) was another model, used by the Ontario Ministry of Natural Resources (OMNR) and the forest industry to develop a weighted area AAC on the provincial management units until approximately 1997/1998 when replaced by SFMM (Hopper 1999).

With the development and application of decision making platforms such as Linear Programming (LP) (Kent 1989), models based on multiple purpose optimization have been created. Some of the models are the Timber Resources Allocation Method or Timber RAM created by Navon (1971) and MAX MILLION II created by Clutter *et. al.*(1978) Like SFMM, these models use LP as the computing platform. Besides the computing platforms mentioned, the Economic Harvest Optimization Model (ECHO) created by Walker (1971), Timber Resource Economic Estimation System (TREES) (created by Johnson *et. al.* 1983) nested another important platform---Binary Search (Hopper 1999).

support forest planning and ecosystem management. They identified 250 software tools which can be applied in the forest industry and related fields. According to Rauscher (1999), all of the decision-making supportive tools were applied at three different levels in forestry: regional assessments, forest planning, or project planning.

During the past decades in Canada, forest management models developed rapidly. There are about 11 kinds of even-aged boreal forest management planning models, ranging from FORMAN versions to SFMM. Street and Arlidge (1996) made an overview of the various models using the following aspects:

. What benefits can you achieve from the models?

. What problem have you encountered with the use of these models?

. What are your likes and dislikes on these models?

. What are your expectations from the models?

They also did some tests on the ability of the models and their functions. How well do the models explain and handle the following current forestry issues?

. Modeling silviculture

. Modeling post-harvest development

. Estimating timber growth and stock volumes

. Projecting yield prediction;

. Doing financial analysis based on the overall cost of harvesting a given stand, including access costs, harvesting costs, hauling costs and silvicultural costs;

. Modeling wildlife habitats

. Modeling wood supply analysis

. Planning product breakdown

Their comparative research for the different models included the input and output requirements (Refer to Table 1, 2, 3, 4). Finally, they concluded that "all of the models examined have assisted in their time, to increase the resource manager's understanding of forest dynamics. Each model added and contributed to better forest management". Compared with the other models, they preferred SFMM because of its complete flexibility in defining species, products, working group, forest units and management units, and its flexibility in defining management objectives, targets, and constraints. Furthermore, its objective optimizing approach used in the model's methology is significantly different from other simulation approaches taken by the other models, which makes it stand head and shoulders above the others (Street and Arlidge 1996).

Table 1. Summary of Model Input Requirements and Operability

TYPE OF INPUT	FORMAN 2.3	GLFC-FORMAN	NORMAN	CROPLAN	FORMAN+	HSG	SFMM
Max no. of management unit	12	12	12	12	120**	one	INF
Forest units	Yes	Yes	Yes	Yes	Yes	wg	Yes
Max. No. of iterations (5 year periods)	40	40	40	40	20	INF	INF
Scale Factor -Y Axis	Yes	Yes	Yes	Yes	Yes	no	Built in
Harvest Rules	6	6	6	6	6	3	Targets & Policies
Silvicultural Rules	No	No	No	No	6	no	–
Silv. Treatment levels	2	2	3	3	3	3	INF
Yield curves -Primary	Yes	Yes	Yes	Yes	Yes	By species	By species
-Secondary	Yes	Yes	Yes	Yes	Yes		
-Product	Yes	Yes	Yes	Yes	Yes		or user Defined
-User defined	Yes	Yes	Yes	Yes	Yes		
Max. No. OF Yield curve sets	200	200	200	200	400	NA	INF
Operability limit	Volume	volume	Volume	Volume	Age	age	Age
Economic Data - Harvest cost	Yes	Yes	Yes	Yes	Yes	yes	Yes
-Silvicultural cost	Yes	Yes	Yes	Yes	Yes	yes	Yes
-Product Value	No	No	No	Yes	Yes	no	Yes
-Other	No	No	No	Yes	Yes	no	Yes

SOURCE: Street and Arlidge, 1996. (NODA file report 36 1996)

Table 2. Summary of Input Requirements/Capabilities from the Front End Loaders and the Models That Prepare Their Own Curves

TYPE OF INPUT	PCNFCS	GLFC-F+1	HSG	SFMM*
Yes	Yes	Yes	Yes**	No***
Pure Species Curve Information	Yes	Yes	Yes	Yes
Site Class Cross Reference	Yes	Yes	Yes	Yes
Silvicultural Information	Yes	Yes	Yes	Yes
Stand Succession Information	No	No	Yes	Yes
Wildlife Information	Yes	Yes	Yes	Yes
Aggregation By WG	Yes	Yes	Yes	Yes
Aggregation By Forest Units	Yes	No****	No*****	No
Economic Information	Yes	No	Yes	Yes

- * SFMM has two options for entering information -Option 2, uses this information to prepare the required curves.
- ** Also requires an field to link to spatial information (Key-Basemap & Stand Number)
- *** Requires a summary of area and weighted ave. species composition and stocking levels for each working group or forest unit.
- *** * "Hard wired" to separate upland and lowland spruce.
- ***** Aggregation by forest unit can be done by writing a program it interpret the output information only.

Note: The SFMM toolbox(under development) will accept input items listed in the table and allow users to interactively prepare area and yield information for input into SFMM.
SOURCE: Street and Arlidge, 1996.

Table 3. Summary of Output for the Front end Loaders and the Models that Prepare Their Own Curves

Type of output	PCNCS	GLFC-F+1	HSG	SFMM
For which models	FORMAN2.1 CROPLAN NORMAN FORMAN FORMAN+1	FORMAN+1	HSG	SFMM
Present Curves	Yes	Yes	Yes	Yes
Future Curves	Yes	No	Yes	Yes
Cost Curves	Yes	No	Yes	Yes
Other Tables/Report				
-Area Summary	Yes	No	Yes	Yes
-Age Class	Yes	No	Yes	Yes
-Stand Volumes	Yes	No	Yes	No
-Wildlife Habitat	Yes	No	Yes	Yes
-Species Composition	Yes	No	Yes	No
-Forest Diversity Indices	No	No	No	Yes

SOURCE: Street and Arlidge, 1996. (NODA file report 36, 1996)

Table 4. Summary of Model Outputs

TYPE OF OUTPUT	FORMAN 2.3	GLFC-FORMAN	NORMAN	CROPLAN	FORMA N+1	HSG	SFMM
Tables	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Graphs	No	No	No	Yes_SCREEN	No	Yes-SCREEN	Yes-SCREEN
Maps	No	No	No	No	No	Yes	No
Input Data	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Reports on the Forest	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Statistics -Volume Harvested	Yes	Yes	Yes	Yes	Yes	Yes	Yes
-Area Harvested	Yes	Yes	Yes	Yes	Yes	Yes	Yes
-Area treated	Yes*	Yes*	Yes	Yes	Yes	Yes	Yes
-Costs	Yes	Yes	Yes	Yes	Yes	Yes	Yes
-Mortality	Yes	Yes	Yes	Yes	Yes	No**	No***

- * Only two levels of silvicultural intensities.
- ** Stands succeed onto new curves.
- *** Stands succeed onto new curves or are held at the oldest age class.

SOURCE: Street and Arlidge, 1996. (NODA file report 36 1996)

Forest management is a very complicated and changing process that includes evolutions of concepts, policy, and tools. With the creation of ecosystem management and sustainable forest management, forest managers are facing new challenges from various sides of society. Instead of using single purpose timber production, the forest management goals vary. Societal goals, preferences, and values are numerous. Quite often they are ambiguous, and in conflict with one another. Legal mandates are complex, unclear and at times self-contradictory. At the same time, the policy directions for forestry may be missing, ambiguous, and sometimes in competition with a tendency to rapidly shift in response to political pressure. There are forces of change sweeping through the forest scene in Canada. Green Registration of Forest management Systems and Certification of Forest Products, the Canadian Model Forest Program, and the National Forestry Strategy are all clear responses to a recognized need for change in forest management (Carrow 1994). Landscape-based Management (Booth *et al.* 1993), Integrated Forest Management (Carrow 1994, Thompson and Welsh 1993), Ecosystem Management (Kimmins 1995) and fundamentally new forest management paradigms (Rowe 1994; Kimmins 1995). All are promising a change in forest management strategies. These changes not only promise a strategic conversion in forest management but an innovation in traditional forest management procedures.

The traditional trial and error methods of forest management need to be improved. Furthermore, public participation in decision-making requires that decision-making support tools are more reliable, precise, flexible and practical. For these reasons, programs developed for forest management are becoming more numerous and more functional. Some, based on the present status of forests, simulate the future development of forests while others arrange a desirable management planning strategy for forests. The theories used in model creation include optimization based on linear programming (SFMM) and simulation based on ecological development model (FORPLAN). This makes SFMM unique and ahead of the other available models (Street and Arlidge 1996). SFMM was developed in Ontario and focuses on the Ontario's forest management procedure, which makes it more popular, and it also required in Ontario (Davis 1999).

2.1.2 Introduction of SFMM

SFMM, the Strategic Forest Management Model, developed by Davis (1995) of Ontario Ministry of Nature Resources in 1994-1995, was derived from a decision support system called Silviplan (Davis 1999) devised at the University of Toronto. SFMM is based on linear programming and is written using AIMMS (Advanced Interactive Mathematical Modeling Software).

SFMM is an optimization model and its approach is significantly different from the simulation approach taken by other models. Also it was designed to help foresters and wildlife biologists to plan and manage forests, analyze wood supply, and gain an understanding of habitat components. It is also helpful for planners and policy makers understand the impacts of policies and land use decision on forest resources. Because of its sequential menu structure, it can help students master forest management planning procedures easily, directly and visually.

It has seven main menu items: data input, land base definition, forest dynamics, silviculture options, and management objectives, execution and results, connected by arrows which shows the processing steps for running the model. When running the model with a data input file or case file, one can either minimize the silvicultural costs, maximize volume production, minimize area harvested and regenerated, or maximize value of timber harvested in one run. It also allows you to simulate forest dynamics with no silviculture or optimize with one of the above 4 choices.

The model has great flexibility and allows the user a wide range of options for growing and renewing the forest. Some unique features in this model include:

- the ability to model over any time horizon (normally 160 years);
- complete flexibility in defining species, products, forest units and management units;
- the ability to control the area lost to fire and a variety of timber reserves through time;
- the ability to allow shifts in the land base between productive and non productive forest lands;

- the ability to describe natural forest succession and succession for silvicultual treatments;
- the ability to direct silvicultural treatments by intensities to a number of future forest units;
- flexibility in creating desired output reports (STANLEY, FARM, FMP).

SFMM is best suited for strategic level planning rather than tactical or operational issues (Davis 1999). Like any other models, SFMM provides an approximation of reality. It is not spatial in design although it does allow you to simulate some pseudo-spatial issues. It is not a standalone program, as it is best used with SFMMTOOL for the processing of input data, and FARM, STANLEY and GIS for output application.

Although it is unreasonable to expect one model to include every aspect of forest ecosystem management, it is preferable to improve the model to deal with different kinds of ecosystem management instead of only wildlife management. In order to use a model effectively, accurate data is required. FRI data is the main input used when running SFMM, although FRI has inherent errors. These errors may lead to errors in the output of SFMM. As Street and Arlidge. (1996) warned, to properly use the model, a great deal of care is required in the setup of inventory data. Accurate up-to-date inventory information is necessary. Using the model is not difficult, but it is very "precise work" and mistakes can be easily made and go unnoticed in running the model. Besides these kinds of evident mistakes, the inherent errors of FRI data may have a large influence on the accuracy of the model output although the model was designed to calculate to more than ten significant digits. For these reasons, the valuable resource of computer calculation may be inefficient because of the inherent error in input data.

2.2 FRI and its error analysis

2.2.1 FRI , Forest Resource Inventory

The first province-wide survey of forest resources in Ontario was started in 1946 under the direction of the division of Timber Management of the Ontario Department of Lands and Forests (Division of Timber Management 1953). It was intended to find out the forest cover area, ownership, volume, composition, and age classes for the judicious use of the land (Ontario's Department of Lands and Forests 1953). Aerial photographs with a scale of 1:15840 were used in the survey. A forester or forest technician who was familiar with ground conditions in the area under study carried out the photo interpretation. Aided by field samples, field experience, stereograms, and stocking density curves, they delineated and outlined stands on aerial photographs into different categories such as water, and non-forested land. More subdivision were determined in the major categories such as forested land.

Generally, FRI data are commonly presented in two different forms, map or data. Forest stand maps delineate individual stands and give information needed for management planning purposes. The attributes interpreted and described on FRI maps are species composition, stocking, stand height, site class, age and area. Information is also available in the forms of six standard FRI report format ledgers for each management unit (Rosehart 1987). Usually, it takes the FRI staff three years from the time that a decision is made to conduct or inventory until the data is provided. In the first year, aerial photographs are taken in the spring and summer at a scale of 1:20000 to 1:10000. In the second year, OMNR photo interpreters measure sample plots or supervise ground crews in the task so that they can gain the necessary field experience that is needed in their photo-interpretation. In fact, these plots also help photo-interpreters to calibrate their photo-interpretation. In the third year, stand area, site class, species composition, age and so on are determined by photo-interpreters based on the gained information.

Rosehart (1987) summarized the most significant changes that the FRI has undergone since 1963 inventory as followings.

- 12 broad working groups for the purposes of volume calculations instead of the original three (softwood type, tolerant hardwood type, intolerant hardwood type);
- size and diameter classes are no longer recorded in the present inventory, but are collected during supplementary surveys such as operational cruising;
- five-year age classes replace mature, immature and reproducing classes;
- "normal" yield table were introduced and are now used to estimate volumes;
- lastly, foresters at the field level now have computer software, called Forest Resources Inventory Data Entry System (FRIDES), which they use to update FRI data faster and easier than before ;

There are also some changes that the FRI underwent since 1986, but these changes are not as significant as the previous ones.

- The inventory is compiled in a digital format that is used as the source of information for lakes and streams.

- GIS was introduced into the FRI, which increased the precision of area measuring and stand delineation;

- Large scale photography (LSP)[1] has been used in forest resource inventory.

- Digital Mapping technology has been used in forest management.

2.2.2 Errors in FRI

Although Moggord (1986) pointed out that the accuracy of the FRI can be increased by more intensive sampling without consideration of operational costs, the FRI has inherent errors even if the sampling intensity is increased to 100%. In the past decades, some researchers such as Raymond (1976), Armson (1976), Rosehart (1987), MNR (1965), Osborn (1986) have mentioned problems related to the inventory as the following.

- Misunderstanding and misuse of FRI data;
- Lack of field staff participation in FRI inventory;
- Nature of operational inventories;
- Inadequate integration of silvicultural and management data;
- Techniques and procedures for inventory;
- Overall systematical shortcoming in FRI data transaction;
- Problems of personnel policy and consequent lag in technical innovation.

As the FRI survey consists of small sample from a large population, the output of the FRI could inevitably produce errors that are related to the above problems. Actually, we can classify errors into two different categories. One category is the systematic error resulting from the following:

- Misusing or improper use of survey methods;

[1] LSP sampling is a procedure in which large scale photographs are taken at scales of 1:2000 and above, plots are located on these photos and are subsequently photo-cruised (surveyed). This technology is

- Accuracy of instruments used in surveying;
- The use of outdated materials such as photos, yield tables;
- The use of inaccurate data from various sources such as forest companies and forest related sections;
- The sample may not represent average stand conditions because of mass area of forest population;
- The variation of yield tables used in forest survey to the actual forest.

The other errors come from some random reasons such as:

- Mis-reading;
- Mis-operating;
- Mis-calculation;
- Mis-delineating of the land types boundary;
- Mis-photo interpretation; and
- Other random and totally unpredictable errors related with the surveyors.

For example, Raymond (1976) found that failure to rigidly observe strip boundaries while sampling could easily introduce a variation of +10 % to –10 % in ground cruising. Some cruisers have a tendency to introduce a downward bias by not including as many borderline trees in a sample plot as they should. Although the situation is somewhat different in photo interpretation survey, the possibilities of producing variation in a survey are the same or greater than for ground cruising because of the small-scale photo interpretation.

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reported to significantly reduce the number of on the ground surveys needed (Dendron, 1986).

Raymond (1976) made a comparison between FRI and operational cruising (OPC)[1] and concluded that the FRI volume was ±30 % greater than that measured by the OPC. Rosehart (1987) made similar comparison based on different townships, different stands and other forest factors such as species composition, height, age, basal area, site index, and Gross total volume (GTV). He also referred to some past research results, and concluded that for townships and larger areas, the FRI in an relative sense varied by about ±20 % when compared to the OPC (Operational Cruising) survey results. Such accuracy is acceptable for broad macro-planning purposes. The accuracy of FRI will also depend on the variables measured, the area to which it refers, and the standard against which it is compared. Table 5 shows their research results based for the township examined by Rosehart (1987).

From the above analyses, we conclude that:

- Variation exists between the OCP and FRI. Although some researchers suggested that a 5 % variation is acceptable, the actual variation can be beyond 5%, from-29% to +200% (for individual tree);

- Raymond (1976) found the variation between OPC and FRI for Gross Total Volume was ±30 %;

- Rosehart (1987) found that the variation of Gross Total Volume was from 78 to -27 m^3/ha or 71%-21% between OPC and FRI (Refer to Table6);

- According to my calculation, the relative volume difference between FRI and OPC is -45 % by area weighted average based on the data

[1] O/C in Raymond paper is same as the OPC in Rosehart paper.

provided in Rosehart's report. By using the same calculation, there is a 7 % relative height variation, 40 % for species composition, 15 % for ages, 22 % for site index, 21 % for stocking (Refer Table 7).

Table 5. FRI –OPC comparison

District	AREA	FRI / OPC / DFA / AFR	SPECIES COMPOSITION															GTV (m^3/ha)
			Pj	Pw	Po	Pr	B	Bw	Sw	Sb	Ba	Bf	Mh	Fb	Or	Mr	Sp	
Halifax TW	1748	FRI	12	20	17	15		22	9	1		2	1		1			168.8
		OPC	11	18	11	14		20	14	1		1	1		9			141.3
		DFA	1	2	6	1		2	-5	0		1	0		-8			-127.3
		DFR	9	11	43	7		10	36	0		67	0		160			-82
Levack TW	3779	FRI	31		27		4	25	2	3	9	2			1	4		117.4
		OPC	40		21		0	18	4	3	7				4	8		144.7
		DFA	-9		6		4	7	-2	0	2				-3	-4		-27.3
		DFR	25		25		200	33	67	0	25				120	67		
																		-19
Fintry TW	981	FRI			7										7		77	141
		OPC			2										13		76	63
		DFA			5										-6		1	78
		DFR			111										60		1	76
Other	411	FRI	39		2			4		54				1				170
		OPC	38		4			3		53				2				181
		DFA	1		-2			1		1				-1				-11
		DFR	3		-75			30		2				67				-6
Average		FRI	25	20	20	15	4	23	4	6	9	2	1	1	2	4	77	134.8
		OPC	31	18	15	14	0	18	7	6	7	1	1	2	7	8	76	131.5
		DFA	2	2	5	1	4	4	3	0	2	1	0	-1	5	-4	1	22
		DFR	19	11	-29	7	200	24	55	0	25	67	0	67	120	67	1	45

DFA means absolute difference between FRI and OPC. DFR means relative difference between FRI and OPC.

Although it is very difficult to conclude exactly how much error exists in the FRI, it is possible to derive error ranges for the different forest factors based on the data of Rosehart's report. Others have indicated that errors exist in the FRI. In a recently completed forest management plan[1], the authors emphasized that there were some errors in FRI, which need to be corrected (p81, p37, p221). Higgins (1988), in his undergraduate thesis, argued that the FRI estimates of height and age were close to the field estimates. For volume and basal area, there were 29-8 % and 30-16 % differences respectively between FRI and the field estimation. Other errors produced by personal bias in a survey because of tendency to over- or under- estimate were also reported by other researchers (Osborn 1986).

Table 6. A comparison of FRI with OPC from five studies

Studies	Variables measured	Estimated value based on OPC	Average area to which the difference refers (hectares)	Average absolute difference (percent)
I	Basal area	143.6	2214	21
II	Gross Total Volume	64.5	2819	19
III	Net merch. Volume	181.4	981	123
IV	Gross Total volume	146.1 m^2 /ha	411	6
V	Gross total volume		12	71

SOURCE: Bob Rosehart, 1987. An assessment of Ontario's forest resources inventory system and recommendations for its improvement.

Summarizing the past and current research, we know that there are two different kinds of errors in the FRI, systematic errors and random error. The magnitude and variation of the errors vary in the different studies, and from township to township. The general error ranges for different measured items is summarized in Table 7.

Table 7. Error Percentage (%) Summary in FRI

AGE	COMPOSITION						HEIGHT	BASAL AREA	GTV	SITE INDEX
	Pj	Pw	Po	Sb	Sw	Mean				
±18	±19	±11	±31	0	±59	±24	±19	±21	71	22

Derived from Rosehart's (1987) research.

In my study, I proposed to assign the largest error as the error limit in the designing of my error test strategy. Other than GTV, most of the survey items have a ±10% to ±25% error variation. Summarizing past research, we can infer that the error in

[1] Forest Management Plan for the Lakehead Forest, Thunder Bay District, Northwest Region for the

GTV is about ±30%. The relative variance in Rosehart's research is a bit higher and thought as an exception (71%). How do the errors in FRI behave in SFMM? Are there any great effects on the output of SFMM? My research proposes to answer these questions.

twenty-year period from April 1, 1997 to March 31, 2017.

3.0 Methods and Materials

3.1 Strategies for methods design and material selection

The main purpose of the thesis is to search the following unknown facts:

. Under a given error percentage of FRI surveying, what are the corresponding SFMM errors produced in different output items such as areas, volumes, biodiversity index, finance and wildlife?

. What relationships are there between FRI errors and SFMM output errors?

. In the SFMM output errors, how much error is introduced by SFMM and how much from FRI?

. Are there any calibrating methods that can be used to correct the errors produced by SFMM? If so, what are these methods?

. Some recommendations on SFMM application should be offered based on the research results.

Therefore, it is very important to design proper methods or methodologies to perform the above tasks. The best methods have the following characteristics and functions:

. They can produce SFMM outputs that have extensive representatives for both management objective setting and practical silvicultural applications.

. The methods should test the general strength and weakness of SFMM.

. The errors produced in SFMM and FRI can be separated from each other in outputs and analyzed.

. Finally, the methods should show error transmission from FRI to SFMM.

3.1.1 Culling of the error items

FRI data is usually produced by photo interpretation and ground reconnaissance with the inherent systematical errors and random errors. Major sources of error occur in species recognition and measurements of height, age, and stocking. For this reason, I did error testing of the following estimates of FRI.

- Age
- Height
- Stock
- Species compositions

By combining these factors, the general rules governing errors in SFMM can be derived. A practical 5% of interval of error class was used in the research with ±20 % used as the upper and lower limits of error class.

3.1.2 Major principles and hypotheses in my research design

It is difficult to detect errors in SFMM because of its complexity and the interaction between different variables. Moreover, the variables involved in planning are so numerous that it is impossible to determine which variables have inherent errors and what errors come from which variables. As mentioned, accurate data are very important and necessary for SFMM to produce exact results. In fact, SFMM has a function to detect and block out evident errors from the input of FRI data. Unfortunately, it does not have the ability to find the inherent error in the FRI data. For this reason, I adopted a three-step method to detect error behavior in SFMM.

Step one, identify the survey factors or estimates in which errors were inherent, find out their error range in FRI data through literature review, and therefore determine the error class standards and parameters of the testing.

Step two, design scenarios based on the error classes and error items identified in step one.

Step three, run SFMM and get outputs for each research scenarios designed (Refer to Table 8).

Table 8. Scenarios for error detect in SFMM

Error Items	Scenarios	Error class value	Abbreviation
Height group	S1	+20	E_h_1
	S2	+15	E_h_2
	S3	+10	E_h_3
	S4	+5	E_h_4
	S0h	0	E_h_0
	S5	-5	E_h_5
	S6	-10	E_h_6
	S7	-15	E_h_7
	S8	-20	E_h_8
Age group	S9	+20	E_a_1
	S10	+15	E_a_2
	S11	+10	E_a_3
	S12	+5	E_a_4
	S0a	0	E_a_0
	S13	-5	E_a_5
	S14	-10	E_a_6
	S15	-15	E_a_7
	S16	-20	E_a_8
Stocking	S17	+20	E_b_1
	S18	+15	E_b_2
	S19	+10	E_b_3
	S20	+5	E_b_4
	S0b	0	E_b_0
	S21	-5	E_b_5
	S22	-10	E_b_6
	S23	-15	E_b_7
	S24	-20	E_b_8
Comb. Group	S25	+20	E_c_1
	S26	+15	E_c_2
	S27	+10	E_c_3
	S28	+5	E_c_4
	SCG0	0	E_c_0
	S29	-5	E_c_5
	S30	-10	E_c_6
	S31	-15	E_c_7
	S32	-20	E_c_8
Species Composition	S33	+30	E_s_1
	S34	+20	E_s_2
	S35	+10	E_s_3
	SSC0	0	E_s_0
	S36	-10	E_s_5
	S37	-20	E_s_6
	S38	-30	E_s_7

3.2 Materials

3.2.1 Basic FRI data file

One inventory file of the1998 survey database file for FortWilliam Forest was downloaded from Prof. Bensons's web-page (http://www.lakeheadu.ca/~cabenson/courses.html) for use as the basic FRI data file.

The selected data file, Base Map #157205330, contains many different forest types and land use types from the FortWilliam Forest. The chosen data file originally contained 288 records. Unfortunately, some data records were invalid because of a data item missing and were deleted. Only 200 records were left in the basic file (see Appendix I).

3.2.2 Height, age, stock test input data files

Based on the predetermined error ranges for different survey factors such as height, age, and stocking, data files with 8 different error classes were produced for each survey factor. The following strategies, illustrated by height, were used to derive these data files from the basic data file.

Assume that there was a record in basic data file read in the following format,

...	Stand Stype	Area	Ownership	Year of Original	Year Until now	Height	...
24	25	43	1	944	989	15	...

Assume also that the error classes for Height were: -20%, -15%, -10%, -5%, 0,5%, 10%, 15%, 20%. The values of other fields were kept constant for each change in the Height field to produce a record of new file. The following formula illustrates the changes made.

HT(i) = ht (basic) + ht (basic) * (i)

Where, (i) = one of the error classes of height;

HT(i) = (i) error class height;

ht (basic) = height in basic data file

For example:

HT(-20%) = ht (basic) + ht (basic) * (-20%)

HT(-10%) = ht (basic) + ht (basic) * (-10%)

HT(15%) = ht (basic) + ht (basic) * 15%

HT(20%) = ht (basic) + ht (basic) * 20% etc.

If ht (basic) = 20, substitute into the above equations, we get the following results:

HT(-20%) = ht (basic) + ht (basic) * (-20%) = 20 + 20 * (-0.2) = 16

HT(-10%) = ht (basic) + ht (basic) * (-10%) = 20 + 20 * (-0.1) = 18

HT(15%) = ht (basic) + ht (basic) *20% = 20 + 20 * 0.15 = 23

19HT(20%) = ht (basic) + ht (basic) * 20% = 20 + 20 * 0.2 = 24 etc.

These results were the values used in the four data files with the corresponding error classes when the other field values remain unchanged. By changing each of the basic data files, we can produce different scenarios data files.

By applying these principles, a total of 24 data files plus one basic data file with the format of dbase IV were produced (see Table 8).

3.2.3 Combination test data files

In addition to the above files created for changes in a single variable, eight combination files were created. These files combined the errors of height, stocking, and age. The combination file with the 15% error class illustrates the method used to produce this kind of file. The objective values of each record in the data file were derived by increasing the 4 field values in the basic data file by 15% respectively.

Example:

Mu.....	wce.....	udfl....	yro	yru	ht	stk
889	0	0	944	989	15	0.6

Increase by 15 % respectively

↓

889	0	0	1086	1137	17.3	0.69

3.2.4 Species composition data files

Species composition of the major species of a stand was changed at the expense of the least prevalent species. Changes were made for ±10, 20, and 30%

	SPP	ERROR CLASSES
↑	SW 8MS 1H 1	+30%
	SW 7MS 2H 1	+20%
	SW 6MS 3H 1	+10%
Basic data file	SW 5MS 4H 1	0
	SW 4MS 5H 1	-10%
	SW 3MS 6H 1	-20%
↓	SW 2MS 7H 1	-30%

In some cases where stands had a low species composition, these species were removed from the working groups

For example

	SPP	ERROR CLASSES
↑	SW 0[1]	+30%
	SW 0[2]	+20%
	SW 9SB 1	+10%
Basic data file	SW 8HE 1 SB 1	0
	SW 7HE 2SB 1	-10%
	SW 6HE 3H 1	-20%
↓	SW 5HE 4H 1	-30%

3.3 Methods

3.3.1 Generate SFMM input file

Input dbase files into SFMMTOOL

The process included two different stages. First, 39 files were created in dbase format from basic data file (see Appendix I) by applying the procedures described in the Materials section. Second, the above dbase format files were imported into SFMMTOOL to create SFMM input files. By running SFMMTOOL, 39 input files were produced subject to the following assumptions:

- FMA Exclusions checklist was placed on "no" position to assign those stands to regular stand types so to test the general strength of the model

1,2 when the proportion of dominant species surpasses 9, the value will become unchangeable, for SFMM TOOL can accept a 0 as the proportion of species composition. Therefore, the proportion of footnoted record remains same for 20% and 30% error classes.

- The character year format was used for all scenarios except for age cases in which a four character year format was used
- Adjust stand age. For this choice, "the adjust to 2000" choice was used so that more factors can be introduced into data processing to test the ability of SFMM to solve more problems
- Boreal Listing of Species was chosen so as to simplify the research work, which has fewer species
- User Defined Custom Choice was defined as default

During the processing, some records were identified having errors because of high stocking. As SFMMTOOL ignores these errors, there was no need to correct this kind of error. The numbers of records identified with errors varied with error class files for the stocking scenarios. For example, there were more records identified with errors in the case of 20% stocking error than for the 10% stocking error.

Another 72 of the 200 records were identified as non-forest land and separated from the data files automatically.

Classifying forest stands and assigning forest units

Only one sub-unit was defined in each scenario, as the basic data were uniform, belonging to one type of ownership.

At the beginning, the classification standards of forest unit recommended by SFMMTOOL were applied in forest classification. Unfortunately, there were too many forest units identified that increased the time for SFMM defining and running. In addition, fewer stands in each forest unit would reduce the representative of the testing and make the analysis and comparison of results lack of suitable sampling size. In this situation, improved standards were used which were shown in Table 8-1. In reality, newer silvicultural techniques and methods of partial harvest have encouraged more complex forest unit definitions (Watkins *et al.* 1999).

Table 8-1. Forest unit labels and descriptions

Forest unit		Classifying standards
SbSha	7	Sb >= 0.7 And Po+Bw <= 0.2
PjSha	9	Pj >= 0.7 And Po+Bw <= 0.2
PoSha	11	Po >= 0.7
BwDom	12	Bw >= 0.6 or Bw+Po >= 0.7
BfDom	16	Bf >= 0.4 And Bf+Sw+Sb+Pj >= 0.5
ConMx	17	Pw+Pr+Sb+Sw+Bf+Pj+Ce + La>= 0.5
HrdMw	19	Po+Bw+Mh+UH+LH >= 0.5

Apply wildlife matrix

The Northwest Regional Wildlife Matrix (Boreal East) was used in each case so that the wildlife management changes from FRI errors could be detected.

Assign Additional Reserve Types

In this research, the assign all stands in specified forest units to specified reserve type option was used. Balsam Fir forest unit was assigned to Bypass Reserve type (the assignment is only for testing without management implication).

View stand data and generate stand level volume

Summarizing stand level data

By clicking Generate Summary Tables, a sub-set of summary tables that allow SFMMTOOL to create yield and input assumptions were generated.

Defining SFMM Parameters

.To create the following yield curves

. Choose Clearcut option as silviculture system of all cases

. No regeneration advance/delay was chosen by selecting No Change

. The following rules were applied in stocking definition section

Exten = Prsnt - 0.1

Basic1 = Prsnt + Prsnt*0.1

Basic2 = Basic1 + prsnt*0.1

Inten1 = Basic2 + Prsnt*0.1

Inten2 = Inten1 + Prsnt*0.1

. Plonski's Modified Growth & Yield Tables was used to generated growth and yield curves. No further modification to the table was made so as to keep the uniform of cases definition.

Generate partial SFMM input file and update input files

- 10 Year Age Class Interval was applied
- Both SFMM input file and SFMM landbase update files were generated for each case at the very beginning.

A comparison between the SFMM input file and update file produced by SFMMTOOL was carried out in SFMM to find out the possibilities for replacing the input file by using an update file in order to reduce the workload repeatedly defining parameters in SFMM. The results show that there was no difference between these two kinds of files when they were input into SFMM. For this reason, only one file for each case was generated as SFMM input file for each estimator, and update files were generated for the rest of cases of the factor. For example, the stocking cases, only one SFMM input file of a case, say the 20% case, was produced from SFMMTOOL. For the other cases, only update SFMM input files were generated. During the running of SFMM for the 20% case, the input file was input, the SFMM running parameter were defined, and final outputs were produced. For the remaining cases, there was no need to define the SFMM running parameters again by using the Load Update SFMMTOOL File function. This saved time by defining the SFMM running parameters repeatedly and at the same time keeping the same management, forest dynamics and silviculture options of SFMM.

3.3.2 Run SFMM

Define forest dynamics

- Defining *Natural Forest Succession*

  The standards applied are shown in Appendix II-1-1 (2).

- *Natural Rehabilitation of Non-Forest to Forest* was defined by using the information in Appendix II-2. For convenience, average annual proportion of 0.01 was applied for all cases.

- *Natural Disturbance Cycles and Succession* was defined according to Appendix II-3.

Defining silvicultural options

- Define *Clearcut Harvest Operability Ranges*. The Dog River Matawin FMP 2000-2020 operability limits were applied (see Appendix II-4)

- Input *Clearcut Growing Stock Volumes Left Unharvested*. In order to be used easily, a proportion of 0.06 was input for all species and silviculture intensities.

- Define *Clearcut Forest Renewal Costs*. An average renewal costs of $400 per ha was assumed and applied in the research (see Appendix II-5).

- *Clearcut Post-renewal Forest Succession* Screen was done based on the Appendix II-6. The table was created by referring to Dog River Matawin FMP 2000-2020 " Post Harvest Renewal " form (see Appendix II-6).
- *Stumpage Volumes and Timber harvesting Costs.* All harvesting costs except for PW and PR were assumed as $2.00 per m^3. PW and PR were assumed to cost $2.5 for harvesting all products per m^3. Although the assumption was not reasonable from the viewpoint of practical operation, it is feasible for the sake of the testing, which can alleviate the job of tedious data entry and reduced the chance to create errors for the many scenarios are involved.
- Determining *Conversion Rate of Harvested Area to Non-forested Land.* A subjective assumption of 0.02 was applied to all of the forest units. For example, with an original forest of Balsam Fir, Balsam Fir barren and scattered non-forested land will be formed after the original forest was harvested. This was based on the assumption of no delay in regeneration but with partially failed.
- *Mid-rotation Tending Treatments &Partial Harvest* options. By referring to the 1991/1992 FMA Silviculture Treatments- Northwest Region. The cost was assumed to be $400 per hectare (detailed can be found from Appendix II-7).
- Assigning *Commercial Tthinning and Partial Harvest Volumes.* Assume 30% of volume was harvested during age 30-40.
- Defining *Active Non-forest Rehabilitation* options. $500 per hectare for rehabilitation cost was applied in the research. The number was determined by

referring to BSW-Stumpage Matrix-March, 1999. The detailed future forest class and non-forest land types are listed in Appendix II-8.

Defining management objectives

- Budget for silviculture

Based on pre-testing of the research, the current solution for silviculture was around $2000 per year. For this reason, a $ 2000 available silviculture budget was applied. Most SFMM runs of this research verified the assumption is applicable. An Annual Discount Rate for calculating net present value was defined as 3.8%, typically between 0 and 4% for long-term forest planning in Ontario (Davis 1999).

- A choice of Limiting *Silvicultural Spending by Budgets* was made.
  - Define S*tability of Forest Unit Areas* screen. First, the Available Forest Only choice was applied. Second, for the direction of change Decrease/Increase, many alternatives were examined. As Davis (1999) points out " using any stability limits can significantly increase the size of models and the time required to solve it, and the solution may become infeasible or erroneous". By trying to run SFMM several times, "inf" was set as the values of increase and decrease parameters so that SFMM can obtain feasible solutions for all cases.
- No A*ge Class Structure Limits* are applied because the data file has a small numbers of stands.
- *Growing Stock Timber Volume Limits*. For each forest unit, 40,000 cubic meters was applied as the limit.

- Defining *Species Group and Harvest Flow Policies*. There is only one sub-unit in the research, we want a very uniform harvest for each period. Therefore, 5% was applied in all cases and all of the four items. At the same time, *Management Objectives* were included.
- *Stability of Harvest Area (Area Regulation)*. A ±10% changes in total area harvested by sub-unit was applied for all sub-unit and the stability of harvest area restricted by forest unit was set as "inf".
- *Seedling limits*. The annual seedlings supply of 65,000 for all sub-units was assumed.

Executing Model

After defining various SFMM parameters, the last step was to run the model.

- Switch execution options to Meet Management Objective and Schedule Silvicultural Activities.
- Set " with" choice of "options" at greatest net present value of silvicultural activities.
- Under "control options" choice box, select all of the items in "forest dynamics"; switch volume targets to "Binding"; switch silvicultural spending limits to " Budgets"
- Run the model.
- Adjusting and running again and again.

Output from SFMM

Generally, SFMM offered two types of results: basic results consisting of a series of screens that show results in different levels of detail, and advanced results consisting of case comparisons. The latter provided a powerful and easy way to carry out the research. Therefore, all advanced results were output. Parts of basic results were also output to assist in analysing outputs.

- Output model size and solve status screens by windows "grab", which showed variables, constraints, and non-zero values.
- Output "compare area by forest unit (all forest) " in table format, copied and saved in Excel format for further analyses.
- Output "compare area harvested by forest unit" in table format, copied and saved in Excel format for further analyses.
- Output "compare volume harvested by species group", "compare stumpage revenues", "compare silviculture expenditure", "compare areas by wildlife habitat unit", "compare area of preferred habitat by wildlife species", "compare indices of forest diversity by forest unit distribution", and "compare indices of forest diversity by age class distribution". They were all copied and saved in Excel file.

The case comparison menu was used for the following reasons:

- It produced summary tables of the different cases, which were more productive to compare with producing it one after one separately for each case from SFMM outputs.
- According to the strategy of the research, under each surveyed forest factor, the derived cases for the factor have only partial differences. This strategy made the application of updated files from SFMMTOOL

possible, which reduced the tedious redefining of the management objectives and silviculture.

- For each surveyed factor, only one set of case comparison at different items was produced to reduce the work of data processing.

3.3.3 Processing and reclassifying the raw data from SFMM.

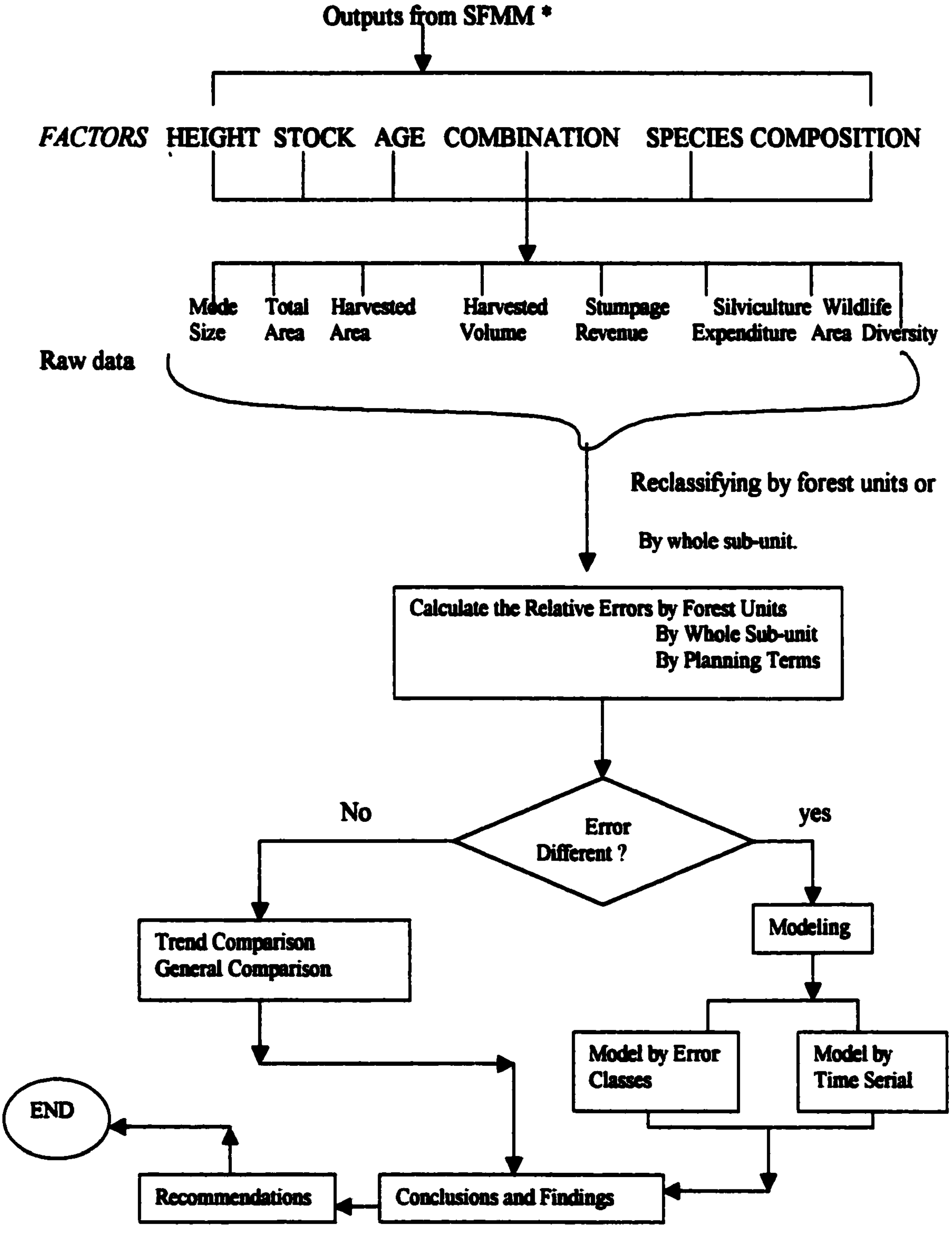

Fig 1. Data processing and Analysing flowchart

4.0 Results and Discussion

This section is separated into five sub-sections and a general discussion section. Each sub section covers one survey factor or combination. In a sub-section, there are error tables, followed by figures and tables, and a discussion. Finally, some models were developed and discussed for factors such as age, stocking, and combination cases if possible.

4.1 Species Composition Errors

There were seven cases (including a Check Case) for this survey factor. The differences between cases were due to proportional differences of dominant and sub-dominant species in stands.

4.1.1. Model size comparison

Table 9 shows that the number of constraints and variables in the model do not vary with changes of species composition. For the other researched factors or estimators of FRI, this result was also applicable. For this reason, the discussion on this issue was omitted for the other factors.

Table 9. Model Sizes of the Species Cases.

	-30%	-20%	-10%	0	10%	20%	30%
Iterations	3892	3044	3383	4135	4732	3714	4252
Equations in the Model	21975	21975	21975	21975	21975	21975	21975
Variables in the Model	22900	22900	22900	22900	22900	22900	22900
Non-zero Values	132362	127067	130172	134087	134672	134657	133937
Objective Values	133291	119974	121582	64726	86413	75252	62420
Relative Error(%)	105.9	85.3	87.8	0	33.5	16.3	-3.6

Error Class Relative Error (%)=((Objective value of some error class - Objective value of non-error Class)/Objective Value of non-error class) * 100. i.e.((133291-64726)/64726)*100=105.9%)

The table also shows that Net Present Value (PNV) varied with the species errors in FRI. In all cases, except for +30% case, changes in species composition increased the objective value. Generally, the objective value errors were 3-8 times the corresponding negative errors of FRI species, but varied for positive errors. For this reason, we cannot infer a general rule or develop a forecasting method for this factor, but it is apparent that the errors in FRI species composition had a large influence on the objective values of SFMM. When the species composition was changed, many corresponding changes occurred in SFMM. First, SFMM TOOL redefined forest units which could change the yield tables applied, and change the calculated site class values that are based on age and height. These would change the values input into SFMM. Second, with completely different original forest conditions, SFMM may find new solutions for the given management objectives and constraints at the expense of objective values. When a dominant species of a stand was changed into a sub-dominant species, the change of species can change the volume of each stand, but not at the same rate for both sides of the species error classes. These changes in turn affect the objective value. Furthermore, species change resulted in the reallocation of stands among forest units, and also changes in forest area, the stumpage revenue, and various costs, which all contribute to the change of the objective value. It was apparent that there was no uniform method to correct the objective deviation resulting from species composition errors.

Therefore, SFMM can transform species error to cause large changes in the objective value, but at a rate difficult to predict.

4.1.2 The Error of Total Forest Area (ETFA)

Table 10 and Fig 2 indicate that species errors can result in ETFA in the SFMM output. If the difference between each error class value and average error value was summed, then divided by number of classes, an approximate -6% (((-24.22)-(-30)+(-23.36)-(-20)+...+ (16)-(30))/6=(-6.12%) of Newly Produced Error (NPE) (algebraic average) was produced in SFMM. For example, the -30% error class had an average error of -24.22% of ETFA which results from the interaction between species composition error and SFMM running error. If the error from species composition was taken out from the current error of ETFA, the rest of the error should be explained as SFMM running error or NPE of the -30% error class. This assumed error transmission at the same rate of error from term 1 to term 16. In Figure 2, the difference between plotting points of species composition error and ETFA at given error class stands for the NPE. The NPE varied from one error class to another, being smaller in the negative error classes and large in the positive error classes.

For a given species error class, the ETFA tended to decrease from term one to term 16. The error ranges (see Table 10) of ETFA within each of the error classes were large. The average error of each case was not high, even if some errors of that class were high (Term1' s error for the 30% case was 146.4%, see Table 10).

Table 10. Error distribution by planning terms in SFMM.

	Total Forest Area Error (%) by Terms and Species Composition Errors						
ERROR/ TERMS	-30.0	-20.0	-10.0	0.0	10.0	20.0	30.0
T1	-33.0	-43.7	-10.0	0.0	10.3	80.8	146.4
T2	-31.3	-36.4	-6.6	0.0	3.6	44.6	80.5
T3	-29.5	-31.4	-16.6	0.0	5.5	24.0	51.3
T4	-27.5	-26.9	-14.7	0.0	5.3	12.3	32.5
T5	-29.0	-25.1	-18.3	0.0	2.5	2.1	11.5
T6	-27.5	-21.1	-20.3	0.0	2.2	1.1	4.0
T7	-22.9	-18.2	-13.9	0.0	5.4	-5.4	-0.4
T8	-22.4	-22.7	-10.5	0.0	5.1	-4.9	-5.7
T9	-23.2	-19.6	-12.6	0.0	0.6	-6.5	-6.3
T10	-22.1	-18.2	-13.4	0.0	0.2	-7.5	-7.2
T11	-21.0	-17.6	-11.6	0.0	0.0	-8.0	-8.2
T12	-20.1	-17.5	-12.7	0.0	0.3	-9.3	-8.6
T13	-19.3	-17.7	-11.7	0.0	0.3	-10.3	-9.1
T14	-19.6	-17.3	-11.4	0.0	0.8	-11.4	-8.6
T15	-19.6	-20.4	-11.5	0.0	1.4	-12.0	-8.4
T16	-19.6	-20.2	-9.5	0.0	2.2	-12.5	-7.5
Range	13.7	26.3	13.6	0.0	10.2	93.3	155.5
TOTAL	-387.5	-373.8	-205.4	0.0	45.5	77.2	256.0
AVERAGE	-24.2	-23.4	-12.8	0.0	2.8	4.8	16.0
NPE(%)	5.8	-3.4	-2.8	0.0	-7.2	-15.2	-14.0

The error value of each term was obtained by averaging the errors of forest units for a term. As some of the errors were large, the pure algebraic averaging method could give the wrong indication of ETFA. For this reason, an area weighted averaging method was applied to produce term errors of each case for each estimator. The results presented in Table 11 shows a different trend from that in Table 10. Average ETFA was not only smaller but also not had different signs for the negative errors, but had a greater deviation for the positive error.

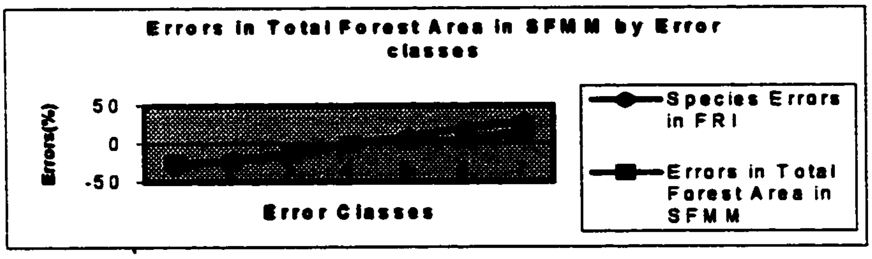

Fig 2. Errors distribution in Total Forest Area in SFMM by species error classes.

Table 11. Total Forest Weighted Area Errors By Terms (Species Composition)

	Total Forest Area Error (%)						
Err_Spe_FRI	-30.0	-20.0	-10.0	0.0	10.0	20.0	30.0
T1	10.7	19.8	25.6	0.0	1.9	108.2	300.6
T2	11.8	16.7	21.8	0.0	0.6	56.3	142.1
T3	8.5	13.1	17.8	0.0	0.5	27.5	76.7
T4	6.9	9.1	14.5	0.0	0.4	12.4	36.0
T5	6.1	8.7	14.3	0.0	0.2	7.2	16.9
T6	5.3	6.5	10.4	0.0	0.2	3.4	8.2
T7	4.9	5.3	8.4	0.0	0.3	2.3	3.4
T8	4.0	4.5	7.1	0.0	0.3	1.7	2.2
T9	3.4	3.9	5.8	0.0	0.6	1.3	1.4
T10	3.0	3.4	5.0	0.0	0.6	1.0	1.3
T11	2.6	3.0	4.4	0.0	0.8	0.8	1.0
T12	2.3	2.6	3.9	0.0	0.8	0.7	0.9
T13	2.1	2.2	3.4	0.0	0.8	0.6	1.0
T14	2.0	2.0	3.0	0.0	0.8	0.5	0.9
T15	1.8	1.7	2.6	0.0	1.0	0.6	1.0
T16	1.7	1.5	2.4	0.0	1.4	0.5	1.5
Total	77.0	103.7	150.2	0.0	11.1	224.6	595.2
Average	4.8	6.5	9.4	0.0	0.7	14.1	37.2

The average ETFA's in Table 11 were very low except for the 30% and 20% cases. Changes in species composition affected the amount of area in each forest unit. This was most dramatic when species composition was increased above 20%. This principle may not be applicable to other forests with very different original forest conditions. Table 12 shows the results of the statistical analysis of Table 11. It shows that there are very significant differences among term errors of each error case, and significant differences among different cases.

Table 12. Analysis result between terms (row) and cases (column)

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	32644.1	15	2176.3	2.528	0.004	1.779
Columns	15702.6	6	2617.1	3.040	0.009	2.201
Error	77469.2	90	860.8			
Total	125815.9	111				

Table 13 shows the errors distribution of total forest area by forest unit. Except for the Commix and Bfdom forest units, most of the forest units have a negative ETFA. The Commix forest units had the largest area, therefore had larger influence on the objective value computed by SFMM. Although the average errors in the table are uniform and easy to understand (more apparently related to corresponding species error value and amount), it can be used only as a reference and has no management implication, as SFMM considers a management unit as a whole in long-term forest management planning. Only when a specific forest unit is defined, do the mentioned results in Table 13 become important. Therefore, there is no discussion about ETFA by forest units in the research of this paper.

Table 13 ETFA by Forest Units in SFMM

Total Forest Area Error by Forest Units (%)							
Error/FU	-0.3	-0.2	-0.1	0.0	0.1	0.2	0.3
SBSHA	-40.1	-40.2	-14.7	0.0	32.5	-0.7	55.1
PJSHA	-36.4	-40.4	-38.6	0.0	-4.0	1.4	17.0
POSHA	-33.2	-40.8	-7.9	0.0	11.0	97.3	157.0
BWDOM	-75.5	-55.7	-54.2	0.0	-1.5	-51.4	-72.1
BFDOM	-3.8	3.5	5.4	0.0	-11.4	13.4	1.8
CONMIX	27.5	21.4	17.2	0.0	-1.5	-0.4	-6.8
HARD-WOOD	-29.7	-20.7	-24.1	0.0	-1.1	-16.8	-27.1
Total	-191.2	-172.9	-116.9		24.0	42.8	124.8
Average.	-27.3	-24.7	-16.7		3.4	6.1	17.8

4.1.3 Annual Harvested Area Error (AHAE)

Annual harvested area errors were positive except for the 30% case (Fig 3a, Fig 3b, Table 14-1). Positive errors indicated that more area was harvested under uniform forest constraints. On the other hand, the negative errors or reductions of the proportion of dominant species, caused SFMM to harvest less area to meet the constraints.

Average AHAE (computed from the class averages of Table 14-1)) was about 13%, which was large enough to have significant influence on forest management activities. Statistical analysis (Table 14-2) indicated that annual harvested area errors were significantly different from term to term and from case to case.

Table 14-1. Error Distribution of Total Annual Harvested Area by Terms

Total Annual Harvested Area Error (%) (Species composition cases)							
Error/Terms	-30.0	-20.0	-10.0	0.0	10.0	20.0	30.0
T1	46.6	43.4	30.3	0.0	14.5	26.4	-4.8
T2	40.2	37.8	28.8	0.0	20.3	17.8	-5.6
T3	21.3	18.6	14.3	0.0	0.4	-0.7	-5.6
T4	8.3	6.5	4.1	0.0	-2.7	-8.7	-5.6
T5	3.3	-1.1	-3.4	0.0	-1.2	-8.0	-11.3
T6	13.2	13.2	13.2	0.0	4.6	-2.2	-6.5
T7	32.0	32.0	32.0	0.0	11.6	7.8	-0.5
T8	38.4	38.4	38.4	0.0	16.9	-1.9	-2.6
T9	30.5	30.5	30.5	0.0	7.2	1.8	1.1
T10	25.2	25.2	25.0	0.0	11.1	4.8	-1.6
T11	23.4	23.4	17.2	0.0	15.9	13.7	-3.8
T12	19.7	16.4	7.3	0.0	9.8	5.7	-3.5
T13	18.5	9.5	0.8	0.0	9.2	12.1	0.8
T14	10.1	4.6	-4.1	0.0	1.2	10.1	1.7
T15	23.6	11.0	11.0	0.0	7.7	15.0	1.4
TOTAL	354.3	309.1	245.6	0.0	126.5	93.7	-46.2
AVERAGE	23.6	20.6	16.4	0.0	8.4	6.3	-3.1

Table 14-2. Statistical Analysis between Different Terms and Species Error Classes

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	5247.2	14	374.8	7.193	1.54E-09	1.811
Columns	9383.8	6	1564.0	30.015	5.74E-19	2.209
Error	4376.9	84	52.1			
Total	19007.9	104				

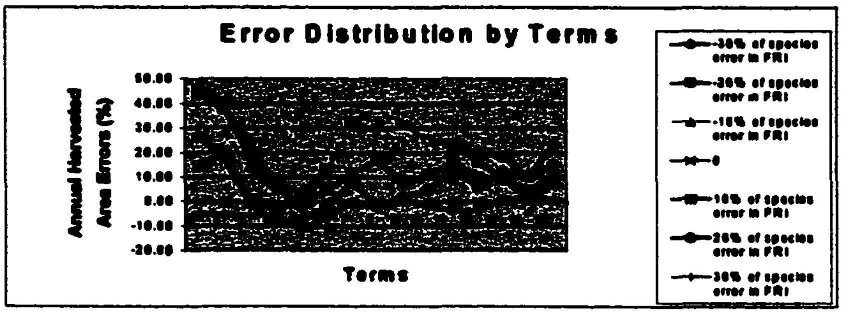

Fig 3 a. Error Distribution of Annual Harvested Area by terms

Incorrect species compositions of stands had a large influence on the annual harvested area. A negative error of species composition in FRI would over-cut forests under SFMM planning while a large positive error reduced annual harvest area.

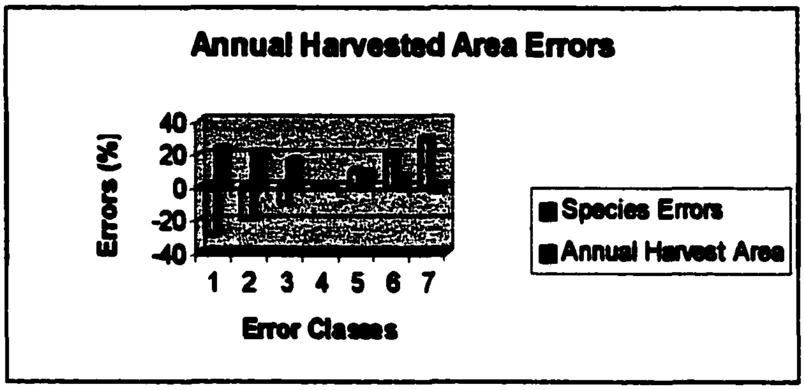

Fig 3 b. Error Distribution of Annual Harvested Area by terms

4.1.4 Harvested Volume Error (HVE)

SFMM produced greater positive HVE from the negative errors of species composition and a trend of negative HVE from positive errors (see Table 15-1). Generally, the HVE had little change from term to term because of the sustainable harvest constraint (see Fig 4a). The case ranges varied little from 1.03% to 5.06% (see Table 15-1), which resulted from defining sustainable harvest constraints.

The locations of the lines of the different error cases did seem unreasonable. For example, the -30% case and the –10% case were similar, and both were above the –20% case. In addition, the 20% case had more effect than the 30% case. Probable reasons for the variations were the various options SFMM had in order to satisfy the constraints. For example, silvicultural treatments, natural succession, and sustainable harvest volume varied in the model for different forest units. Fig 4b shows that the errors of harvested volume had a decreasing trend from the –30% case to the +30% species cases.

Table 15-1. Error distribution of Volume Harvested by Planning Terms

Harvested Volume Error (%) Species Cases							
Errors	-30	-20	-10	0	10	20	30
T1	73.3	60.6	74.8	0	16.4	-15.1	-8.2
T2	73.3	60.7	74.9	0	16.4	-15.3	-8.3
T3	73.0	61.2	74.9	0	16.1	-15.2	-8.5
T4	71.9	61.0	75.1	0	15.8	-15.4	-8.9
T5	71.9	61.0	75.1	0	15.9	-15.4	-8.8
T6	71.8	61.1	75.2	0	15.8	-15.5	-9.0
T7	71.5	60.8	75.2	0	15.6	-15.5	-9.2
T8	69.6	58.8	72.0	0	15.3	-15.7	-9.5
T9	69.6	58.7	72.0	0	15.3	-15.7	-9.5
T10	69.5	58.9	72.1	0	15.2	-15.8	-9.7
T11	69.1	58.5	72.0	0	15.0	-15.8	-9.9
T12	68.7	58.2	21.0	0	14.6	-16.0	-10.3
T13	68.7	58.2	72.0	0	14.7	-16.0	-10.2
T14	68.7	58.3	72.1	0	14.6	-16.1	-10.4
T15	68.3	57.9	72.0	0	14.3	-16.1	-10.6
T2	67.8	57.6	72.0	0	14.0	-16.3	-11.0
Total	1126.7	951.4	1173.3	0	244.9	-250.9	-152.0
Average	75.1	63.4	78.2	0	16.3	-16.7	-10.1
Range	5.1	3.3	3.2	0	2.1	1.0	2.4
NPE	-45.1	-43.4	-68.2		-6.3	36.7	40.1

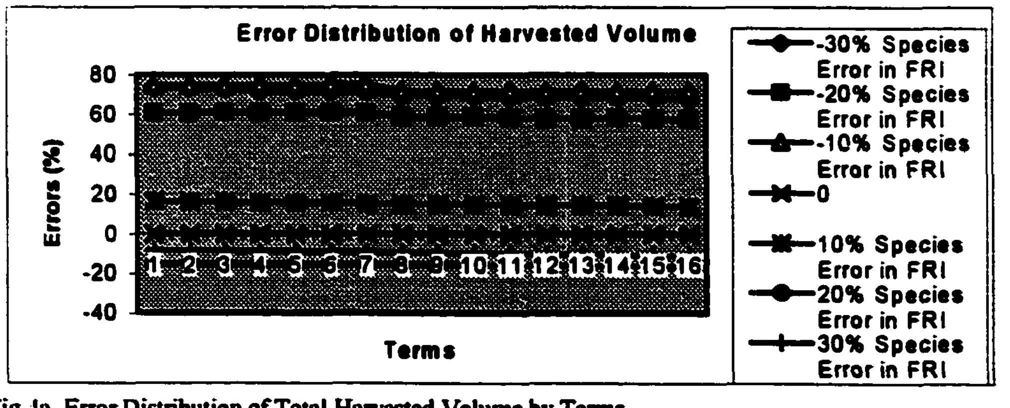

Fig 4a. Error Distribution of Total Harvested Volume by Terms

The algebraic average of NPE was -14.37% and the average of absolute NPE was 60%. This indicated that change of species composition can produce a large HVE. The NPEs had reversed signs from the errors of species composition except for the 10% case.

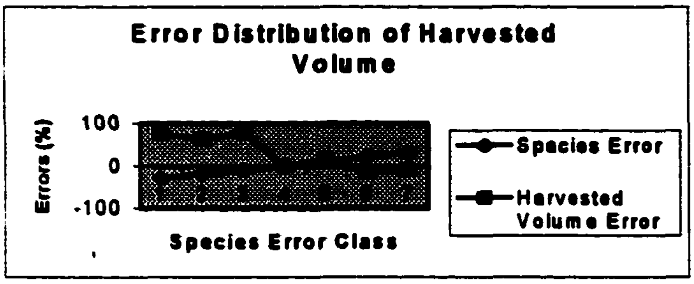

Fig 4b. Error Distribution of Total Harvested Volume by Terms

Statistical analysis (Table 15-2) indicated that there were slight differences among terms and significant differences between cases. This suggests that the species errors were closely related to the HVE, and they could be propagated during the running of SFMM. For all these reasons, in practical forest management planning, species errors must be minimized, as it is difficult to find a useful formula to adjust for the errors.

Table 15-2. Statistical Analysis between Terms and Species Error Classes

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	80.0	14	5.7	11.303	4.94E-14	1.811
Columns	136799.7	6	22800.0	45100.66	4.3E-145	2.208
Error	42.5	84	0.5			
Total	136922.2	104				

Species error could cause large errors in the harvested volume produced by SFMM. The errors varied significantly by planning term and by case. It was not possible to find a predicative equation by regression as the difference of original forest condition may produce very different error values of HVE. It is wise to do best to minimise species error in Forest Resource Inventory before any effective way adjusting the errors of harvested volume in SFMM application can be developed.

4.1.5. Stumpage Revenue Errors (SRE)

Table 16-1 (Appendix III) and Fig 5a show that the SRE had a trend similar to HVE. Both negative and positive errors of species of FRI were changed into positive errors of SRE in SFMM except for the 30% case. The SRE was about 3-6 times the species error, depending on the original error values. On the other hand, for different planning terms, the errors had the same level trend for different cases a bit reduction after term 11. The ranges of cases varied from 42.2% to 7.5%. The positive error side had narrow ranges and the negative side had wide ranges. It was understandable that the stumpage revenue had a similar trend in range as HVE because of the direct relationship between them.

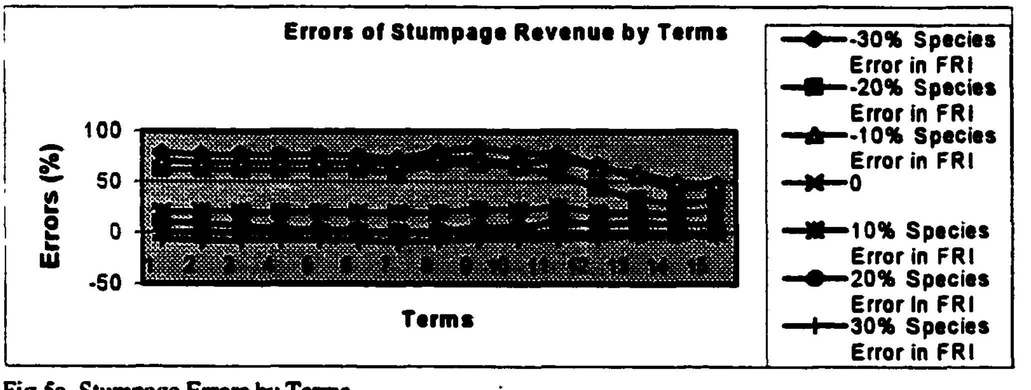

Fig 5a. Stumpage Errors by Terms

The NPE was -35.7% for the algebraic average and 52.2% for the average of absolute value. This suggested that species composition had a large effect on the SRE.

Statistical analysis (16-2, Appendix III, Appendix IV) indicated that there were significant differences between planning terms and between cases. Figure 5a shows that the average error of cases varies from 80% to –10% and shows an obvious linear trend. Although it is possible to develop a linear model to predicate the errors and adjust them, the model would be applicable to only this particular forest.

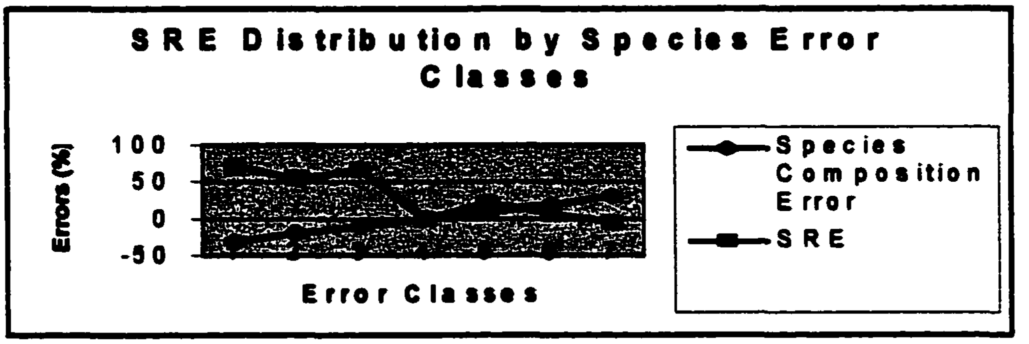

Fig 5b. Stumpage Errors by Species Error Classes

It was concluded that the errors of species composition can introduce positive errors of stumpage revenue that are 3-6 times the magnitude of species errors on negative side, and variable results occurred on the positive side.

4.1.6. Silvicultural Expenditure Errors (SEE)

Table 17 (Appendix III), Fig 6a, and Fig 6b indicate that the error distribution trend of silviculture expenditure errors by error classes is similar to that of harvested volume. Compared with stumpage revenue errors, the errors have greater fluctuations over planning terms and error classes. The errors had opposite signs to the species errors except for case 10%. Reduction of major species might lead to an over-cutting, in turn, a rising of silviculture expenditure.

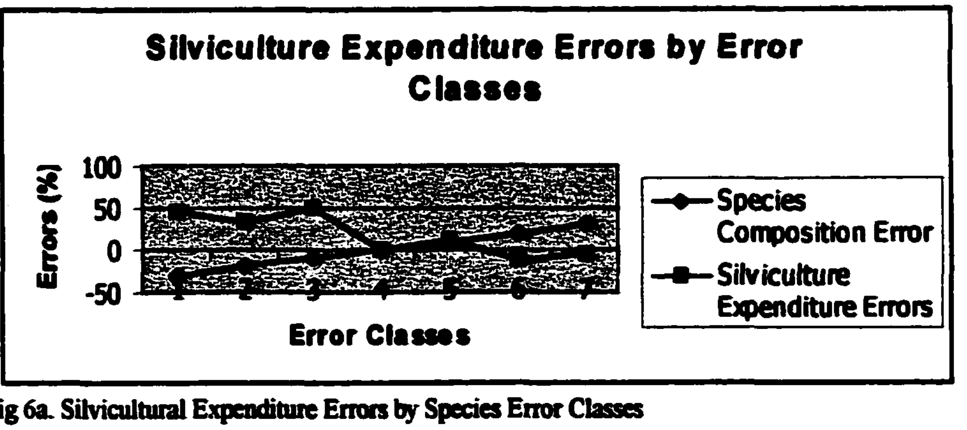

Fig 6a. Silvicultural Expenditure Errors by Species Error Classes

The NPE was about -20.24% for the algebraic average and 42.8?% for the average of absolute values. The minus sign indicated that the newly produced errors had reverse signs from the species composition errors.

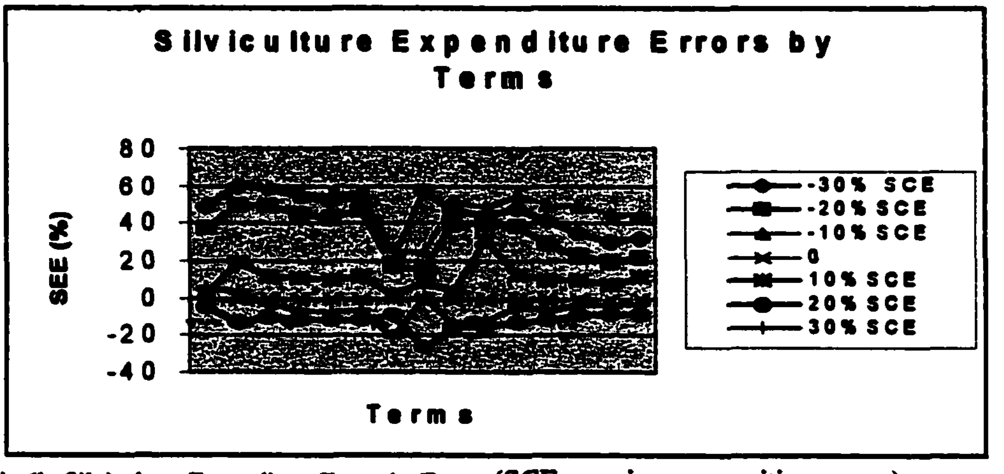

Fig 6b. Silviculture Expenditure Errors by Terms (SCE: species composition errors)

Species errors do introduce errors to the silviculture expenditure planned by SFMM. Average class errors produced by SFMM varied from -15% to 40%.

4.1.7. Shannon-Weiner Index Errors (SWIE)

Shannon-Weiner Index is used to describe the biodiversity in SFMM. Fig 7A, Fig 7B, and Table 17-1 (Appendix III) show that the indices had the same error signs as corresponding species errors but with higher values. The index errors had less sensitivity to the positive errors of species composition in FRI. All the errors of Shannon Weiner indices were smaller than the corresponding species errors. On the other hand, the errors tended to decrease over the terms, especially for the positive side of species composition errors.

Compared with the other survey factors, species errors should have a greater influence on the Shannon Weiner index than other factors such as tree height, age and stocking. However, SFMM seems to be less sensitive to species composition errors for this item. Changes with error classes of species were less significant too. As for the other index used to describe the biodiversity such as Shannon Index, the same trends were found.

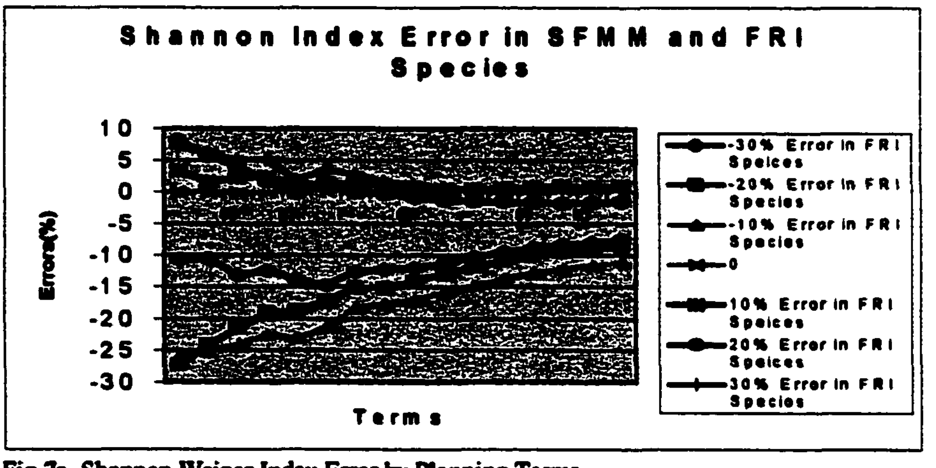

Fig 7a. Shannon Weiner Index Error by Planning Terms

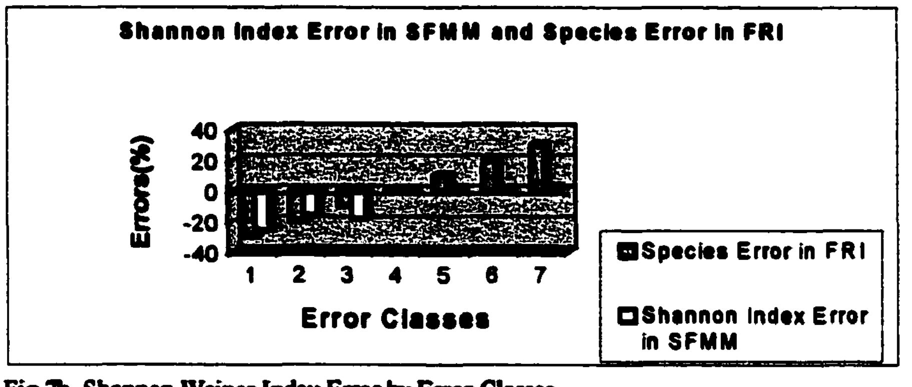

Fig 7b. Shannon Weiner Index Error by Error Classes

This result may suggest that the calculations of these indices lack enough consideration of species composition and further modification of the function of the tool needed.

4.1.8. Wildlife Area and Preferred Area Error (WAPAE)

Fig 8a, Fig 8b shows that the errors tend to increase from the lower to higher terms. The maximum error was about 80%. A large error range from case to case can be observed.

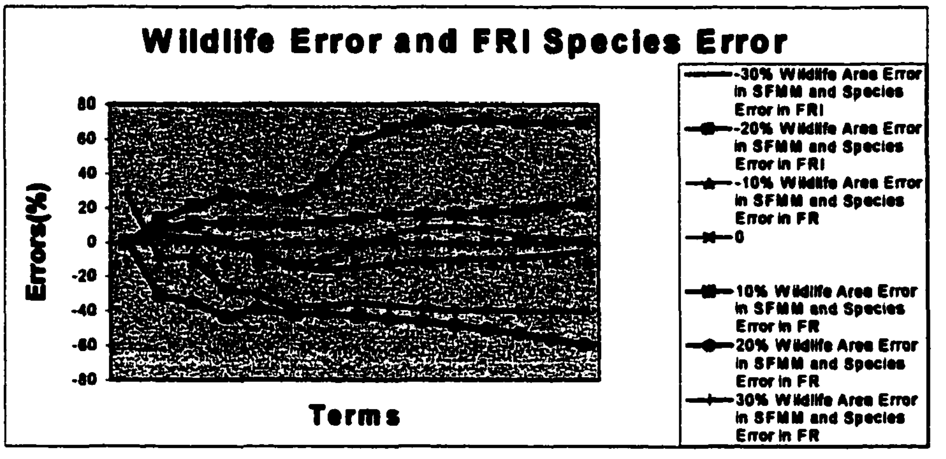

Fig 8a. Wildlife Area Errors by Terms

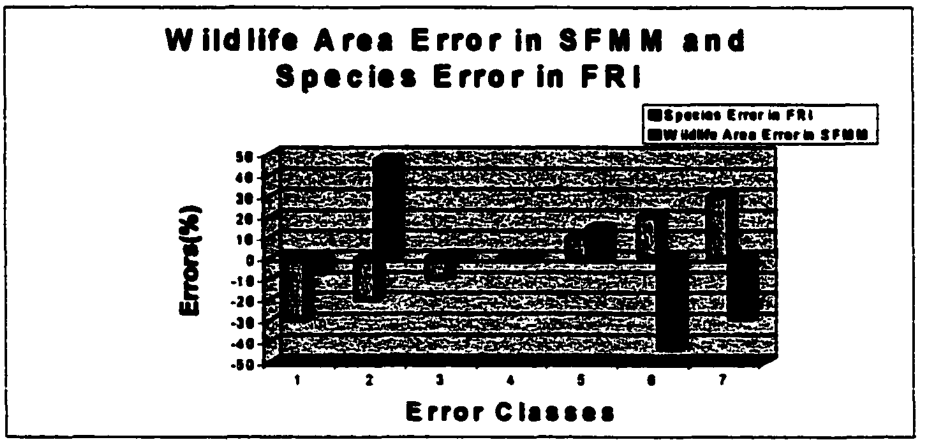

Fig 8b. Wildlife Area Errors by Species Error Classes

4.2 Age Error Cases

4.2.1 Total Forest Area Error (TFAE) By Forest Unit

Table 18 shows that the distribution of TFAE appears uniform for the cases. Except for case 20's high value, the remainder had errors under 2%.

Within error classes, there was no uniform pattern by terms. Average error ranges varied greatly from one case to another. For example, case 20 had a range of 4.5% but case 5 was 0.9%. The standard error for each error class was small.

The above results suggest SFMM did not change total forest area very much with the age error from-20% to 20%. The small values of 0 to 4.5% were attributed to the random errors caused by defining natural succession and conversion of harvested area to non-forest area.

Table 18. Error Distribution of Total Forest Area by Planning and Age Error Classes

Err_sto_FRI	-20.0	-15.0	-10.0	-5.0	0.0	5.0	10.0	15.0	20.0
T1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
T2	0.3	0.3	0.8	0.7	0.0	0.7	2.1	1.6	2.0
T3	0.4	1.0	0.7	0.9	0.0	0.4	1.5	1.9	4.5
T4	0.9	1.0	0.5	0.3	0.0	0.7	0.9	1.8	3.8
T5	2.0	1.3	0.4	0.2	0.0	0.2	0.7	1.0	2.7
T6	1.6	1.7	0.7	0.1	0.0	0.9	1.1	2.0	2.4
T7	3.0	0.8	0.5	0.1	0.0	0.3	0.1	0.4	2.4
T8	0.3	0.3	0.1	0.1	0.0	0.1	0.1	0.3	2.5
T9	0.0	0.1	0.1	0.2	0.0	0.2	0.1	0.3	2.1
T10	0.0	0.1	0.1	0.1	0.0	0.2	0.3	0.5	2.1
T11	0.3	0.2	0.2	0.3	0.0	0.2	0.2	0.4	2.2
T12	0.3	0.4	0.4	0.5	0.0	0.1	0.0	0.2	2.5
T13	0.3	0.5	0.6	0.7	0.0	0.1	0.1	0.2	2.8
T14	0.4	0.8	0.9	1.0	0.0	0.1	0.1	0.2	3.0
T15	0.7	1.2	1.4	1.5	0.0	0.1	0.0	0.2	3.8
T16	1.1	1.6	1.7	1.8	0.0	0.0	0.1	0.3	4.1
Total	11.5	11.3	9.1	8.7	0.0	4.1	7.3	11.3	42.8
Average	0.7	0.7	0.6	0.5	0.0	0.3	0.5	0.7	2.7
Range	3.0	1.7	1.7	1.8	0.0	0.9	2.1	2.0	4.5
Standard ERR	0.2	0.1	0.1	0.1	0.0	0.1	0.2	0.2	0.3

4.2.2 Harvested Volume Errors (HVE)

Table 19-1 shows that the average error of harvested volume were within ±5%, except for case 20%. The ranges within terms varied from 5.5% to 18.3%.

Table 19-1. Error Distribution of Harvested Volume by Terms and Age Error Classes

Error (%) Distribution of Harvested Volume by Planning Terms (Age Case)									
Err_Age_FRI	-20.0	-15.0	-10.0	-5.0	0.0	5.0	10.0	15.0	20.0
T1	-10.3	-5.4	-7.0	-8.1	0.0	6.0	-1.6	-5.4	-28.2
T2	-8.7	-5.3	-6.8	-7.9	0.0	4.6	-1.6	-5.2	-27.9
T3	-8.4	-5.1	-6.6	-7.6	0.0	4.7	-1.6	-5.0	-27.5
T4	-8.1	-4.9	-6.4	-7.2	0.0	4.9	-1.6	-4.9	-27.2
T5	-7.8	-4.8	-6.2	-6.9	0.0	5.1	-1.5	-4.7	-26.8
T6	-7.4	-4.6	-5.9	-6.6	0.0	5.2	-1.5	-4.5	-26.4
T7	-7.1	-4.4	-5.7	-6.2	0.0	5.4	-1.5	-4.3	-26.1
T8	-3.0	-0.3	-1.6	-2.1	0.0	5.4	2.5	-0.3	-22.7
T9	-2.0	0.4	-0.8	-1.2	0.0	2.8	4.3	1.6	-24.2
T10	2.9	3.9	3.2	3.5	0.0	2.8	9.0	6.5	-19.0
T11	1.5	8.9	8.3	8.7	0.0	2.2	10.2	10.8	-15.4
T12	1.0	6.1	5.5	6.8	0.0	1.8	10.7	12.4	-11.5
T13	-1.5	3.3	2.7	3.6	0.0	0.5	8.0	10.4	-9.9
T14	-5.7	-1.3	-1.9	-1.1	0.0	0.5	3.8	4.7	-10.2
T15	-8.7	-4.7	-5.2	-4.5	0.0	1.2	0.7	5.5	-10.0
Total	-73.2	-18.0	-34.3	-36.8	0.0	53.2	38.3	17.8	-312.8
Average	-4.9	-1.2	-2.3	-2.5	0.0	3.5	2.6	1.2	-20.9
Range	13.2	14.4	15.3	16.9	0.0	5.5	12.2	17.8	18.3

Statistical analysis (Table 19-2) showed a significant difference both between terms and between age error classes. Cases 20% and -20% had higher average error percentages, case 20 in particular. When the age error was large, such as 20% or -20%, significant variance of average error class of the harvested volume was caused.

Table 19-2 Two factor analysis of harvested volume (age cases)

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	1872.0	14	133.7	11.765	2.96E-16	1.781
Columns	6386.1	8	798.3	70.235	4.32E-40	2.022
Error	1273.0	112	11.4			
Total	9531.0	134				

Rows = Age Error Class Columns = Terms

Four sources of error were responsible for the high HVE value of case 20%. First, SFMMTOOLkit did not produce similar forest unit yield curve for all cases. Table 19-3 shows the total yield by age class of the Conmix forest unit for five age error classes. At age class 105, the total yield of cases 15% and 20% was larger than the value for other cases. These differences led to some errors of HVE of case 20%. It is not clear why this change occured.

Table 19-3. Total Yield of Some Cases by Age Class (Conmix Forest Unit)(m3/year).

Total Yield for Each Age Class (Age Error Cases)						
Age Class	-20%	-15%	0%	5%	15%	20%
A5	0	0	0	0	0	0
A15	0	0	0	0	0	0
A25	2	2	2	2	2	2
A35	11	11	11	11	12	12
A45	22	22	22	22	26	26
A55	34	34	34	34	39	39
A65	46	46	46	46	52	52
A75	59	59	59	59	64	64
A85	75	75	75	75	81	81
A95	87	87	87	87	94	94
A105	95	95	95	95	100	100
A115	91	91	91	91	99	99
A125	80	80	80	80	82	82
A135	66	66	66	66	68	68
A145	60	60	60	60	62	62
A155	57	57	57	57	60	60
A165	55	55	55	55	58	58
A175	54	54	53	53	57	57
A185	51	51	51	51	55	55
A195	49	49	49	49	52	52
A205	47	47	47	47	50	50
A215	46	46	47	47	49	49
A225	46	46	46	46	47	47
A235	44	44	44	44	46	46
A245	43	43	43	43	45	45
A255	42	42	41	41	45	45

Second, changes in age affected the age distribution of initial forest areas. For example, the age error of 20% shifted the age distribution of the Conmix forest unit up

10-30 years to produce a more mature forest than the base case. The yield per hectare of the more mature forest is less than for the younger forest of the base case (Table 19.3).

Third, the silviculture operability limits affected the harvestable forest area (Table 19-4). Based on the defined upper operability limit of 125 and lower limit of 70, at planning term 1, the harvestable area for case 20 was 474 ha, a reduction of 26.28% from the base case 0 (643 ha).

Table 19-4 Initial Age Class Distribution of the Conmix Forest Unit by Age Error Cases

Conmix Forest Unit Initial Area (ha) by Age Class			
Age Class	CASE -20%	CASE 0	CASE 20%
A5	7	7	
A15	7	7	7
A25	6		7
A35		6	
A45	29		6
A55	163	29	
A65	188	49	9
A75	158	228	51
A85	127	120	132
A95	90	112	114
A105		127	120
A115	128	56	112
A125		34	
A135			183
A145		128	34
A155			
A165			
A175			128
TOTAL	903	903	903
Mature Forest Area	503	805	874
Harvestable Area	503	643	474
Change Rate (%)	-21%	0	-26.28%

Fourth, the natural succession rate affected the HVE for case 20. Fig 9A shows that 30% of the Conmix forest unit at age of 115 was changed into the BfDom Forest unit and another 30% to age class 55 of the Conmix forest unit. At age 135, the Conmix forest unit of 40% was changed to BfDom, and of 60 to younger Conmix.

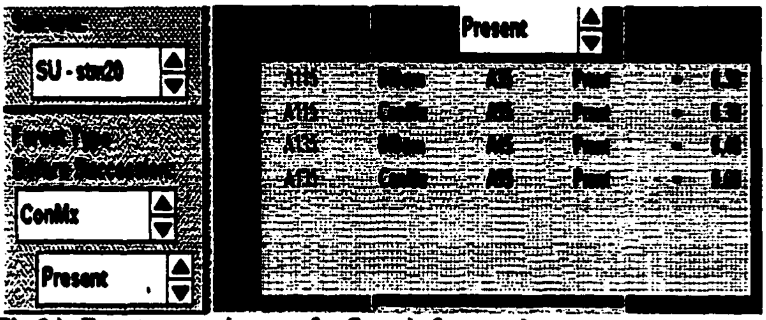

Fig 9A. Forest succession rate for Conmix forest unit.

Age errors had various effects on the errors of harvested volume, depending on the magnitude of the errors and their sign. Although it is impossible to apply a general method to correct HVE, Fig 9B shows a polynomial regression equation for the HVE caused by age errors. The equation was developed from the particular forest and SFMM setup. Unfortunately, the equation has less value in the actual error evaluation of SFMM because of the difference of original forest condition which will change some parameters of the model. It maybe possible to develop similar models for other forests and SFMM setups. For this reason, in the following part, some poly-simulation equation were shown, but only used as an example of error adjustment method in SFMM.

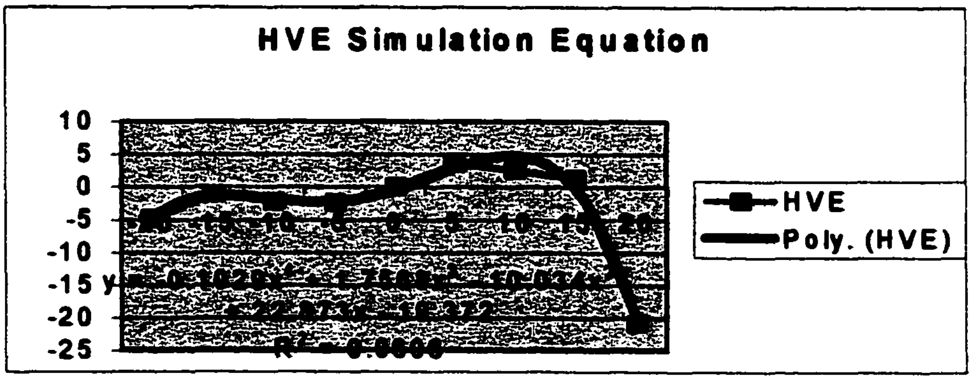

Fig 9B. HVE Simulation Equation (X=Age Error, Y=Average Error of HVE)

4.2.3 Stumpage Revenue Error (SRE)

Table 20-1 shows the error distribution of stumpage revenue by term. The results were similar in magnitude to the harvested volume errors. This was expected as the stumpage revenue was based upon the volume harvested. The only difference was that the age error can result in different species being harvested at different stumpage rates (white pine had a stumpage rate of $11 and poplar $0.50).

Statistical analysis (Table 20-2) shows that there is significant difference of stumpage revenue between cases, but no significant differences among terms for given a case. Fig 10 shows a correction equation for SRE, which provides a possible way to correct the error for this particular study.

Table 20-1 Error Distribution of Stumpage Revenue by Planning and Age Error Classes

Error (%) of Age Cases									
Err_Age_FRI	-20.0	-15.0	-10.0	-5.0	0.0	5.0	10.0	15.0	20.0
T1	-8.4	-5.7	-6.0	-8.8	0.0	0.9	-5.2	-8.9	-28.3
T2	-8.1	-3.3	-5.6	-8.0	0.0	4.1	-2.0	-6.1	-27.3
T3	-8.7	-3.6	-5.8	-9.4	0.0	2.1	-3.5	-8.4	-28.3
T4	-7.7	-4.3	-6.1	-8.3	0.0	2.7	-3.5	-8.1	-28.2
T5	-7.5	-3.6	-6.0	-7.9	0.0	2.1	-3.9	-6.9	-28.5
T6	-6.1	-2.9	-5.1	-7.6	0.0	3.1	-2.5	-6.8	-26.9
T7	-6.2	-2.8	-5.7	-7.3	0.0	4.4	-1.2	-4.7	-25.6
T8	-8.5	-3.9	-5.4	-7.4	0.0	3.1	-0.6	-4.4	-25.9
T9	-10.2	-7.3	-9.1	-11.1	0.0	2.5	-0.3	-3.9	-25.1
T10	-9.4	-9.4	-9.7	-10.1	0.0	3.1	0.3	-2.9	-20.1
T11	-9.9	-6.7	-6.8	-7.1	0.0	2.4	2.5	4.7	-13.7
T12	-8.3	-7.8	-7.9	-7.1	0.0	1.6	3.4	8.5	-9.2
T13	-8.9	-8.3	-8.0	-8.1	0.0	-0.1	1.9	8.4	-7.5
T14	-9.5	-8.5	-8.3	-8.5	0.0	0.2	1.2	4.1	-7.3
T15	-10.7	-10.1	-9.9	-9.9	0.0	-0.5	-1.2	3.4	-9.4
Total	-128.0	-88.1	-105.5	-126.5	0.0	31.8	-14.5	-31.9	-311.4
Average	-8.5	-5.9	-7.0	-8.4	0.0	2.1	-1.0	-2.1	-20.8
Range	4.6	7.4	4.9	4.1	0.0	4.8	8.6	17.4	21.2

Table 20-2 Two Factor Analysis of SRE (ANOVA)

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	294.1	14	21.0	1.486	0.1277	1.781
Columns	5594.1	8	699.3	49.467	2.72E-33	2.022
Error	1583.2	112	14.14			
Total	7471.4	134				

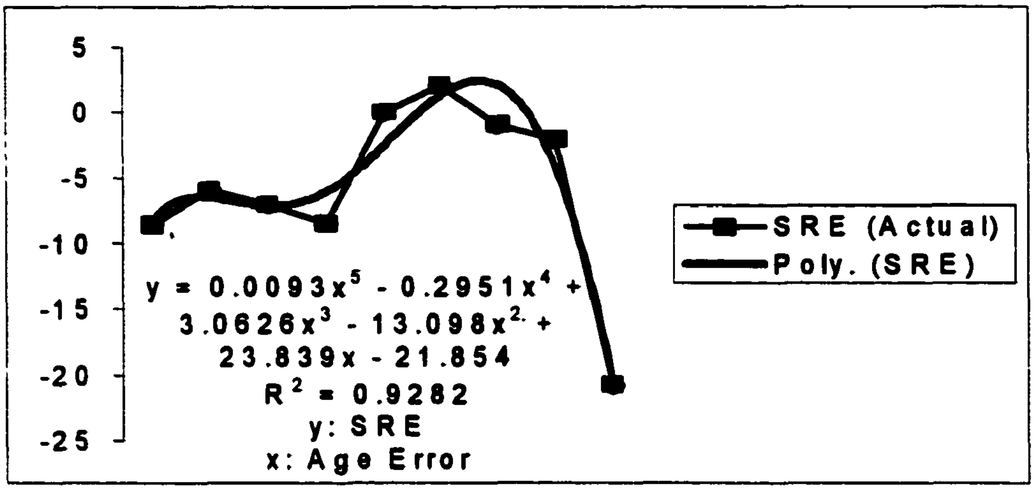

Fig 10. SRE Correction Equation

4.2.4 Silviculture Expenditure Error (SEE)

Table 21-1 presents the distribution of SEE. The table shows a similar pattern to HVE but with lower errors by terms and for the averages of age error class.

Table 21-1 Error Distribution of Silviculture Expenditure by Terms and Age Error Classes

	Error (%) of Age Cases								
Err_Age_FRI	-20.0	-15.0	-10.0	-5.0	0.0	5.0	10.0	15.0	20.0
T1	-7.6	-5.9	-2.4	-4.5	0.0	3.4	2.0	-9.9	-29.9
T2	-10.5	2.0	-3.1	-4.6	0.0	6.4	-5.5	-9.9	-29.4
T3	-3.8	3.7	-1.1	-6.5	0.0	2.3	-5.5	-8.6	-27.4
T4	-2.6	1.6	-0.3	-1.4	0.0	4.4	-1.4	-4.3	-23.9
T5	-2.2	-0.8	-2.2	-2.5	0.0	4.1	-0.3	-5.0	-24.8
T6	-4.5	-0.5	-1.8	-3.6	0.0	4.4	-3.3	14.2	-4.8
T7	-18.3	2.7	0.5	-0.5	0.0	6.9	0.2	-6.3	-26.0
T8	-14.4	2.1	0.1	-1.0	0.0	2.6	-0.9	-6.7	-19.5
T9	-4.2	-11.2	-3.3	-4.0	0.0	4.7	0.0	-20.8	-41.8
T10	-13.8	1.3	0.3	-5.6	0.0	1.7	4.6	-19.6	-38.6
T11	0.3	24.2	33.4	19.5	0.0	3.0	8.8	7.9	-14.0
T12	2.3	6.3	6.1	7.6	0.0	2.8	9.9	11.8	-9.7
T13	1.0	4.1	4.1	5.0	0.0	0.5	7.5	11.0	-7.5
T14	-2.2	1.3	1.4	1.9	0.0	1.0	4.4	4.9	-7.5
T15	-4.1	-1.8	-1.4	-0.9	0.0	1.3	1.2	5.3	-8.1
Total	-84.6	29.0	30.5	-1.0	0.0	49.5	21.7	-36.1	-312.8
Average	-5.6	1.9	2.0	-0.1	0.0	3.3	1.5	-2.4	-20.9
Range	20.5	35.3	36.7	26.0	0.0	6.4	15.4	35.0	37.0
Standard ERR	1.6	1.9	2.3	1.7	0.0	0.5	1.2	2.8	3.1

The ranges of silviculture Expenditure by terms varied from 6.4% to 37%. Case 20% had the widest range and the highest average SEE. Standard error of the case was also the largest. This indicated that 20% of age error had a greater effect on the silviculture expenditure than the other age errors.

The errors of silviculture expenditure showed a very complicated change from term to term. This was caused by many reasons associated with age such as harvesting different species, operability limits, and using different rates to calculate the costs. The more silvicultural options added, the more tools and flexibility SFMM has to design effective strategies to meet the stated management objectives.

Statistical analysis (Table 21-2) indicated that there were significant differences of silviculture expenditure errors between terms and cases too. It was possible to make a good predication of the errors of silviculture expenditure for this study (Fig 11).

Table 21-2 Two Factor Analysis of SEE

ANOVA

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Rows	3040.763	14	217.1974	6.018547	1.02E-08	1.78105
Columns	6717.873	8	839.7342	23.26906	1.26E-20	2.022091
Error	4041.857	112	36.08801			
Total	13800.49	134				

SEE changed little from one age error class to another between -20% to +20%, but when the age error surpassed 20%, a large increase in error occurred.

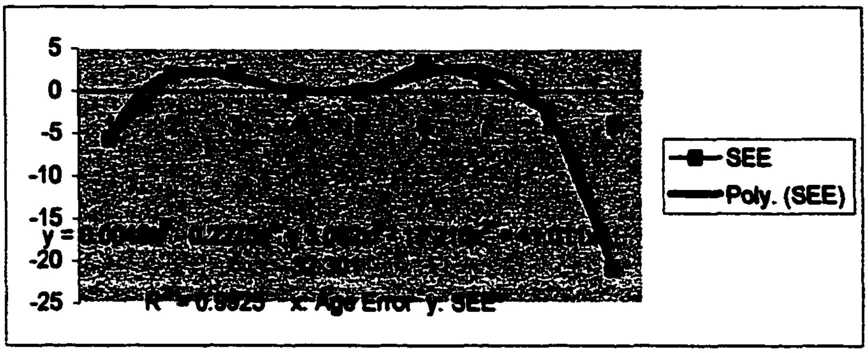

Fig 11. SEE Correction Equation.

4.2.5 Shannon-Weiner Index Errors

Table 22-1 shows the error distribution of the Shannon Weiner Index Error by terms and age error classes. Generally, the errors have a reverse sign to the age errors except for some terms of case -20% and case-15%.

Table 22-1. Error Distribution of Shannon Weiner Index by Terms and Age Error Classes

Error (%) of Age Cases									
Err_Age_FRI	-20	-15	-10	-5	0	5	10	15	20
T1	0.83	-0.04	0.33	0.89	0.00	1.25	1.79	1.64	1.30
T2	-1.43	-1.45	-0.98	-0.07	0.00	-0.88	0.17	-1.43	-5.87
T3	-0.78	1.05	0.41	0.52	0.00	-2.32	-2.51	-4.25	-6.14
T4	2.46	2.86	1.84	1.78	0.00	-0.41	-0.32	-1.99	-7.03
T5	1.12	2.38	1.82	1.27	0.00	-3.10	-1.93	-5.77	-8.25
T6	3.25	2.72	1.90	0.91	0.00	-1.19	-0.68	-3.50	-6.19
T7	1.19	2.02	0.34	0.58	0.00	-0.46	-0.03	-2.41	-5.36
T8	-0.26	1.19	0.01	0.18	0.00	-1.04	-0.75	-3.00	-6.61
T9	0.07	1.54	0.48	0.59	0.00	-1.60	-1.65	-3.63	-6.18
T10	1.20	1.74	0.69	0.85	0.00	-0.60	-1.04	-3.09	-4.88
T11	0.84	2.06	0.56	0.77	0.00	-0.21	-0.24	-2.05	-4.20
T12	0.00	1.57	0.35	0.49	0.00	-0.35	-0.24	-1.94	-3.97
T13	-0.21	1.31	0.27	0.32	0.00	-0.37	-0.23	-1.88	-3.98
T14	-0.09	1.26	0.19	0.26	0.00	-0.46	-0.20	-1.69	-3.61
T15	-0.12	1.14	0.06	0.15	0.00	-0.42	0.09	-1.34	-3.60
Total	7.90	21.21	8.17	9.48	0	-12.06	-7.62	-36.13	-74.76
Average	0.53	1.41	0.54	0.63	0	-0.80	-0.51	-2.41	-4.98
Range	4.68	4.31	2.88	1.85	0.00	4.35	4.30	7.41	9.55
Standard ERR	0.31	0.28	0.20	0.12	0.00	0.26	0.26	0.43	0.57

The ranges of age error classes varied from 1.85% to 9.55%. Case 20% also gained the widest range. Compared with age error, the ranges were not large even for case 20%.

(1) The absolute average errors by age error classes showed an increasing trend from case -20% to case 20%.

(2) Statistical analysis (Table 22-2) indicated that there was no significant difference between different terms but significant differences between age error classes.

Table 22-2 Two Factor Analysis of Shannon Weiner Index Error

ANOVA

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Rows	48.62753	14	3.473395	2.889403	0.000935	1.78105
Columns	466.0475	8	58.25594	48.46121	6.56E-33	2.022091
Error	134.6369	112	1.202115			
Total	649.3119	134				

Shannon-Weiner Heterogeneity Index is most sensitive to changes in relatively rare elements or species (Davis, 1999). If the variable Pi of Shannon-Weiner Index is the proportion represented by the total area of the stands in age class I (one of three choices in the formula), the index should have a change with the change of age. If Pi is the proportion of age class, the index must be changed with the age change. If Pi is the proportion represented by wildlife habitat unit, the index should have a small change with the age change. The SFMM user guide does not indicate which choice is used. It is difficult to decide if there should be some changes of the index with the age errors. The small change may mean slightly regulating age classes of a forest unit as age errors were not large enough.

Although there were significant differences of Shannon Index Errors between age error classes, the errors were too small and had little influence on long-term forest management. Therefore, SFMM has a weak response to the age error in its Shannon-Weiner Index.

4.2.6 Wildlife Habitat Area Errors

Table 23-1 shows the error distribution of wildlife habitat area. Similar to the Shannon Weiner Index error, the errors of wildlife habitat area were very small and varied from 1.46% to -11.70% with most of the errors negative. The average error by age error classes varied from -0.78% to -7.07%.

Table 23-1. Error Distribution of Wildlife Habitat Area by Terms and Age Error Classes

Error (%) of Age Cases)									
Err_Age_FRI	-20.00	-15.00	-10.00	-5.00	0.00	5.00	10.00	15.00	20.00
T1	-3.91	-2.80	-9.59	-9.97	0.00	-6.53	-5.92	0.17	-7.15
T2	-3.86	-6.52	-8.89	-10.69	0.00	-1.96	-6.07	-0.49	-2.25
T3	-3.18	-7.66	-8.88	-6.93	0.00	1.46	-2.20	0.53	-5.54
T4	-2.79	-1.96	-3.59	-2.83	0.00	-2.09	-0.96	1.43	-1.73
T5	1.23	-0.78	-1.97	-0.84	0.00	0.37	6.16	5.97	-1.10
T6	-4.11	-1.57	-2.48	-1.25	0.00	-2.40	1.59	-0.36	-6.59
T7	-1.82	-1.58	-2.48	-2.69	0.00	-2.74	-0.68	-1.32	-8.05
T8	-0.89	-2.61	-3.33	-4.09	0.00	-2.49	-0.93	-1.34	-7.63
T9	-1.67	-3.63	-4.72	-5.17	0.00	-1.38	0.12	-0.61	-7.56
T10	-3.68	-5.00	-5.72	-5.90	0.00	-2.10	-1.17	-1.40	-8.39
T11	-4.14	-5.74	-6.31	-6.51	0.00	-2.00	-1.74	-2.31	-8.50
T12	-4.66	-6.52	-7.05	-7.25	0.00	-1.59	-1.94	-2.44	-9.02
T13	-5.79	-8.01	-8.51	-8.62	0.00	-1.44	-2.28	-2.79	-9.89
T14	-7.55	-9.55	-9.95	-10.05	0.00	-1.23	-2.77	-3.12	-10.95
T15	-8.98	-10.79	-11.04	-11.12	0.00	-0.62	-3.21	-3.54	-11.70
Total	-55.82	-74.72	-94.52	-93.88	0.00	-26.73	-21.98	-11.63	-106.10
Average	-3.72	-4.98	-6.30	-6.26	0.00	-1.78	-1.47	-0.78	-7.07

Statistical analysis (Table 23-2) showed that there were significant differences between age error classes and between terms although the average errors were very small. Wildlife habitat specifies a minimum area of potential preferred habitat that a forest must provide for specific wildlife species. Age classes can have influence on the distribution of forest types which lead to the different wildlife habitat areas. Table 23-1 shows Sb-Lowland, CISB3 unit had a small change with age error as the habitat unit counted Sb-related forest area which is 3% of total management unit area. On the other hand, some wildlife habitats require upper age limits. In that case, age change must have a large influence on the distribution of the wildlife habitat.

Table 23-2, Two Factor Analysis for Wildlife Habitat Area Error

ANOVA

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Rows	492.1241	14	35.15172	9.558751	1.33E-13	1.78105
Columns	856.9836	8	107.123	29.12977	4.44E-24	2.022091
Error	411.8731	112	3.677438			
Total	1760.981	134				

Therefore, SFMM has ability to response to the age errors in wildlife habitat area and only manipulate the term's value to satisfy the age's influence depending upon actual wildlife habitat unit.

4.2.7 NPV Errors (NPVE)

Table 24-1 shows the NPVE over age error classes. All age error reduced NPV in order to meet the requirement of the forest management objectives. The errors in NPV had weak relationships with age error classes (Table 24-2) by linear regression, but still possible to make a predication for the error in the particular study by using polynomial trend (Fig 12).

Table 24-1. Error Distribution of NPV by Terms and Age Classes

Error (%) Distribution of NPV by Planning Terms (Age Cases)									
Err_Age_FRI	-20.00	-15.00	-10.00	-5.00	0.00	5.00	10.00	15.00	20.00
NPV	74.32	75.01	73.30	70.79	81.82	82.04	77.15	75.90	58.81
Err_NPV	-9.17	-8.33	-10.41	-13.48	0.00	0.27	-5.71	-7.24	-28.12

Table 24-2. Linear Correlation between NPV and Age Error Classes

	Err_Age_fri	*NPV*
Err_Age_FRI	1	
NPV	-0.267296104	1

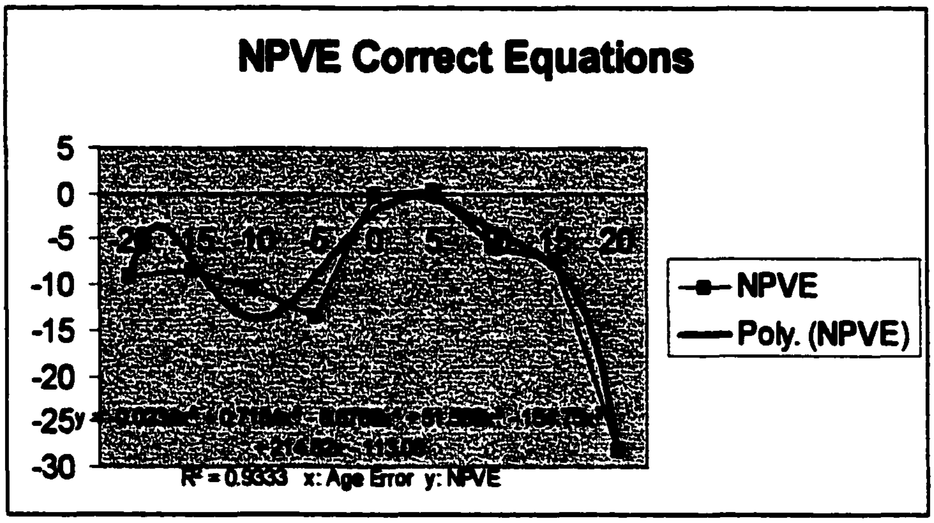

Fig 12. NPVE Correction Equations

4.2.8 General analysis on age cases

Fig 13 shows that most errors resulted from age errors distributed between 5% and -10%. There was a very weak linear relationship between age errors and the researched errors of SFMM outputs. The research indicates that only when the age error was equal or greater than one age class, that is, 20 years error in FRI, SFMM adjusted its various outputs in response to the age errors.

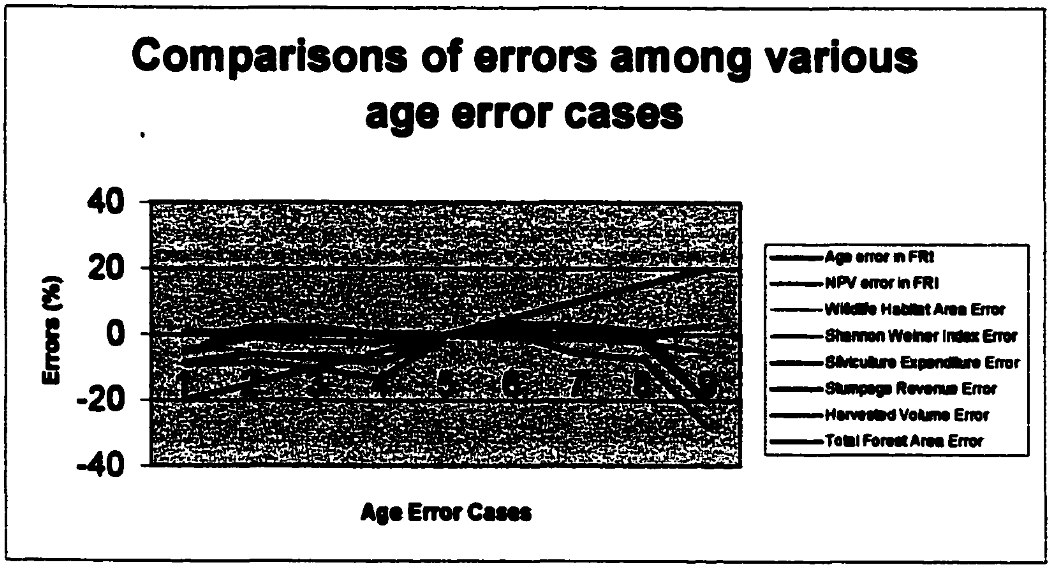

Fig 13. Comparisons of errors among various age error cases.

4.3 Stocking Error Cases

4.3.1 Total Forest Area Error by Forest Units (TFAE)

Table 25 shows that most of the errors produced in total forest area are positive as the sign does not change with cases or terms. The greatest error range was only 2%, which was much less than the 40% of error range in stocking. Statistical analysis indicated no significant error difference of total forest area from one stocking error class to another and from one planning term to another (Appendix VI-1). Therefore, observed errors ranging from –0.02% to 0.09% might be caused by random factors during data transformation. In long-term forest planning, the error would have no management effects.

Table 25. Error Distribution of Total Forest Area by Terms and Stocking Error Classes

Error (%) of Stocking Cases									
Err_sto_FRI	-20	-15	-10	-5	0	5	10	15	20
T1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T2	0.01	0.02	0.02	0.00	0.00	0.13	0.00	0.12	0.16
T3	0.03	0.02	0.01	0.00	0.00	0.02	0.01	0.00	0.00
T4	0.05	0.02	0.02	0.00	0.00	0.05	0.02	0.02	0.00
T5	0.05	0.03	0.03	0.00	0.00	0.10	0.06	0.03	0.01
T6	0.03	0.02	0.02	0.00	0.00	0.13	0.07	0.01	0.00
T7	0.04	0.03	0.04	0.00	0.00	0.09	0.06	0.01	0.00
T8	0.03	0.02	0.05	0.02	0.00	0.12	0.08	0.01	0.04
T9	0.02	0.01	0.03	0.00	0.00	0.07	0.04	0.00	-0.02
T10	0.04	0.01	0.02	0.00	0.00	0.04	0.03	0.00	-0.02
T11	0.02	0.01	0.02	0.00	0.00	0.03	0.02	0.00	-0.01
T12	0.02	0.01	0.01	0.00	0.00	0.01	0.01	0.00	-0.01
T13	0.02	0.01	0.01	0.01	0.00	-0.02	0.01	-0.01	-0.01
T14	0.02	0.01	0.01	0.01	0.00	-0.01	0.00	-0.01	-0.02
T15	0.02	0.02	0.01	0.01	0.00	0.00	0.00	-0.01	-0.02
T16	0.04	0.09	0.13	0.06	0.00	-0.19	-0.15	-0.06	0.04
Total	0.44	0.34	0.44	0.10	0.00	0.56	0.25	0.11	0.15
Average	0.03	0.02	0.03	0.01	0.00	0.04	0.02	0.01	0.01

The errors mentioned here were computed by weighted area averaging, which might mask the error differences among forest units or planning terms. With changes in stocking, SFMM must adjust the area distribution by terms to satisfy the management objectives, such as harvesting sustainability.

Stocking errors cannot be transformed into Total Forest Area in SFMM. Although there are some errors existing in Total Forest Area in SFMM, the errors are not significant from the viewpoint of either forest management planning or statistics.

There were large errors of Total Forest Areas between different forest units caused by the specific definition of forest units used in this study.

4.3.2 Harvested Volume Error (HVE)

With a constraint of sustained harvest volume, the errors of harvested volume changed little over terms or time for individual cases (Fig 14A) due to changes of stocking. Fig 14B and Table 26 (Appendix VI) show a strong proportional relationship between stocking errors and the errors of harvested volume. Error ranges decreased from ±5% to ±20% class and averaged 4.8% (Refer to Table 26). The newly introduced errors by SFMM varied with stocking error, ranged from 5.97% (stocking error – error of harvested volume) to –1.74%, and averaged 2.6%.

In order to check the deviation of errors of harvested volume, a factor analysis was done (Appendix VI-1). The result indicated a significant difference between different terms, and between stocking error classes. This confirmed that the error differences of harvested volume caused by stocking errors were not random.

The average errors of Harvested Volume by error classes showed a strong linear relationship. Using regression analysis, a predicative model was developed (Appendix VI –2). The result from the regression suggested a very good model with a regression coefficient r of 0.977654, and provided the possibility for the user to adjust the errors of harvested volume in using SFMM. This result was expected as a change in stocking was used directly to modify the yield table.

Therefore, SFMM transformed stocking errors to the harvested volume by the same sign and high percentage. The error variance of harvested volume by terms was small and can be ignored in practical forest management planning. It was possible to adjust the harvested volume by the regression method if necessary.

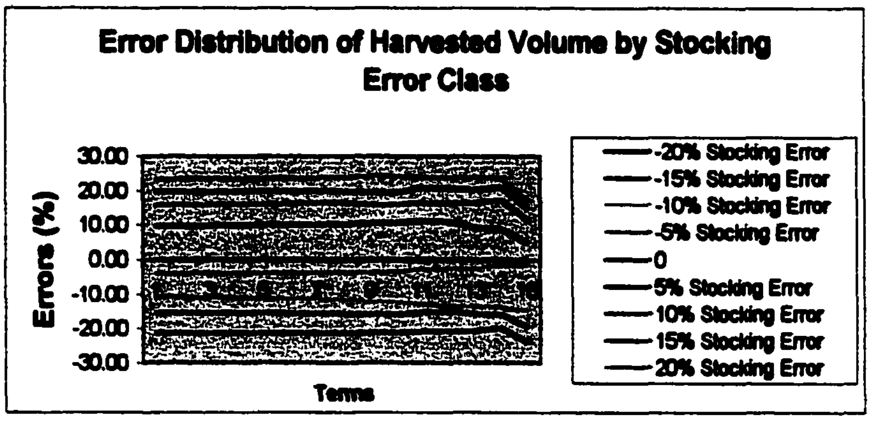

Fig 14a. Harvested Volume Error Distribution by Terms.

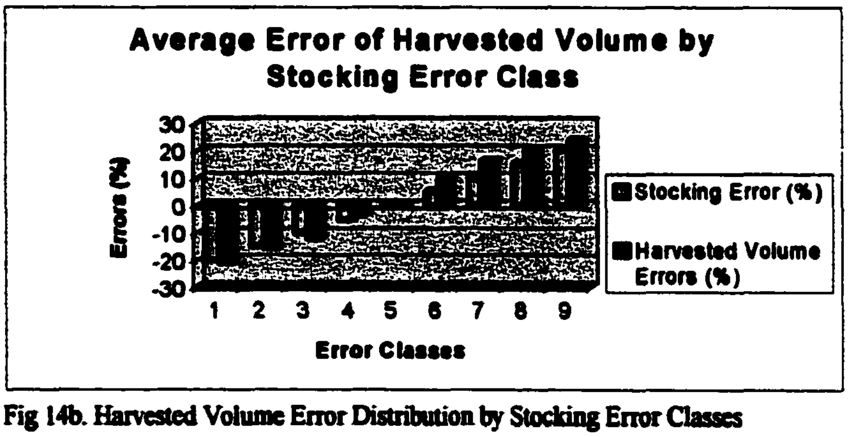

Fig 14b. Harvested Volume Error Distribution by Stocking Error Classes

4.3.3 Stumpage Revenue Error

Table 27 (Appendix VI), Fig 15A, and Fig 15B show the distribution of errors of stumpage revenue by term and stocking error class. The errors had same signs as stocking errors. Compared with the stocking errors, the errors were matched very well on the negative side but a bit large on the positive side. Fig 15B shows the same trend for the average error and with a great discrepancy on the positive side. These could mean that there were no new errors produced in SFMM running for the negative side and some new errors in SFMM as well as inherited errors from stocking errors for the positive side.

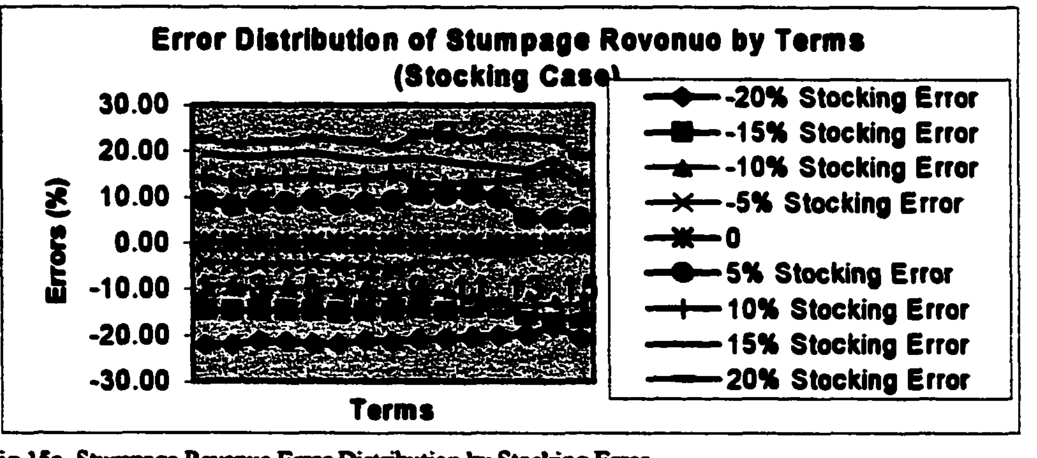

Fig 15a. Stumpage Revenue Error Distribution by Stocking Error

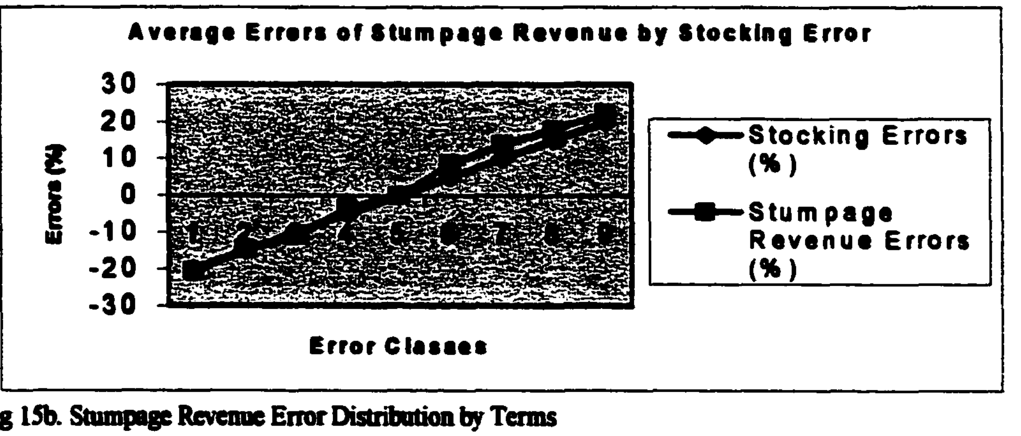

Fig 15b. Stumpage Revenue Error Distribution by Terms

Error ranges by term were from 2.56% to 5.28% and averaged to 4.22. The range of the errors by term is 2.65%, which indicates there is no significant variance by terms in different stocking error case. Statistical analysis (Appendix VI-1) indicated that the difference among different terms was insignificant. Therefore, the difference can be ignored in SFMM application. Compared with term errors, cases average errors were significantly different from case to case.

The new errors produced in SFMM (Stocking error – Stumpage Error) varied from –1.57% to 3.86% and average to 1.93%. Compared with the stocking errors, the new errors were very low and could be ignored for a long term forest management planning. The error changes from one stocking error class to another were very large, which suggested a need of adjustment in real forest management planning. The regression equations presented in Appendix VI-2 can be applied to make an adjustment for stumpage revenue errors (Further instruction on the use of the Appendix VI-2 will be discussed in the following section of the thesis).

As stumpage was derived directly from harvested volume, a close relationship was expected. The variations from term to term were caused by SFMM's allocating different species to meet the management objectives.

SFMM inherited the errors of stocking, and transformed it into stumpage revenue with nearly same rate as the original value. Newly produced error averaged to 1.93%.

4.3.4 Silviculture Expenditure Errors

Table 28 shows the error variance of silvicuture expenditure with terms and error classes of stocking. From Fig 16A and Fig 16B, the following conclusions were reached.

(1) Given each error class of stocking, errors of silviculture expenditure have little variance with planning terms, although there are some exceptions such as term 2 and term 8-10. This result was expected as equal renewal costs and seedling requiring was defined in the silviculture objective screen. This could hide the cost difference caused by forest unit changes that SFMM made to keep harvested volume stable by terms. The exception of term 8-10 was caused by tending stands.

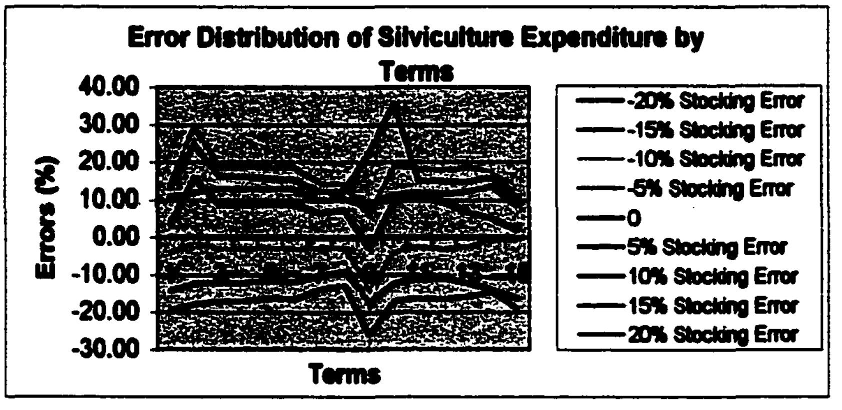

Fig 16a. Silviculture Expenditure Error by Terms

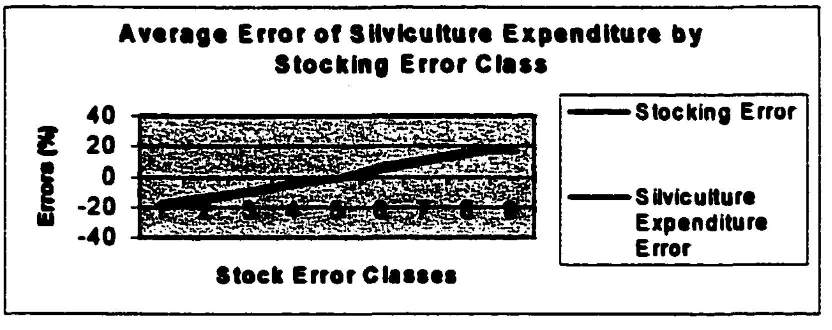

Fig 16b. Silviculture Expenditure Error by Stocking Error classes

(2) The error ranges of classes vary. For example, error class 15% has the largest range of 24.48%, but on the other hand, error class –15% gained the smallest range of

5.07%. The large variance of ranges was expected as SFMM adjusted the term distribution of silvicuture costs to respond to the stocking change.

(3) The average errors by stocking error class were close to the values of corresponding stocking error values but a bit lower. The new errors produced in SFMM varied from –3.02% to 2.03% and averaged 2.17% that was close to the value of stumpage revenue's case. This means that silviculture expediture errors had close co-relationships with stocking errors (See also Appendix VI-2).

(4) A statistical analysis (Appendix VI-1)showed that there were significant differences between terms, and between stocking error classes.

(5) A stong linear relationship between stocking error and silviculture expenditure error suggested that it was possible to predicate and adjust the errors in SFMM. The regression results are presented in Appendix VI-2.

SFMM transformed stocking errors to silviculture expenditure. Newly produced errors by SFMM averaged 2.17% above the stocking error line.

4.3.5 Shannon Weiner Index and Wildlife Habitat Area Errors

Table 29 (Appendix VI) shows the error distribution by terms and stocking error classes. Generally, there was no universal pattern that could be used to describe the error characteristic in a given term. Compared by different error classes, the error of Shannon Weiner Index was uniform on the negative side and less uniform for the positive side although a general small increasing trend was observed from ±5% to ±20%.

Compared with stocking errors, the maximum was only 0.39% and at the same time, the error range in a given term was very low too.

Statistical analysis (Appendix VI-1) indicated a significant difference between stocking error classes, and between terms. Fortunately, the whole errors were not large enough to compare to the values of stocking error classes (Fig 17). Shannon-Wiener index is only related with the forest type and age classes or wildlife habitat unit to which a forest belongs. Stocking change has no influence on the above aspects. These small changes may be caused by the natural succession and silvicuture resulted from stocking change.

This suggests that SFMM did not transform the stocking errors to Shannon Weiner Index.

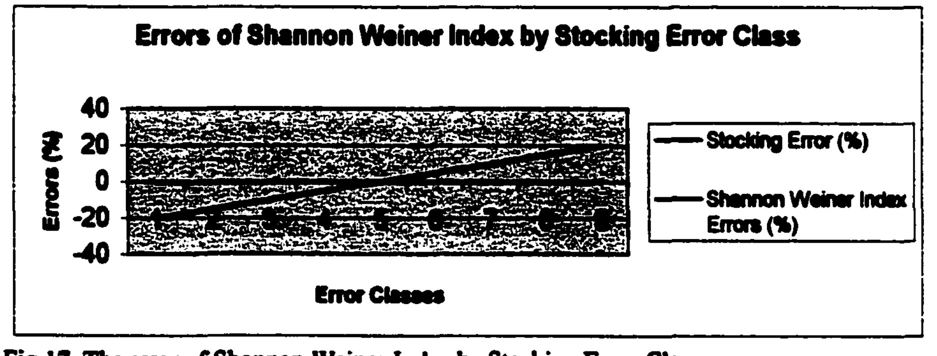

Fig 17. The error of Shannon Weiner Index by Stocking Error Classes

Fig 18 indicates that there were no relationships between the errors of wildlife habitat area and stocking errors too, similar to the Shannon Weiner Index. Although the errors presented in Table 30 (Appendix VI) were a bit larger those in Table 29, the statistic analysis (Appendix VI-1) indicated significant difference between terms, and

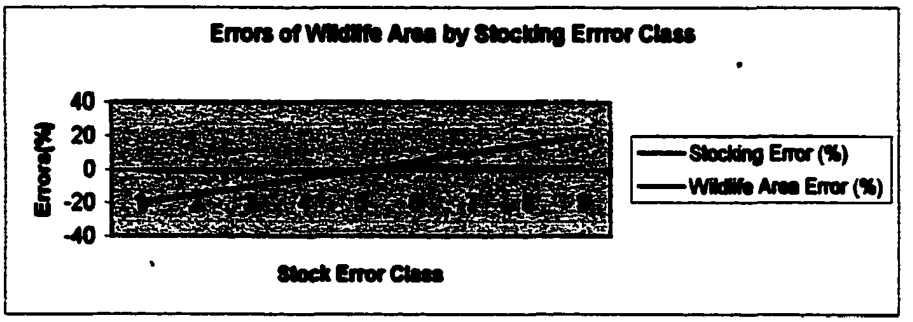

Fig 18. Error Distribution of Wildlife Habitat Area By Stocking Error Classes

between stocking error classes. Similar to the Shannon Weiner Index, the whole errors in the item were small and can be ignored in practical forest management planning without any problems for future forest management.

4.3.6 Net Present Value (NPV) Errors

Fig 19 shows that errors of NPV in different stocking error classes are comparable to the stocking errors. Generally the errors are larger than stocking error, which means that SFMM could amplify the stocking error and transform them to NVP.

The newly produced errors in NPV vary from 6.01% to 0.55% (Table 31), positive deviations were expected depending on different stocking errors. Appendix VI-2 presents the adjustment regression equation.

Table 31 Financial Summary Errors in SFMM.

Sto_Err_FRI	-20	-15	-10	-5	0	5	10	15	20
Stu_Ren_Err	-21.65	-14.43	-9.72	-4.20	0.00	8.77	13.89	19.14	22.07
Sil_Exp_Err	-21.61	-15.07	-10.76	-3.87	0.00	9.35	15.18	19.61	22.88
Har_Costs	-6.25	-5.95	0.46	0.12	0.00	5.79	1.67	7.71	8.32
Ren_Costs	-13.54	-9.32	-5.45	-9.67	0.00	-10.11	-2.02	20.84	-8.97
NPV	-26.01	-16.26	-11.69	-5.55	0.00	9.43	16.39	21.81	25.67

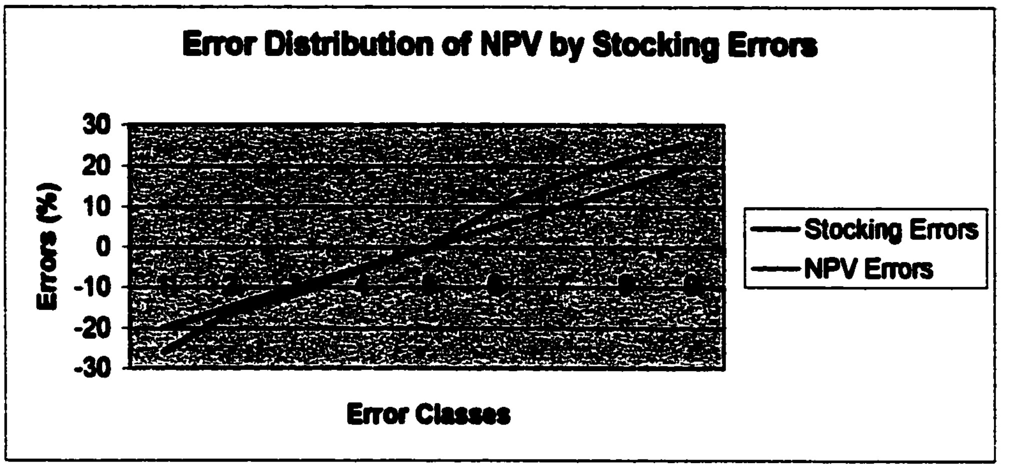

Fig 19. Error distribution of NPV by Stocking Error

4. 4 Combination cases

4.4.1 Total Forest Area Error

Table 32 summarises the error distribution of the total forest area by planning terms and by error classes.

Table 32. Error Distribution of Total Forest Area by Planning Terms (Area Weighted Average)

Error Distribution of Total Forest Area									
Co_err_FR I	-20%	-15%	-10%	-5%	0	5%	10%	15%	20%
T1	0	0	0	0	0	0	0	0	0
T2	0.34	0.29	0.71	0.73	0	1.16	2.67	2.86	-4.9
T3	1.43	1	0.75	0.94	0	0.39	1.35	1.85	-2.36
T4	0.93	0.96	0.37	0.3	0	0.81	1.12	2.14	-3.06
T5	2.26	0.97	0.33	0.2	0	0.15	0.6	0.98	-4.45
T6	1.39	1.2	0.44	0.09	0	0.91	1.23	2.18	-4.41
T7	2.7	0.7	0.31	0.22	0	0.33	0.12	0.57	-4.08
T8	0.29	0.41	0.16	0.34	0	0.12	0.06	0.32	-3.96
T9	0.14	0.28	0.26	0.51	0	0.27	0.22	0.41	-4.56
T10	0.1	0.27	0.25	0.47	0	0.13	0.17	0.33	-4.58
T11	0.34	0.38	0.41	0.58	0	0.07	0.14	0.3	-4.65
T12	0.36	0.57	0.45	0.68	0	0.06	0.05	0.21	-4.47
T13	0.23	0.53	0.51	0.7	0	0.05	0.06	0.2	-4.37
T14	0.3	0.76	0.78	0.96	0	0.03	0.04	0.2	-4.14
T15	0.67	1.16	1.19	1.4	0	0.04	0.06	0.28	-3.57
T16	0.91	1.47	1.42	1.65	0	0.01	0.12	0.34	-3.47
Total	12.41	10.94	8.35	9.76	0	4.56	8.02	13.16	-61.02
Average	0.89	0.78	0.6	0.7	0	0.33	0.57	0.94	-4.36

In order to find the significance of the difference between the error classes of the combination of the errors of age, height, and stocking in FRI, a statistical analysis was applied (Appendix VII-1-1, and Appendix VII-1-2 where case 20% was excluded from for simplifying the analysis). The results showed that the terms and error classes had effects on the errors of total forest area by forest units. By included or excluded case 20%, statistical analysis showed similar results, which suggest that large errors in case 20% were not causal but from the compound effect of stock and age error.

Compared with age errors and stock errors applied in the study, the TFAE were very small and had no significant effects on forest management planning as the errors came from the sum of TFAE of forest units.

Therefore, in the application of SFMM, we can ignore TFAE.

4.4.2 Harvested Volume Error

Table 33-1 shows a strong proportional relationship between combination errors of FRI and errors of harvested volume in SFMM.

Table 33-1. Error Distribution of Harvested Volume in SFMM by Planning Terms

Error (%) Distribution of Harvested Volume									
CO_err_FRI	-20%	-15%	-10%	-5%	0	5%	10%	15%	20%
T1	-22.98	-20.74	-15.3	-6.32	0	10.11	15.54	11.55	-7.63
T2	-22.65	-20.69	-15.6	-6.09	0	9.25	15.64	11.75	-7.2
T3	-23.17	-20.65	-15.38	-5.84	0	9.43	15.75	11.98	-6.76
T4	-22.89	-20.6	-15.15	-5.58	0	9.62	15.87	12.16	-6.29
T5	-22.59	-20.55	-14.92	-5.32	0	9.81	15.99	12.41	-5.81
T6	-22.27	-20.5	-14.68	-5.04	0	10.02	16.11	12.65	-5.31
T7	-21.95	-20.44	-14.42	-4.75	0	10.2	16.25	12.9	-4.79
T8	-21.6	-20.36	-14.14	-4.44	0	10.42	16.41	13.18	-4.24
T9	-21.15	-21.17	-14.81	-5.17	0	5.89	16.63	13.04	-7.8
T10	-20.7	-21.89	-15.46	-5.63	0	1.41	16.84	9.17	-5.66
T11	-23.68	-21.68	-14.46	-4.06	0	-2.23	14.51	10.54	-4.49
T12	-25.89	-23.83	-15.15	-6.97	0	-1.89	15.95	12.26	-2.51
T13	-25.64	-22.41	-13.67	-5.43	0	0.45	16.71	16.51	3.25
T14	-28.45	-24.75	-16.75	-8.46	0	0.42	14.09	17.62	4.67
T15	-28.71	-24.84	-17.14	-8.75	0	4.46	13.13	20.3	8.43
Total	-354.31	-325.1	-227.22	-87.84	0	87.37	237.43	198.04	-52.13
Average	-23.62	-21.67	-15.15	-5.86	0	5.82	15.83	13.2	-3.48

To survey the difference between planning terms, two-factor statistical analysis was carried out. The results showed that there was no significant difference between different planning terms but large significant differences between cases (The results are presented in Appendix VII-2-1).

Although there was no significant difference between terms, for each error class, the error does increase, with an error range of 16.23% in the larger error classes and 33.27% in the smaller error classes. There was no uniform pattern to describe the ranges.

Generally, it seems that average of each case was very close to the corresponding error in combination but a bit higher. If we drop out case 30%, the newly produced error (current error minus the corresponding combination error, see species cases) averaged to 2.3%. This tells us the error produced by SFMM might be around 2.3% because of the error combination of height, stock and age.

A strong relationship between error classes of FRI and harvested volume errors were observed and generally indicated an evident linear relationship on the negative side. However there was no that kind of evident linear relationship on the positive side. This relationship seems to corresponds to the species composition cases.

Table 33-2. Regression Summary of Harvested Volume Errors in SFMM (Excluding case 20%).

Regression Statistics	
Multiple R	0.983333
R Square	0.966944
Adjusted R Square	-1.33333
Standard Error	2.993394
Observations	1

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	8	1572.656	196.5821	175.5117	0.006
Residual	6	53.76246	8.96041		
Total	14	1626.419			

Coefficients

		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B	
Model		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	-.872	1.083		-.805	.452	-3.522	1.779
	Err_class	1.224	.092	.983	13.248	.000	.998	1.450

* Dependent Variable: Error of Harvested Volume in SFMM

Negative FRI errors generally cause negative and somewhat higher (absolute value) errors of harvested volume in SFMM, and positive FRI errors, positive errors but a bit lower. A regression equation was found for harvested volume with combination errors (Table 33-2 excluding case 20% and VII-2-2 excluding case 20%).

The table above shows that the regression relationship is very significant (F>>>Fa) and the regression coefficient (R) is 0.983, a good indicator of close relationship and efficiency of the equation used to adjust the deviation of harvested volume.

4.4.3 Stumpage Revenue Error

Table 34 shows the errors of stumpage revenue by terms. It suggests that the error rates in SFMM were roughly the same as FRI errors. Take case –20% as an example, we can find that the average error of terms was –26.42%, a difference of 6.42% from corresponding case error. The second class 15%, a difference of 5.53%, the third and fourth class 10% and 8.07%, only a 3.69% of difference. Compared with the negative side, the other side is a bit different. The errors for class 5% and 10% were nearly same as FRI's errors, which suggests that the secondary error produced in SFMM was not high, and the errors came mainly from FRI errors. Case 15% had lower error. Unfortunately, the case 20%, showed very different results. This case, as mentioned before, must involve some specific reason and very unique, which might suggest a further research needed.

Compared with different terms by case, the error ranged of from –20% error class to 20% of FRI are presented in the following table (Table 35). From the table, we know that the average of range was about 11.73%. We can also find that most ranges are very close 11.73%, which suggested a similar trend existed in each term between different cases.

Table 34 Error Distribution of Stumpage Revenue in SFMM by Terms.

Error (%) Distribution of Stumpage Revenue									
Co_err_FRI	-20%	-15%	-10%	-5%	0	5%	10%	15%	20%
T1	-23.48	-19.68	-15.12	-5.78	0	4.89	9.44	7.14	-7.85
T2	-24.23	-17.82	-14.88	-6.01	0	7.21	13.71	10.38	-7.02
T3	-24.8	-18.22	-15.74	-6.85	0	5.98	10.62	7.79	-8.21
T4	-23.81	-18.44	-14.96	-5.51	0	6.08	12.37	8.58	-7.37
T5	-23.09	-17.8	-14.23	-4.76	0	6.35	12.94	10.18	-7.19
T6	-22.64	-17.35	-14.25	-5.24	0	6.55	13.18	9.61	-6.44
T7	-22.84	-17.2	-14.56	-5.36	0	7.92	14.21	12.23	-5.53
T8	-24.63	-17.5	-14.17	-5.62	0	7.22	13.43	11.15	-6.31
T9	-23.46	-20.56	-17.7	-9.57	0	7.16	15.15	12.41	-5.84
T10	-23.66	-22.82	-20.26	-11.36	0	6.55	14.88	13.89	-0.15
T11	-26.08	-27.58	-22.95	-12.9	0	0.9	13.4	15.83	2.4
T12	-32.4	-29.19	-25.2	-15.04	0	0.73	16.76	19.4	3.74
T13	-32.91	-26.49	-22.53	-12.14	0	2.96	19.49	20.18	7.74
T14	-33.58	-26.32	-22.43	-12.16	0	3.5	15.39	20.74	8.35
T15	-32.89	-25.92	-22.04	-12.09	0	4.3	13.31	19.47	7.95
Total	-396.29	-322.89	-271.01	-130.39	0	78.31	208.27	198.97	-31.75
Average	-26.42	-21.53	-18.07	-8.69	0	5.22	13.88	13.26	-2.12

Within each class, the lowest errors generally appeared before mid-term on the negative side. From term one to term 15, errors increased generally to some extent depending on classes.

Table 35. Descriptive Statistic of Stumpage Errors (%) by Error Classes.

	N	Range	Minimum	Maximum	Mean
-20%	15	10.94	-33.58	-22.64	-26.4200
-15%	15	10.28	-15.04	-4.76	-8.6927
-10%	15	11.99	-29.19	-17.20	-21.5260
-5%	15	11.03	-25.20	-14.17	-18.0660
0	15	.00	.00	.00	.0000
5%	15	7.19	.73	7.92	5.2200
10%	15	10.05	9.44	19.49	13.8853
15%	15	13.60	7.14	20.74	13.2653
20%	15	16.56	-8.21	8.35	-2.1153
Valid (listwise)	N15				

Two factor analysis (Appendix VII-3-1) showed that there is no significant difference between terms but a significant difference between cases. Generally, average 6% of newly produced error from the corresponding case error was derived. In other words, SFMM not only inherited combination error values from cases but also added extra 6% (approximately) to the stumpage revenue. It is possible to correct the error because of a strong linear relationship between the errors with combination errors.

Therefore, the important conclusions are SFMM inherits all of the errors from FRI and adds another 6% to Stumpage Errors, which errors have same signs as FRI errors. Within every FRI error class, the stumpage error increases from low terms to higher terms and increment varies from 7.19 to 13.6. It is possible to adjust the stumpage error by using linear equation developed in the research (see Appendix VII-3-2).

4.4.4 Silviculture Expenditure Error

Table 36 shows a trend different from the stumpage revenue. Except for the case 20%, the other cases produced silviculture expenditure errors, same signs as case errors. It seems that SFMM inherited the errors of FRI and transmitted them to silviculture expenditure with a bit reduction for negative end and but with a bit increasing for the positive side without taking consideration of case 15% and 20%. If we compute the error deviation from FRI error class and get an absolute value of accumulated error equal to 15.44 (|20-18.44|+|15-15.99|+|10-9.07|+|5-3.01|+|5-5.99|+|10-12.75|+|15-7.67|) or 1.93% of average error. This means that error transmission is very precise and little secondary error produced in the SFMM application.

Table 36. Error Distribution of Silivicalture Expenditure in SFMM by terms (Species Composition Cases)

Error Distribution of Silviculture Expenditure									
Co_err_FRI	-20%	-15%	-10%	-5%	0	5%	10%	15%	20%
T1	-17.05	-18.1	-11.15	0.08	0	11.59	18.11	4.37	-10.22
T2	-22.81	-17.92	-10.24	-6.28	0	4.48	12.72	5.08	-14.64
T3	-16.39	-13.67	-12.87	-5.39	0	9.59	8.26	4.47	-10.92
T4	-13.88	-12.15	-7.27	0.02	0	8.51	13.87	10.51	-5.53
T5	-13.82	-13.82	-8.11	-0.77	0	8.37	14.62	9.02	-7.05
T6	-17.18	-14.36	-9.68	-2.51	0	7.8	10.41	27.49	12.3
T7	-17.97	-18.3	8.75	15.79	0	26.69	29.54	27.05	11.5
T8	-17.33	-10.76	-8	-2.2	0	6.87	7.92	6.14	-6.66
T9	-11.82	-15.28	-8.31	-3.82	0	4.37	9.27	-16.5	-29.73
T10	-25.25	-14.02	-10.32	-15.28	0	1.66	8.92	-21.2	-30.07
T11	-16.96	-12.5	-12.1	-4.12	0	-1.52	10.2	6.89	-5.86
T12	-18.64	-19.73	-11.68	-5.29	0	-1.24	13.84	10.64	-3.85
T13	-20.33	-18.89	-10.7	-3.97	0	-0.41	15.51	12.61	0.46
T14	-23.59	-20.39	-12.36	-5.78	0	-0.12	10.16	13.78	2
T15	-23.51	-18.93	-12.05	-5.65	0	3.27	7.87	14.65	4.38
Total	-276.55	-239.81	-136.1	-45.2	0	89.92	191.24	114.99	-93.89
Average	-18.44	-15.99	-9.07	-3.01	0	5.99	12.75	7.67	-6.26

Within a given error class, the silviculture Expenditure Errors vary from lower terms to higher terms too for most of researched cases. Unfortunately there are some exception occurred in some cases such as case 10% and case 15%. Being compared with stumpage revenue, the error ranges seem wider (see Table 37), the mean value of ranges is 27.09 and two times of the average range of stumpage revenue errors.

Statistic analysis results (see Appendix VII-4-1) shows there are significant statistical differences between different terms and cases.

The general conclusion is that SFMM transmits FRI error to Silviculture Expenditure precisely although the range of error existing in each term seems to be big. The regression equation in Appendix VII-3-1 can provide a mean of adjustment of error even if the error produced in SFMM is very small.

Table 37. Ranges of Silviculture Expenditure Error

Cases	-20%	-15%	-10%	-5%	0	5%	10%	15%	20%
Range(%)	13.43	9.63	21.62	31.07	0	28.21	21.67	48.69	42.37

4.4.5 Shannon Weiner Index Error

From Table 38, it is easy to find that the errors have reverse signs and very small values compared to the corresponding case errors. The error ranges of cases varied from case to case among 1.24 ~ 9.74%. These indicate small influence on the index from changes of term and combination errors compared with the error values of combination cases. The smaller error corresponding to large error classes is not casual, but indicates larger influence from the larger error classes than from the smaller error classes. This [illegible]

[illegible] Error by Terms in SFMM

Error (%) Distribution of Shannon Weiner Index									
Co_err_FRI	-20%	-15%	-10%	-5%	0	5%	10%	15%	20%
T1	0.92	0.1	0.38	1.08	0	0.63	-0.05	0.3	2.32
T2	-0.63	-2.47	-1.01	-0.12	0	-0.51	0.05	-1.69	-3.57
T3	-0.94	0.31	-0.35	-0.16	0	-0.97	-1.72	-3.38	-3.74
T4	0.82	1.73	0.9	0.84	0	-0.07	-0.43	-1.85	-5.78
T5	0.1	1.04	1.15	0.44	0	-3.03	-2.63	-6.45	-7.42
T6	3.27	2.59	1.87	0.94	0	-0.86	-0.91	-3.85	-4.79
T7	1.38	2.4	0.43	0.97	0	-0.44	-0.07	-2.44	-4.02
T8	-0.18	1.5	0.18	0.41	0	-1.08	-1.1	-3.35	-4.97
T9	0.5	1.34	0.74	0.91	0	-0.9	-0.86	-3.1	-4.5
T10	0.93	1.38	0.81	1.03	0	-0.65	-0.79	-3.05	-4.23
T11	0.78	1.6	0.66	0.93	0	-0.28	-0.23	-2.2	-3.72
T12	0.09	1.18	0.36	0.61	0	-0.33	-0.31	-2.06	-3.73
T13	-0.11	0.96	0.15	0.44	0	-0.36	-0.32	-1.95	-3.68
T14	0.05	0.96	0.14	0.44	0	-0.25	-0.08	-1.54	-3.4
T15	-0.14	0.8	-0.03	0.27	0	-0.26	0.17	-1.29	-3.59
Toatal	6.84	15.4	6.39	9.03	0	-9.36	-9.28	-37.87	-58.79
Average	0.43	0.96	0.4	0.56	0	-0.58	-0.58	-2.37	-3.67
Range	4.21	5.06	2.88	1.24	0	3.66	2.8	6.75	9.74

Appendix VII-5-1 shows there is significant difference between various terms and between cases. This result suggested a smaller but close relationship between the errors of the index and combination errors. In age and stock case sections, significant differences between cases but not terms had been derived from the study. The significant differences both between terms and between cases for this section are reasonable.

The average of each class of error does not show a trend with case error although the statistical analysis presented a very significant difference. For this reason, like species composition, it is not possible and practical to develop an adjustment equation. All of the errors in Shannon Weiner Index could be neglected in forest management and except for biodiversity.

Shannon Weiner Index is sensitive to the combination cases of age, height and stock but at a very small change.

4.4.6 Net Present Value (NPV) Error

Table 39. Errors of Financial Summary by Error Class

Finances Errors (%) Distribution of Financial Summary									
	-20%	-15%	-10%	-5%	0	5%	10%	15%	20%
St_Revenue	-17.86	-12.30	-8.46	1.43	0.00	7.94	14.38	20.46	17.48
Sil_Expenditure	-16.07	-13.67	-7.65	2.37	0.00	7.40	16.42	21.02	17.48
Har_Costs	28.78	26.76	34.35	37.44	0.00	31.81	42.88	55.23	22.04
Ren_costs	-58.92	-44.30	-10.05	-15.29	0.00	-36.91	-8.38	-6.38	5.14
NPV	-26.78	-17.52	-16.81	-5.46	0.00	5.11	8.06	14.34	16.95

ST_Revenue: Stumpage Revenue/ Sil_Expenditure: Silviculture Expenditure
Har_costs: Harvesting costs / Ren_costs: Renewal costs.

Table 39 shows the errors of final financial summary items in the combination cases. The stumpage revenue and silviculture expenditure have been discussed before of this section and no further discussion will be offered here. Renewal costs had a very great range of errors between different cases. From the negative side we can observed that that errors are 3 to 5 times of case errors, but the other side shows a very random error distribution. On the other hand, it consists of only a very small part of financial summary, and for this reason, will not discussed too much.

Net Present Value has a uniform changing pattern. Generally, newly produced error by SFMM had an average value of about -2.76%. This means SFMM has a very good predication to the Net Present Value, which must benefit from the defining of choice Greatest Net Present Value when SFMM was running.

It is reasonable and possible to develop a predicative equation for NPV. The Appendix VII-6-1 shows the results of regression analysis of NPV. The equation developed has very good correlation coefficient with significantly linear relationship and can be used in adjust the NPV in practical forest management planning.

4.5 General Discussion

4.5.1 Total Forest Area Errors

From Table 40 (Appendix VIII) and Fig 20, we know that the total forest area errors had no significant co-relationship with the errors of survey factors except for species cases. The detailed reasons for each have been discussed (see section 4.0). The average errors of the total forest area by different survey factor in a given class varied with classes, generally, from 0.31% to 3.1% (excluding species cases). The range of the error was only 2.79%, suggesting a little change of errors with survey factor. On the other hand, the error values were very low. Statistical analysis (Table 41) indicated that there were no significant differences between different survey factors, and between different error classes.

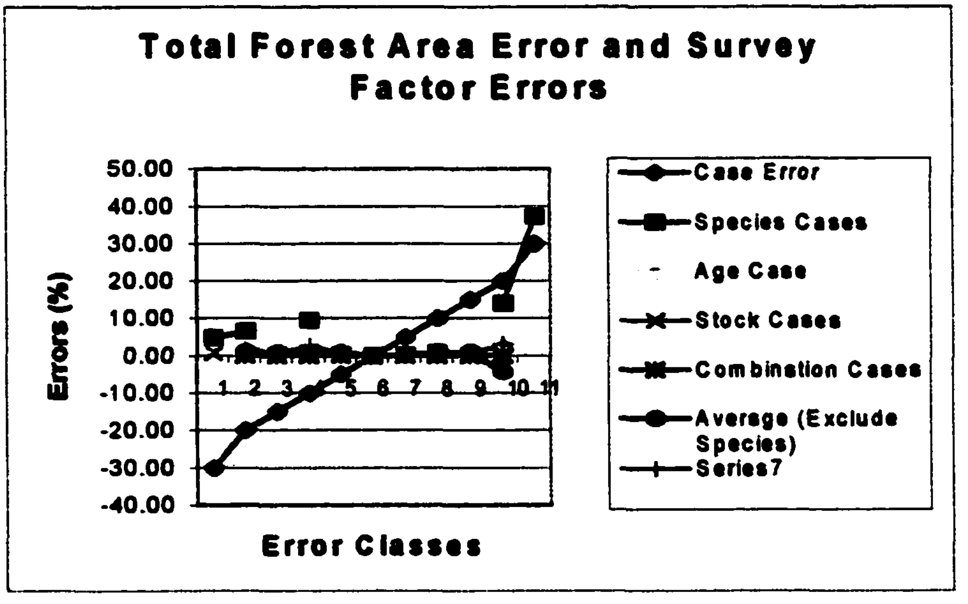

Fig 20. total forest area error by survey factor errors

Therefore the errors in Table 40 are attributed to random errors, and can be ignored to practical forest management planning. The conclusion is reasonable for practical forest management planning.

Table 41 Two Factor Analysis of Total Forest Area Error (row: survey factors, column: error cases)

ANOVA

Source of Variation	SS	Df	MS	F	P-value	F crit
Rows	3.322908	2	1.661454	0.969931	0.403185	3.73889
Columns	2.660967	7	0.380138	0.221919	0.973623	2.764196
Errors	23.981455	11				
Total	29.96533	23				

4.5.2. Harvested Volume Errors

Fig 21 and Table 42 indicated a strong linear relationship among error classes, combination cases and stock cases, although age cases did not have this kind of relationship. Species cases had very different characteristics as discussed (section 4.1). Combination cases showed a trend similar to stock cases. This explained that stock errors played an important part in the error of the combination cases.

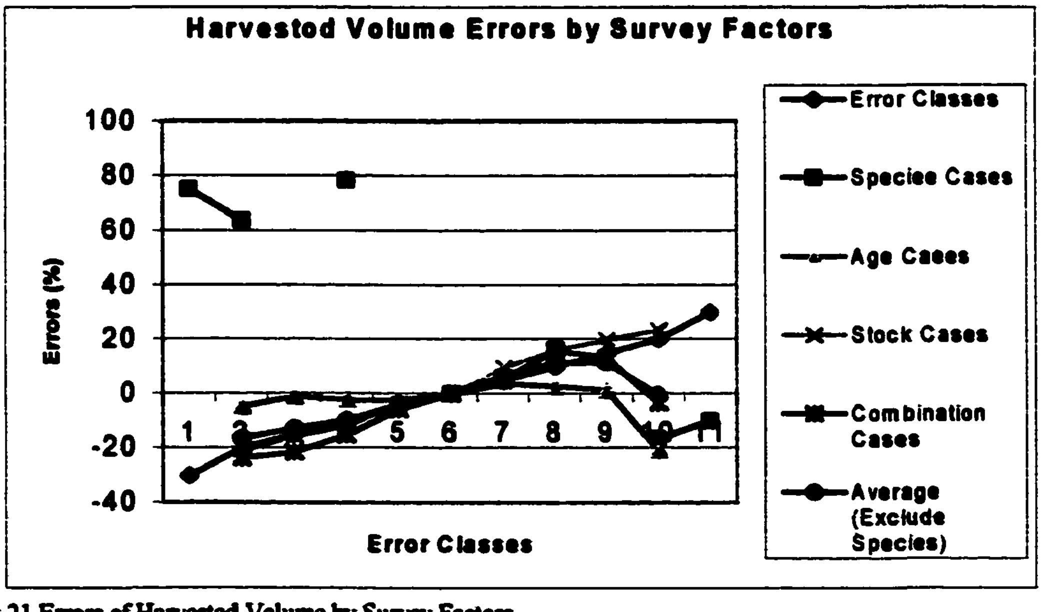

Fig 21 Errors of Harvested Volume by Survey Factors

Statistical analysis (Appendix VIII, Table 43) indicated no significant difference by different survey factors, but a significant difference between error cases. The variance of stock cases and combination cases were very close to each other. The age case seems to have very different variance but the statistical analysis indicated no difference. A correlation analysis (Table 44) and a covariance analysis (Table 45) were applied to analyze the difference of harvested volume error between survey factors. Both of them indicated that age case had less relationship with combination cases, and stock cases are more related with combination case. This also confirms that age had less effect on the harvested volume error. The errors of the combination cases combining with age, stocking and height, mainly resulted from stock because my preliminary research showed that height has no effect on outputs of SFMM.

Therefore, compared with stocking and combination cases, age had less effect on the harvested volume errors although different age error might produce different harvested volume errors. Stocking had the large influence on the harvested volume.

Table 44 Correlation Analysis

	*Row 1**	*Row 2*	*Row 3*
Row 1	1		
Row 2	-0.19189	1	
Row 3	0.284583	0.871971	1

*Row 1 stands for harvested volume errors of the age cases; row 2 stands for the harvested volume errors of stocking cases; and Row 3 stands for the harvested volume errors of combination cases.

Table 45. Covariance

	*Row 1**	*Row 2*	*Row 3*
Row 1	59.61638		
Row 2	-25.6969	300.8181	
Row 3	33.32008	229.3343	229.9481

* see also Table 44's note.

4.5.3 Stumpage Revenue Errors

Table 46 (Appendix VIII) shows a very complicated error distribution. The species introduced stumpage revenue not only greater error values but also various signs of error. Age introduced less error to stumpage revenue than the others did. The average errors of stumpage revenue caused by stocking error were larger than the error class values of stocking. Combination cases caused large errors to stumpage revenue than a corresponding stocking error with an exception of case 20. Compared with the other survey factors, age can had a complex effect on the combination cases, and caused the error elevations and reduction for case 20.

Fig 22 shows various errors among different error classes and survey factors. Age cases had a very different error distribution than the stocking and combination cases. The stocking and combination cases caused very similar error distribution of stumpage revenue similar to harvested volume errors.

Statistical analysis (Appendix VIII Table 47, Table 48-1 and Table 48-2) indicated that there were significant difference between error classes (columns) and no significant differences between survey factors (rows). This was similar to the harvested volume error.

Fig 22. Stumpage Revenue Errors by Survey Factors

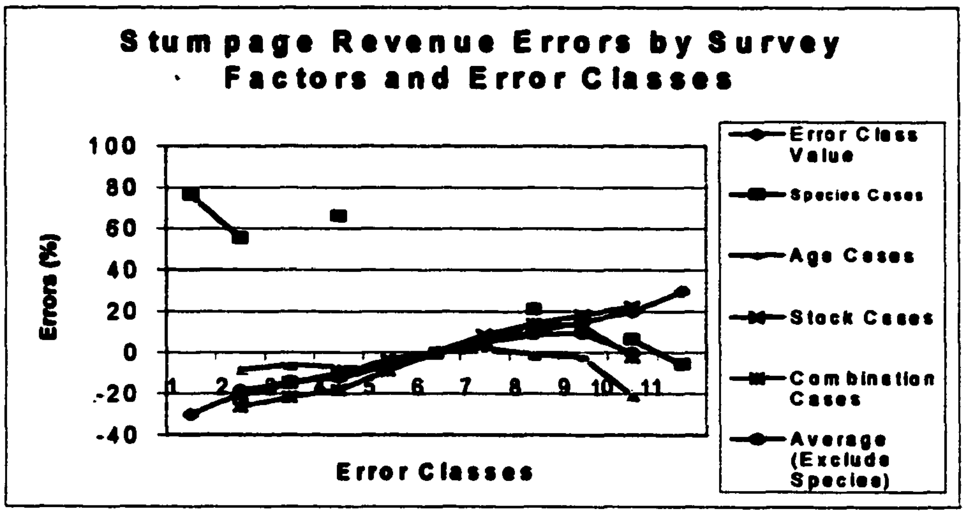

Table 48-1 Correlation between Error Classes

	*Row 1**	*Row 2*	*Row 3*
Row 1	1		
Row 2	-0.06304	1	
Row 3	0.385486	0.883308	1

* Refer to Table 44's note

Table 48-2 Covariance between Error Classes

	*Row 1**	*Row 2*	*Row 3*
Row 1	46.62445		
Row 2	-6.53901	230.7777	
Row 3	38.85298	198.0697	217.8804

* see Table 44's note

In conclusion, the age had little effect on stumpage revenue error. Stocking and combination cases had similar trends each other but combination introduced more errors than stocking cases did, which may have been caused by the age's additive effect. Generally, the average errors by survey factors were very close to error class value for the negative side of error classes, but were lower for the positive side of error classes.

4.5.4 Silviculture Expenditure Errors

Fig 23 shows that the age case had less effect on silviculture expenditures for classes -15% to 15%. Beyond that range, age cases had large minus errors of silviculture expenditures, the same trends as shown by the stocking cases and combination cases. This helps to explain why age case had less effect on many items of output errors of SFMM. The errors might overpass -20% to +20%. Just as age case, after error class 8 (15% error), the stocking case showed a discrepancy from the error class line and greater negative errors, which was similar to age cases. Stocking cases had a very similar pattern as the combination case. This can be observed in Table 49 (Appendix VIII).

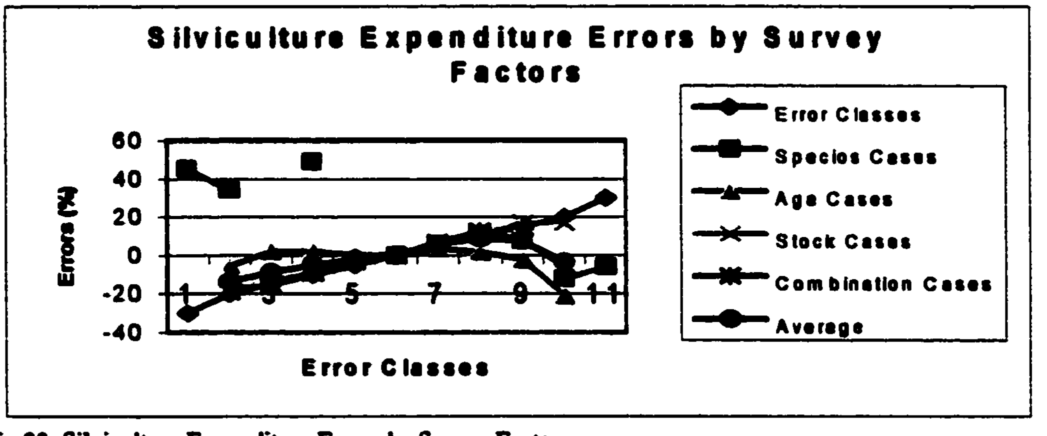

Fig 23. Silviculture Expenditure Errors by Survey Factors

Table 50 (Appendix VIII) indicated that there was no significant difference at the 95% of confidence level, but a significant difference between error classes at 85% of confidence level. Correlation analysis (Table 51) showed a weaker relationship between different survey factors.

Table 51 Correlation between FRI Factors

	Row 1	*Row 2*	*Row 3*
Row 1	1		
Row 2	-0.36351	1	
Row 3	0.219761	0.798118	1

* See Table 44's note

In a word, silviculture expenditure errors are slightly different between different error classes and survey factors, depending on how much the original error is. On the contrary, the average errors by survey factors are much lower than error class values exception for case 20 (a difference of 3% to 7%).

4.5.5 Shannon Weiner Index Errors

Table 52 shows the errors of Shannon Weiner Index. Species error had a great influence on the Shannon Weiner Index except for the positive errors of species. On the contrary, age, stock and combinations have a little influence on the Shannon Index Error.

Table 52 Shannon Weiner Index Error by Survey Factors and Error Classes

Shannon Weiner Index Error (%)											
Error Class	-30	-20	-15	-10	-5	0	5	10	15	20	30
Species	-11.1	-15.3		-17.9		0		1.29		0.59	2.36
Age		-3.72	-4.98	-6.3	-6.26	0	-1.78	-1.47	-0.78	-7.07	
Stock		-0.45	-0.34	-0.49	-0.47	0	2.91	1.42	1.39	0.88	
Combine		-0.43	-0.96	-0.40	-0.56	0.00	0.58	0.58	2.37	3.68	

Stocking, age, and combination cases has no effects on the Shannon Weiner Index change. The species case had a greater influence on the Shannon Index.

4.5.6 NPV errors

Table 53 shows the errors of NPV by survey factors. Generally, the average errors by survey factors seemed to close to the error classes for negative errors but were a bit higher. The positive errors are smaller. Statistical analysis (Table 54) indicates slight difference between survey factors and error classes.

Table 53 Net Present Value Errors (%) by Survey Factors and Error Classes

NPV Error (%)											
Error Class	-30	-20	-15	-10	-5	0	5	10	15	20	30
Species	105.9	85.36		87.84		0		33.51		16.26	-3.56
Age		-9.17	-8.33	-10.4	-13.5	0	0.27	-5.71	-7.24	-28.1	
Stock		-26	-16.3	-11.7	-9.67	0	9.43	16.39	21.81	25.67	
Combine		-26.8	-17.5	-16.8	-5.46	0	5.11	8.06	14.34	16.59	
Total		-62	-42.1	-38.9	-28.6	0	14.81	18.74	28.91	14.14	
Average		-20.7	-14	-13	-9.54	0	4.937	6.247	9.637	4.713	

Species errors increased NPV errors and caused positive errors for both sides of error classes. Fig 24 shows that species cases had very high errors, and had a very different pattern compared with the other survey factors. Age, stocking and combination cases were well matched to error classes for the negative side, but less for the positive sides.

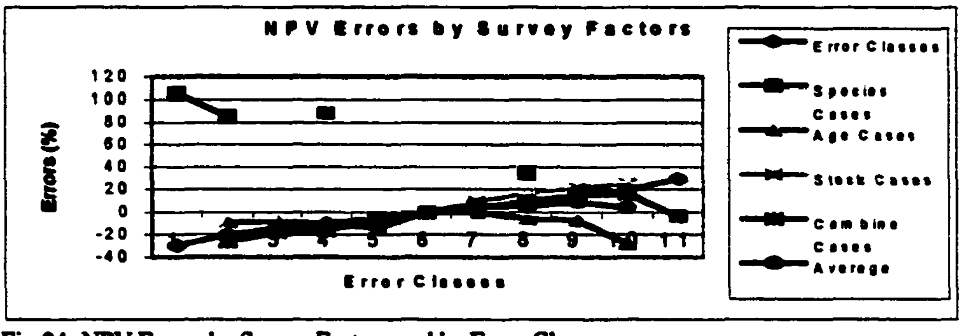

Fig 24. NPV Errors by Survey Factors and by Error Classes

Table 54. ANOVA table of NPV between survey factors.

ANOVA

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Rows	482.8784	2	241.4392	1.736567	0.207717	2.140951
Columns	2849.5	8	356.1874	2.561902	0.051999	1.803958
Error	2224.519	16	139.0324			
Total	5556.897	26				

Rows stand for survey factors, and columns for error classes.

5.0 Conclusions

The purpose of this research was to determine the effect that various errors of information from FRI would have on the accuracy of SFMM outputs and to determine the transmission of errors from FRI to SFMM. In the research, comparison, graphical, and statistical methods were applied to analyze the error transmission and distribution in SFMM outputs.

5.1 About height errors in FRI

Among all of the chosen survey factors: height, stocking, age, species and combination of height, age, and stocking, height was the only one which had no effect on the SFMM output. Nine cases with various height errors introduced in the basic data file showed that SFMM did not change its various outputs based on the height variance. From the viewpoint of dynamic forest management, future forest management planning must reflect or make response to various changes of forest conditions in which height is an very important descriptive factor. Unfortunately, SFMM does not have this sensitivity to respond to the slight changes of forest conditions.

In practical forest management, when deciding how much forest should be harvested each year, or how much profit a forest can make each year, one must consider height and age as they directly express the productivity of sites, relate to the volume harvested, and stumpage revenue. Usually height is considered when yield curves are generated or yield tables are selected, however, SFMM is not designed to do this. This was illustrated in nine cases with different heights and no changes in other factors.

In SFMMTOOL, the basic input file format required contains some fields to describe real forest conditions i.e. height, year, stock, site index, and species composition, Changing the value of one field should cause SFMMTOOL to generate different outputs or SFMM input file. In turn, based on different input files, SFMM should output various management planning results corresponding to different heights used. Unfortunately, the error test did not show any changes with varying height.

Therefore, SFMM did not respond to the height errors from FRI. It is possible that the error rates in the data set were not large enough. All of these suggested further research needed.

5.2 About age errors in FRI.

As discussed before, the errors of age cases showed very complicated patterns in the different outputs from SFMM, depending on the age errors and outputs.

First, SFMM inherited age errors in FRI and transformed them into Total Forest Area but shrunk them in the large scale. Although the error difference of the total forest area between age cases were significant statistically, it was not necessary to adjust the errors because their values were so low that they were of little consequences in large scale and long term forest management.

Second, age errors had various effects on the errors of harvested volume to some degree, depending on the magnitude of the errors and their signs. Only when the errors of age surpass 20% were the errors inherited by SFMM and transformed into harvested volume. On the other hand, the errors were subjected to changes with different initial forest conditions. Fortunately, an age error of 20% is not a common case in FRI and the errors of harvested volume can be ignored if age errors are not beyond +20% or -20%. According to the trends indicated by the research, one might expect that the errors of more than 20% might reduce harvested volumes by 20%.

Third, SFMM transformed the age errors to stumpage revenues but not at the same rate as age errors, rather at a lower rate. The stumpage revenue errors had reverse signs to the age errors for the positive errors of age. Stumpage revenue errors had weak correlation with negative age errors but a strong reverse correlation with the positive age errors. Similar to harvested volume case, stumpage revenue errors became more important and significant when the errors of age were more than 20%. This could suggest that it may be necessary to make an adjustment.

Fourth, silvicultural expenditure errors changed slightly from one age error class to another between -20% to +20%. But when the age errors were beyond ±20%, the error could increase. On the other hand, the error changes from one planning term to another were large. Both of the changes had indications of statistical significance but no discernable patter was observed.

Fifth, although there were indications of significant differences of Shannon Index Errors between age error classes, the errors were too small and had little influence on the long-term forest management or sustainable forest management strategies. Therefore, SFMM had a weak response to the age error in its Shannon Weiner Index.

Finally, SFMM has a weak ability to modify its financial output items based on the age errors, and only manipulate the term's value of various financial outputs to satisfy the age's change. This result did not seem to be reasonable, as different age should constitute very unique wildlife habitat environment. Possibly the researched error rates imposed in the research were too narrow to cause changes of wildlife habitat area.

5.3 About Stocking Errors

Compared with age cases, there were more influences detected in SFMM outputs produced by stocking errors.

Stocking errors could not be transformed into Total Forest Area in SFMM. Although there were some errors existing in total forest area in SFMM, the errors were not significant from the viewpoint of either forest management planning or statistics, and can be attributed as random errors and ignored.

SFMM transformed stocking errors to the harvested volumes with the same sign and in large unit. The error variance of harvested volume varied by planning terms was very small and can be ignored in practical forest management planning. It was possible to adjust the harvested volume by the regression model developed in the research.

SFMM inherited the errors of stocking and transformed it into stumpage revenue with nearly same rate as the stocking error value. It was possible to adjust the stumpage errors by using regression equations developed in the research because of linear relationship between stocking errors and stumpage revenue errors.

Silviculture expenditure errors were generally higher than stocking errors. Newly produced errors by SFMM averaged 2.17%, which made the silviculture expenditure error line shift up a bit comparing with the stocking error line.

Similar to the age cases, the Shannon Weiner Index had no significant relationship with stocking errors. The small error detected in the research could be attributed to the random reasons.

As for NPV, newly produced errors in SFMM varied from 6.01% to 0.55%, which made NPV line rotated anti-clockwise. Errors could be adjusted by using the equation developed in the research.

5.4 About species errors in FRI.

Species compositions had very complicated influences on the outputs of SFMM because they can change the forest management planning by the changing constitution of forest units and yield curves. As the influences from species errors were so large, it is necessary to develop a feasible method to adjust various errors produced in SFMM outputs. Unfortunately, the influences were related to many factors such as the original forest species composition, original area of each forest types, and yield curves used in calculating yield. The percentage errors used in the research were not well matched with the various output values, thus it was not possible to develop a predicative method.

Generally, SFMM transformed species errors to the objective values at a larger rate than corresponding species error. Underestimation of species compositions had greater effects than overestimations.

SFMM introduced error in total forest area in response to the species errors in FRI. The newly produced error was about 6-9%, and changed with planning terms, which could be caused by an area reallocation of forest units.

With management for a stable harvest volume, the errors incurred no error deviations from term to term in a given error class, but species errors did cause large errors to the harvested volume. The underestimation of species compositions might over-cut forest and vice versa. Over-cutting can be more than 45% and under-cutting 17% less.

The errors of species composition can introduce errors into stumpage revenue. Underestimation of species could wrongly increase stumpage revenue by 3-6 times of species errors. Overestimation could introduce errors to stumpage revenue, but no discernable pattern for the various and minus errors was found.

Species errors introduced errors to the silviculture expenditure planned by SFMM. Errors produced by SFMM varied from -10% to -30% and increased from 10% to 30%. The results had no discernable pattern.

Underestimation of species compositions could produce errors in Shannon Weiner Index equal to the species errors. Overestimation of species, on the other hand, reduced the Shannon Index. The change rates decreased from case -30% to case 30%.

The errors of wildlife habitat area had large fluctuations among the researched error ranges with no evident pattern.

5.5 About combination cases

The total forest area did not change with error combinations of height, age, and stock.

Negative FRI errors generally caused negative and somewhat higher errors (in the error absolute values) of harvested volume in SFMM. Positive FRI errors caused a positive error but a bit lower than the error class value of combination case.

SFMM inherited all of the errors in the combination cases and added another 5% to Stumpage Errors. Errors had the same sign as FRI errors. Within every FRI error class, the stumpage error increased from the low terms to higher terms and increment varied from 7.19% to 13.6%. It was possible to adjust the stumpage error by using linear equation developed in the research.

Silviculture Expenditure errors were about same as the case errors although the range of errors in each term seemed to be large. The regression equation in Appendix VII-3-1 could provide a mean of adjustment of error even if the error produced in SFMM is very small.

Shannon Weiner Index was not sensitive to the combination cases of age, height and stock. Negative errors of FRI caused positive errors of Shannon Weiner Index and the vice versa.

Net Present Value has a uniform changing pattern. Generally, the newly produced error by SFMM had an average value of about -2.76%. This means SFMM had a very good predication to the Net Present Value, which must be caused by the defining of Greatest Net Present Value when SFMM was running.

6.0 Recommendations on SFMM applications

This study of SFMM was the first of its kind and was by no means the most optimal. Very little work has been done to validate SFMM and therefore it is difficult to find standardized methodologies in the research. The methodologies developed in this research were well matched with the purposes for detecting and checking behaviors of FRI errors in SFMM outputs.

SFMM is a very effective tool for forest management planning from the point of view that it is easy to learn, understand and use. It is really an accurate model for modern forest management. Most of its responses to various errors were precise, sensible, and predicative, which means the model could be adjusted in applications to satisfy different client's needs. There is still a room to improve the design and performance of SFMM. In this section, two categories of recommendations will be offered based on my research. The first category is about the error issue and treatment in FRI, and the second category is some suggestion related to the operational efficiency of the model.

6.1 Error issues and treatments in FRI

1. Age issue. SFMM has less sensitivity to age errors and change its outputs only when the age error is beyond ±20%. The age errors could shift forest area from one age class to another in SFMMTOOL, which could incur greater errors in SFMM outputs. In the real forest management planning, a survey must be done to find out the error rate in FRI, and then an adjustment can be done before using SFMM. It is easier to reduce the bias in the forest management planning at this phase than at using SFMM.
2. Stocking issues. Compared with the other survey factors, stocking errors transformed more directly into SFMM outputs. For this reason, stocking must be carefully

interpreted in FRI to control the errors. It is possible that the errors of stocking come from various channels such as interpreting error in cruising, mis-using of stocking from tables, and inherent errors in the stocking tables. Therefore, the best way is to find the best stocking tables, equipments and cruising to do the FRI survey. This might minimize the errors in the SFMM applications. On the other hand, it is possible to using regression techniques to modify the SFMM outputs because of close relationship between stocking errors and SFMM outputs.

3. Height issue. Height had no influence on the SFMM outputs. SFMM derived decisions mainly based on the site information that is associated with dominant tree height without considering the average height of a forest. This is a drawback of SFMM and forest management too.
4. Combination error issue. Of the combination cases, stocking had the prevailing role in determining the errors in the SFMM outputs. The age had an additive effect and interacting effect only when the errors were greater than 20%. It is wise to reduce this kind of combination of errors in FRI.

6.2 Some suggestions on using SFMM

1. A closer relationship should be established between the output of SFMMTOOL and SFMM. In SFMMTOOL, some summary data such as querying results and age distribution data should be available in SFMM at any time so that the user of SFMM can make a decision by referring to these data.
2. Although SFMM has a friendly interface, it was not easy to read the menu or choose items because of the large-size fonts. Secondly, the information rate per screen seems to be very low. Each time when you select a choice, you have to read the large letter

one by one on the screen, which might reduce the reading speed, and working productivity. You have to move mouse arrow from the top of the screen to the bottom. Thirdly, the color and graphical pictures (see the following Fig 25) not only distracts one, but also make the screen untidy and complicated. Considering that there are only five categories of menu items. If a pull down menu design was used, a smaller space would be needed in the design for the five categories. For example, in the figure 25 of this section, the item *Save Input Data in this Text Input File*

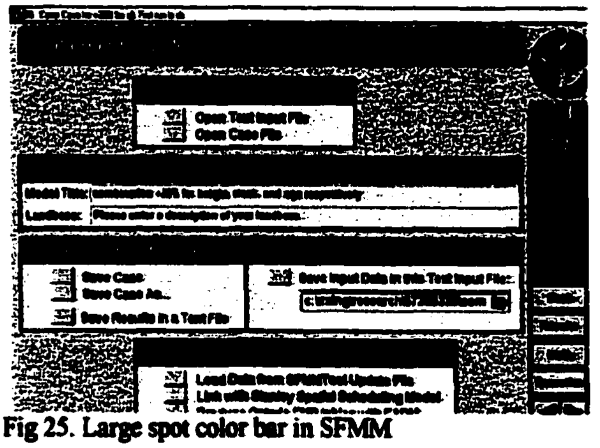

Fig 25. Large spot color bar in SFMM

The following improvements could be made to the example screen:

- A large font size had better be changed into a simple screen design.
- A smaller icon design could be used rather than the large color spot menu bar.
- A reference item that can show related information to prevent using the wrong definition or using the wrong parameter.
- Reduce the explanations on a screen. Too much information on a screen impacts the beauty of the screen or makes the screen look congested.

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Appendices

Appendix I- Basic Input File

N1	N2	N3	N4	N5	N6	N7	N8	N9	N16	N10	N11	N12	N13	N14	N15
888	0	157205330		2	31010	0	52	10	1			0.0	0.0		
888	0	157205330		1	31470	0	70	10	1			0.0	0.0		
888	0	157205330		1	31670	33	20	10	1	943	993	18.0	1.0	2	PO 5B 2BW 2SB 1
888	0	157205330		1	32460	0	70	10	1			0.0	0.0		
888	0	157205330		1	33000	0	70	10	1			0.0	0.0		
888	0	157205330		1	32000	0	52	15	5			0.0	0.0		
888	0	157205330	PW	1	70	33	20	1	1	923	993	22.0	0.6	2	PO 5B 3CE 1BW 1
888	0	157205330		1	550	0	54	1	1			0.0	0.0		
888	0	157205330		1	630	12	39	1	1	993	993	0.0	0.0	2	SW 0
888	0	157205330		1	820	13	20	1	1	938	993	12.0	0.6	1	B 4PO 2SB 1AB 1SW 1CE 1
888	0	157205330		1	1580	0	54	1	1			0.0	0.0		
888	0	157205330		1	1980	0	52	1	1			0.0	0.0		
888	0	157205330		1	2280	0	52	1	1			0.0	0.0		
888	0	157205330		1	3290	33	20	1	1	913	993	24.0	0.6	2	PO 4B 2BW 2SW 1CE 1
888	0	157205330		1	3550	0	54	1	1			0.0	0.0		
888	0	157205330		1	3590	4	39	1	1	993	993	0.0	0.0	2	PR 0
888	0	157205330		1	4610	0	52	1	1			0.0	0.0		
888	0	157205330		1	17270	0	52	1	1			0.0	0.0		
888	0	157205330		1	18990	33	20	1	1	913	993	23.0	0.8	2	PO 5BW 2CE 2B 1
888	0	157205330		1	19540	0	70	1	1			0.0	0.0		
888	0	157205330		1	19710	13	20	1	1	923	993	15.0	0.8	1	B 4PO 3PW 2CE 1
888	0	157205330		1	20710	0	52	1	1			0.0	0.0		
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888	0	157205330		1	24680	0	52	1	1			0.0	0.0		
888	0	157205330		1	24690	0	52	1	1			0.0	0.0		
888	0	157205330		1	25850	0	70	1	1			0.0	0.0		
888	0	157205330		1	25900	0	70	1	1			0.0	0.0		
888	0	157205330		1	28970	0	70	1	1			0.0	0.0		
888	0	157205330		1	30700	0	70	1	1			0.0	0.0		
888	0	157205330		1	31690	13	20	1	1	928	993	14.0	1.0	1	B 4SB 2PO 2PJ 1BW 1
888	0	157205330		1	31710	13	20	1	1	933	993	13.0	0.7	1	B 4BW 3PO 1SB 1PW 1
888	0	157205330		1	32290	13	20	1	1	938	993	13.0	0.6	1	B 5PO 3SB 1SW 1
888	0	157205330		1	32320	33	20	1	1	913	993	24.0	0.6	2	PO 4CE 2B 2SB 1BW 1
888	0	157205330		1	22030	0	54	1	5			0.0	0.0		
888	0	157205330		1	26010	0	52	1	5			0.0	0.0		
888	0	157205330		1	33020	1	20	1	5	901	993	20.0	0.8	2	PW 5PR 2B 1PO 1BW 1
888	0	157205330	PW	1	300	33	20	2	1	908	993	25.0	0.8	2	PO 5B 2SW 1BW 1SB 1
888	0	157205330		1	330	0	52	2	1			0.0	0.0		
888	0	157205330		1	660	0	54	2	1			0.0	0.0		
888	0	157205330		1	760	13	20	2	1	947	993	18.0	0.5	X	B 6PO 2SB 1BW 1
888	0	157205330		1	890	0	52	2	1			0.0	0.0		
888	0	157205330		1	2320	17	20	2	1	846	993	12.0	0.7	3	CE 7SB 2B 1
888	0	157205330		1	3910	0	70	2	1			0.0	0.0		
888	0	157205330		1	5630	0	70	2	1			0.0	0.0		
888	0	157205330		1	6910	0	70	2	1			0.0	0.0		
888	0	157205330		1	11210	0	52	2	1			0.0	0.0		
888	0	157205330		1	15760	17	20	2	1	913	993	11.0	0.5	2	CE 6SB 3BW 1
888	0	157205330		1	16730	0	52	2	1			0.0	0.0		

888	0	157205330		1	16780	0	52	2	1			0.0	0.0
888	0	157205330		1	18270	0	52	2	1			0.0	0.0
888	0	157205330		1	18610	0	70	2	1			0.0	0.0
888	0	157205330		1	19820	0	54	2	1			0.0	0.0
888	0	157205330		1	21710	0	52	2	1			0.0	0.0
888	0	157205330		1	24460	11	20	2	1	883	993	14.0	0.7 2 SB 5PO 3CE 2
888	0	157205330		1	26850	0	52	2	1			0.0	0.0
888	0	157205330		1	29820	33	20	2	1	916	993	23.0	0.7 2 PO 5B 2SB 1CE 1BW 1
888	0	157205330		1	29960	17	20	2	1	908	993	13.0	0.6 2 CE 5B 2SB 1BW 1PO 1
888	0	157205330		1	30270	33	20	2	1	986	993	12.0	0.8 2 PO 5CE 2B 1BW 1SB 1
888	0	157205330		1	30300	0	52	2	1			0.0	0.0
888	0	157205330		1	30310	0	70	2	1			0.0	0.0
888	0	157205330		1	31380	11	20	2	1	913	993	11.0	0.7 2 SB 6CE 3L 1
888	0	157205330		1	32210	11	30	2	1	993	993	0.0	0.0 3 SB 0
888	0	157205330		1	5040	0	54	2	5			0.0	0.0
888	0	157205330		1	4910	0	52	3	1			0.0	0.0
888	0	157205330		1	7260	0	52	3	1			0.0	0.0
888	0	157205330		1	7780	0	52	3	1			0.0	0.0
888	0	157205330		1	10240	0	54	3	1			0.0	0.0
888	0	157205330		1	14860	0	52	3	1			0.0	0.0
888	0	157205330		1	24430	0	54	3	1			0.0	0.0
888	0	157205330		1	31300	0	52	3	1			0.0	0.0
888	0	157205330		1	32310	11	20	3	1	913	993	11.0	0.7 2 SB 6CE 3L 1
888	0	157205330		1	32360	11	20	3	1	913	993	11.0	0.7 2 SB 6CE 3L 1
888	0	157205330		1	28020	1	20	3	5	907	993	22.0	0.7 2 PW 4PO 3B 2BW 1
888	0	157205330		1	1570	33	20	4	1	908	993	20.0	0.7 3 PO 5SB 2B 1BW 1L 1
888	0	157205330		1	4270	0	50	4	1			0.0	0.0
888	0	157205330		1	4370	0	70	4	1			0.0	0.0
888	0	157205330		1	6250	0	52	4	1			0.0	0.0
888	0	157205330		1	13520	33	20	4	1	903	993	27.0	0.7 2 PO 6SW 2BW 1B 1
888	0	157205330		1	22900	0	52	4	1			0.0	0.0
888	0	157205330	PW	1	50	33	20	4	5	923	993	22.0	0.8 2 PO 5B 3CE 1BW 1
888	0	157205330		1	2040	0	54	4	5			0.0	0.0
888	0	157205330		1	9050	33	20	4	5	921	993	25.0	1.2 2 PO 6B 4
888	0	157205330		1	7830	0	52	4	1			0.0	0.0
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888	0	157205330		1	16760	0	70	5	1			0.0	0.0
888	0	157205330	SS PW	1	29860	33	25	5	1	928	993	23.0	0.7 2 PO 4BW 3B 3
888	0	157205330		1	31020	1	20	5	1	901	993	20.0	0.8 2 PW 5PR 2PO 1BW 1B 1
888	0	157205330	SS	1	1170	7	25	5	1	928	993	16.0	0.8 3 PJ 6PO 2BW 1B 1
888	0	157205330		1	1670	11	20	5	1	883	993	14.0	0.5 2 SB 4L 2PO 2CE 1B 1
888	0	157205330		1	6650	17	20	5	1	847	993	12.0	0.8 3 CE 7B 2PO 1
888	0	157205330		1	6780	0	52	5	1			0.0	0.0
888	0	157205330		1	10210	0	52	5	1			0.0	0.0
888	0	157205330		1	16740	0	52	6	1			0.0	0.0
888	0	157205330		1	18900	11	20	6	1	958	993	6.0	0.4 2 SB 5CE 3L 1B 1
888	0	157205330		1	32240	33	30	6	1	993	993	0.0	0.0 2 PO 0
888	0	157205330	PW	1	1290	33	20	7	1	913	993	24.0	0.8 2 PO 5BW 2B 2PW 1
888	0	157205330		1	23340	0	70	7	1			0.0	0.0
888	0	157205330		1	32190	4	20	7	1	983	993	2.0	0.7 1 PR 7SW 2PO 1
888	0	157205330		1	25040	33	20	7	5	933	993	20.0	1.0 3 PO 6B 2PJ 1BW 1
888	0	157205330		1	3890	11	20	7	1	973	993	4.0	1.0 1 SB 5PO 2BW 1B 1PJ 1
888	0	157205330		1	12170	13	20	7	1	928	993	13.0	0.5 1 B 5PO 2AB 1CE 1SB 1
888	0	157205330		1	17260	0	50	8	1			0.0	0.0
888	0	157205330		1	23450	0	54	8	1			0.0	0.0
888	0	157205330		1	28960	17	20	8	1	908	993	13.0	0.6 2 CE 6B 2BW 1SB 1PO 1
888	0	157205330		1	29560	0	54	8	1			0.0	0.0

888	0	157205330		1	930	13	20	9	1	938	993	12.0	0.7	1	B 3BW 2PO 2CE 1SW 1SB 1
888	0	157205330		1	5330	11	30	9	1	993	993	0.0	0.0	2	SB 0
888	0	157205330		1	16980	36	20	9	1	928	993	17.0	0.7	2	BW 6PO 2CE 1B 1
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888	0	157205330		1	23120	7	20	9	1	933	993	17.0	1.0	2	PJ 8PO 2
888	0	157205330		1	1130	36	20	1	1	948	993	12.0	0.8	3	BW 5PO 3B 2
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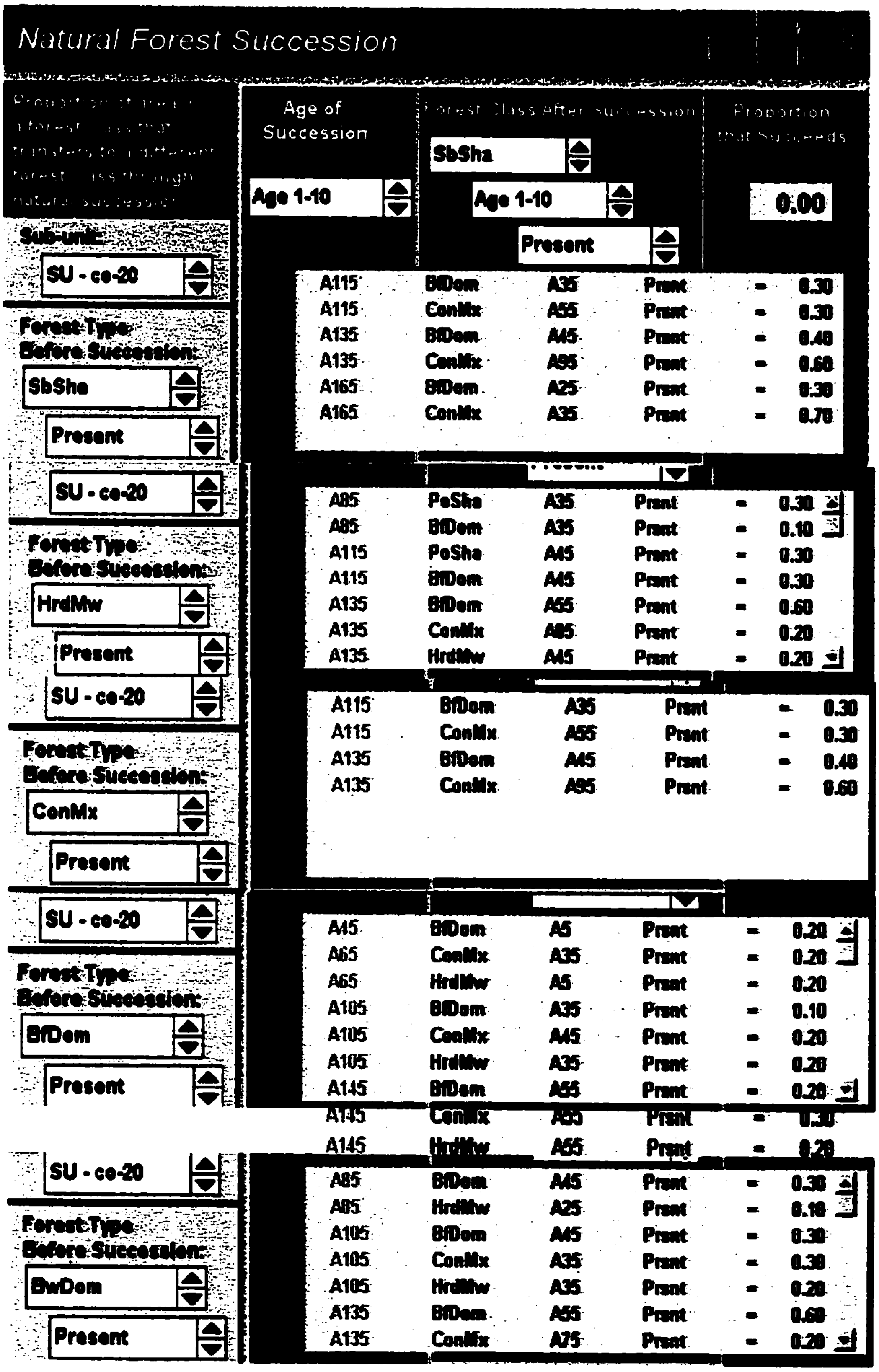
888	0	157205330		1	7640	17	20	10	1	847	993	12.0	0.8	3	CE 7B 2PO 1
888	0	157205330		1	9580	11	39	10	1	993	993	0.0	0.0	2	SB 0
888	0	157205330		1	10280	33	20	10	1	908	993	25.0	0.8	2	PO 7B 2SW 1
888	0	157205330		1	21570	0	54	10	1			0.0	0.0		
888	0	157205330		1	27470	0	54	10	1			0.0	0.0		
888	0	157205330		1	29320	33	20	10	1	913	993	24.0	0.6	2	PO 4CE 2B 2SB 1BW 1
888	0	157205330		1	30490	0	54	10	1			0.0	0.0		
888	0	157205330		1	20780	17	20	11	1	913	993	11.0	0.5	2	CE 6SB 3BW 1
888	0	157205330		1	26140	7	20	11	1	933	993	17.0	1.0	2	PJ 8PO 2
888	0	157205330	SS PW	1	27930	33	25	11	1	928	993	23.0	0.7	2	PO 4B 3BW 3
888	0	157205330		1	8180	13	20	12	1	928	993	13.0	0.5	1	B 5PO 2CE 1AB 1SB 1
888	0	157205330		1	5050	33	20	12	1	933	993	21.0	1.0	2	PO 6B 2BW 2
888	0	157205330		1	11380	11	20	13	1	868	993	13.0	0.8	3	SB 6CE 3L 1
888	0	157205330		1	24330	13	20	13	1	958	993	7.0	0.5	1	B 4PO 2SB 2BW 1L 1
888	0	157205330		1	9270	0	50	14	1			0.0	0.0		
888	0	157205330		1	11330	11	20	14	1	963	993	5.0	0.6	2	SB 7L 2B 1
888	0	157205330		1	14460	11	20	14	1	913	993	16.0	0.7	1	SB 9PO 1
888	0	157205330		1	18540	0	54	14	1			0.0	0.0		
888	0	157205330		1	19840	33	20	14	1	948	993	18.0	1.0	2	PO 6B 2PW 1SB 1
888	0	157205330		1	23410	11	20	14	1	883	993	12.0	0.7	3	SB 5CE 3L 2
888	0	157205330		1	30010	0	52	14	5			0.0	0.0		
888	0	157205330		1	2520	11	20	15	1	923	993	18.0	1.0	1	SB 8PO 1L 1
888	0	157205330		1	5480	11	20	15	1	908	993	16.0	0.8	1	SB 9L 1
888	0	157205330		1	30800	11	20	15	1	908	993	14.0	0.7	1	SB 6CE 2L 1B 1
888	0	157205330		1	27280	33	20	16	1	988	993	12.0	0.8	2	PO 5CE 2SB 1B 1BW 1
888	0	157205330		1	32040	1	20	16	1	907	993	22.0	0.7	2	PW 4PO 3B 2BW 1
888	0	157205330		1	12800	13	20	17	1	933	993	12.0	0.6	1	B 5SB 2PO 1CE 1BW 1
888	0	157205330		1	15450	11	20	17	1	903	993	13.0	0.8	2	SB 9L 1
888	0	157205330		1	22730	13	20	17	1	923	993	15.0	0.8	1	B 4PO 3PW 2CE 1
888	0	157205330		1	8450	0	54	18	1			0.0	0.0		
888	0	157205330		1	22510	0	70	18	1			0.0	0.0		
888	0	157205330	SS	1	2240	36	25	19	1	923	993	18.0	0.9	2	BW 4PO 3B 2SW 1
888	0	157205330		1	3770	13	20	19	1	938	993	12.0	0.6	1	B 4PO 2SW 1AB 1SB 1CE 1
888	0	157205330		1	7520	33	20	19	1	908	993	20.0	0.7	3	PO 5SB 2L 1B 1BW 1
888	0	157205330		1	11580	12	39	19	1	993	993	0.0	0.0	2	SW 0
888	0	157205330		1	15080	33	20	19	1	928	993	22.0	1.2	2	PO 6B 2BW 1SW 1
888	0	157205330		1	29520	7	20	19	1	918	993	18.0	0.8	2	PJ 7SB 2PO 1
888	0	157205330		1	30200	11	20	19	1	903	993	13.0	0.7	2	SB 4CE 3B 2BW 1
888	0	157205330		1	5160	11	25	20	1	933	993	11.0	0.6	2	SB 4PO 3B 1BW 1PJ 1
888	0	157205330		1	9420	17	20	21	1	868	993	12.0	0.8	3	CE 7SB 2L 1
888	0	157205330		1	14640	17	20	21	1	848	993	14.0	0.5	3	CE 5PO 2B 2SB 1
888	0	157205330		1	17240	33	20	21	1	913	993	24.0	0.8	2	PO 4B 3SB 1SW 1BW 1
888	0	157205330	PB	1	25670	33	20	21	1	920	993	21.0	0.7	3	PO 5B 2PJ 2SW 1
888	0	157205330		1	29250	33	20	21	1	874	993	24.0	1.4	2	PO 6B 2SW 1BW 1
888	0	157205330		1	2210	36	20	22	1	923	993	18.0	1.0	2	BW 5PO 3PJ 1B 1
888	0	157205330	PW	1	25970	33	20	22	1	918	993	22.0	0.8	3	PO 5B 3CE 1BW 1
888	0	157205330		1	19480	11	20	24	1	883	993	14.0	0.7	2	SB 5PO 3CE 2
888	0	157205330		1	21970	36	20	24	1	928	993	15.0	0.7	3	BW 4B 2PO 2PO 1SW 1
888	0	157205330	SS	1	27160	36	25	24	1	928	993	16.0	0.8	3	BW 5PO 3B 2
888	0	157205330		1	15380	11	20	25	1	868	993	11.0	0.6	3	SB 8L 2

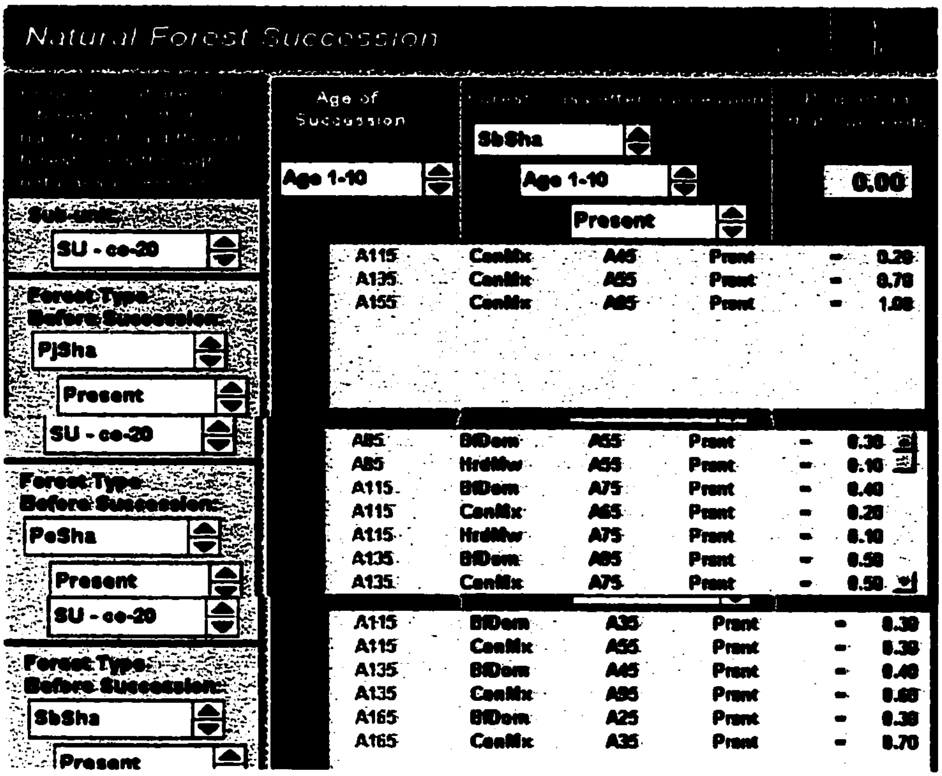
888	0	157205330		1	15050	33	20	25	5	928	993	22.0	1.2 2 PO 6B 2SW 1BW 1
888	0	157205330		1	24530	7	25	26	1	928	993	17.0	0.8 2 PJ 5SB 2PO 2B 1
888	0	157205330		1	29670	33	20	27	1	918	993	21.0	0.8 3 PO 3B 3PW 2BW 1PR 1
888	0	157205330		1	30430	33	20	27	1	903	993	23.0	0.4 3 PO 5B 2SB 2CE 1
888	0	157205330		1	2080	33	20	28	1	933	993	21.0	1.0 2 PO 6BW 2B 2
888	0	157205330		1	15490	0	54	29	1			0.0	0.0
888	0	157205330		1	27570	7	20	29	1	918	993	19.0	1.0 2 PJ 9PO 1
888	0	157205330		1	2840	13	20	30	1	948	993	18.0	0.5 X B 4PO 3SW 1BW 1AB 1
888	0	157205330		1	2740	33	20	33	1	908	993	24.0	1.0 2 PO 4PW 2PJ 2B 1BW 1
888	0	157205330	PW	1	27760	13	25	33	1	933	993	13.0	0.6 1 B 4SB 2BW 2PO 1PJ 1
888	0	157205330		1	7210	33	20	34	1	913	993	24.0	0.8 2 PO 4B 2BW 2CE 1SW 1
888	0	157205330		1	6660	13	20	36	1	933	993	13.0	0.5 1 B 4SW 2PO 2CE 1BW 1
888	0	157205330		1	25610	33	20	39	1	948	993	18.0	1.0 2 PO 6B 2SB 1PW 1
888	0	157205330		1	2390	17	20	40	1	848	993	12.0	0.7 3 CE 7SB 2B 1
888	0	157205330		1	25210	33	20	40	1	913	993	24.0	0.8 2 PO 5B 3CE 1BW 1
888	0	157205330		1	3450	11	20	41	1	863	993	14.0	0.9 2 SB 6CE 2L 2
888	0	157205330		1	16420	11	20	41	1	863	993	12.0	0.7 3 SB 5CE 3L 2
888	0	157205330	PW	1	22290	33	20	41	1	913	993	24.0	0.8 2 PO 5B 2BW 2PW 1
888	0	157205330		1	16110	13	20	45	1	933	993	14.0	0.8 1 B 5PO 2BW 1SW 1AB 1
888	0	157205330		1	9540	4	39	46	1	993	993	0.0	0.0 2 PR 0
888	0	157205330		1	25740	13	20	48	1	933	993	13.0	0.7 1 B 4BW 3SB 1PO 1PW 1
888	0	157205330		1	9360	17	20	50	1	848	993	12.0	0.7 3 CE 7SB 2B 1
888	0	157205330		1	28360	17	20	50	1	898	993	12.0	0.4 2 CE 6SB 3B 1
888	0	157205330		1	6110	33	20	53	1	921	993	25.0	1.2 2 PO 6B 4
888	0	157205330		1	10730	1	20	56	1	879	993	21.0	1.0 2 PW 5PR 2PO 1B 1BW 1
888	0	157205330		1	16670	33	20	57	1	918	993	21.0	0.8 3 B 3PO 3PW 2PR 1BW 1
888	0	157205330		1	20360	17	20	57	1	898	993	12.0	0.4 2 CE 6SB 3B 1
888	0	157205330		1	12800	33	20	61	1	913	993	23.0	0.7 2 PO 3PW 2B 2BW 1SW 1CE 1
888	0	157205330		1	2640	12	39	63	1	993	993	0.0	0.0 2 SW 0
888	0	157205330		1	15190	33	20	66	1	908	993	25.0	0.8 2 PO 7B 2SW 1
888	0	157205330	PW	1	10300	33	20	67	1	913	993	24.0	0.8 2 PO 5BW 2B 2PW 1
888	0	157205330		1	17580	33	20	70	1	903	993	27.0	0.7 2 PO 6SW 2BW 1B 1
888	0	157205330		1	15020	0	70	74	1			0.0	0.0
888	0	157205330		1	11860	13	20	75	1	933	993	12.0	0.6 1 B 5SB 2CE 1PO 1BW 1
888	0	157205330		1	28090	33	20	78	1	933	993	20.0	1.0 3 PO 6B 2BW 1PJ 1
888	0	157205330		1	13140	33	20	88	1	936	993	19.0	1.0 3 PO 6BW 2B 2
888	0	157205330		1	22850	13	20	119	1	946	993	15.0	0.6 X B 4SB 2PW 1PJ 1PO 1CE 1
888	0	157205330		1	14950	13	20	178	1	933	993	13.0	0.8 1 B 4SB 2PO 2PJ 1BW 1

Appendix II

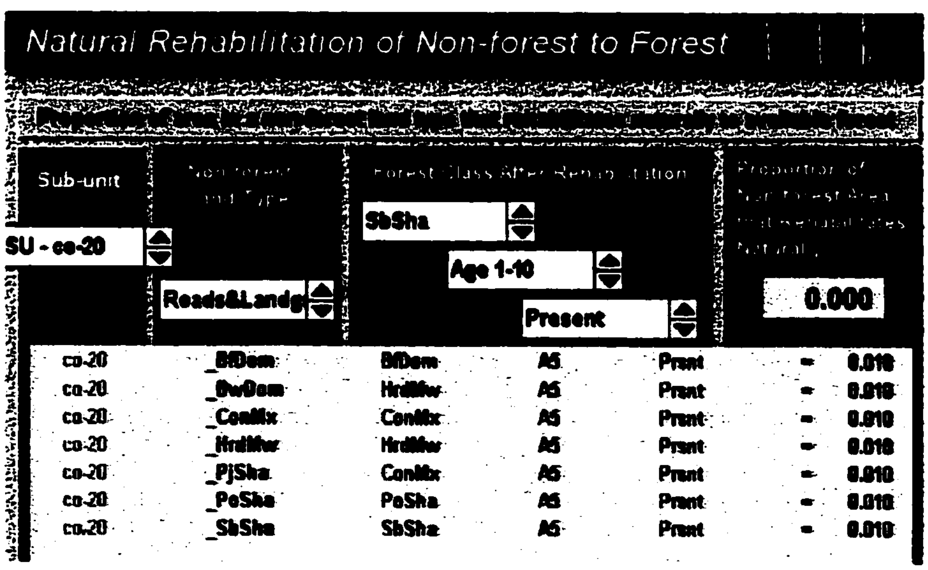
Appendix II-1-1. Natural Forest Succession Parameters



Appendix II-1-2. Natural Forest Succession Parameters



Appendix II-2. Natural Rehabilitation of Non-forest to Forest



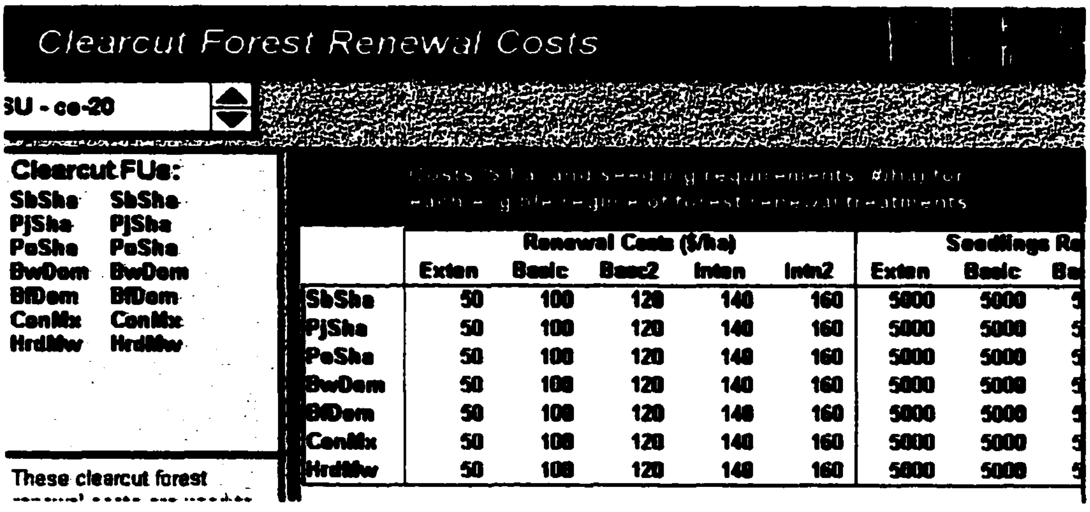
Appendix II-3. Natural Disturbance Cycles & Succession

	Proportion Succeeding to Forest Unit after Disturbance							
	Fire Cycle	SbSha	PjSha	PoSha	BwDom	BfDom	ConMx	HrdMw
Test								
SbSha	60	0.3	0.3				0.4	
PjSha	60		0.7				0.3	
PoSha	80			0.7			0.3	
BwDom	80					0.1		0.8
BfDom	80	0.1				0.1	0.8	
ConMx	80		0.1				0.8	0.1
HrdMw	60			0.6				0.4

Appendix II-4 Clearcut Harvest Operability Ranges

	Clearcut Harvest Operability Ranges											
Sbsha	90	155	90	155	70	155	65	135	inf	inf	inf	inf
Pjsha	65	125	65	125	65	105	55	85	55	85	55	85
Posha	60	125	55	125	inf	inf	45	85	55	85	inf	inf
BwDom	60	135	60	135	inf	inf	55	85	inf	inf	inf	inf
BfDom	40	115	40	115	inf	inf	55	95	inf	inf	inf	inf
ConMx	70	125	60	125	60	105	50	105	inf	inf	inf	inf
HarMw	60	125	60	125	inf	inf	inf	inf	inf	inf	inf	inf

Appendix II-5. Clearcut Forest Renewal Costs



	Renewal Costs ($/ha)					Seedlings Re		
	Exten	Basic	Basc2	Inten	Intn2	Exten	Basic	Ba
SbSha	50	100	120	140	160	5000	5000	5
PjSha	50	100	120	140	160	5000	5000	5
PoSha	50	100	120	140	160	5000	5000	5
BwDom	50	100	120	140	160	5000	5000	5
BfDom	50	100	120	140	160	5000	5000	5
ConMx	50	100	120	140	160	5000	5000	5
HrdMw	50	100	120	140	160	5000	5000	5

Appendix II-6. Clearcut Post-renewal Forest Succession

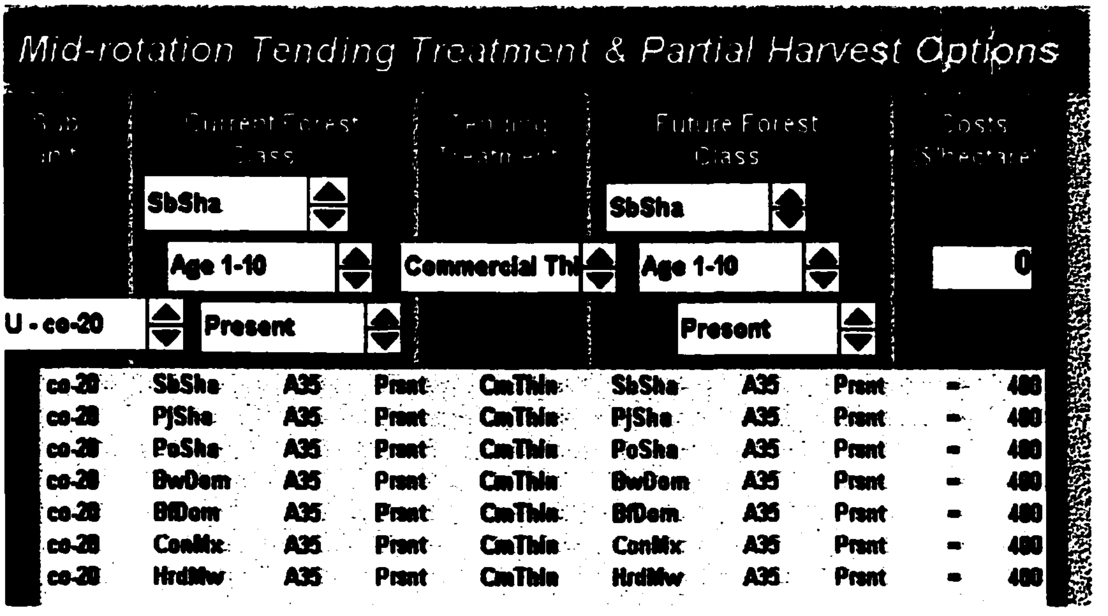
Clearcut Post-renewal Forest Succession

SU - ce-20

Proportion of area harvested from each forest
each silvicultural intensity expected to enter

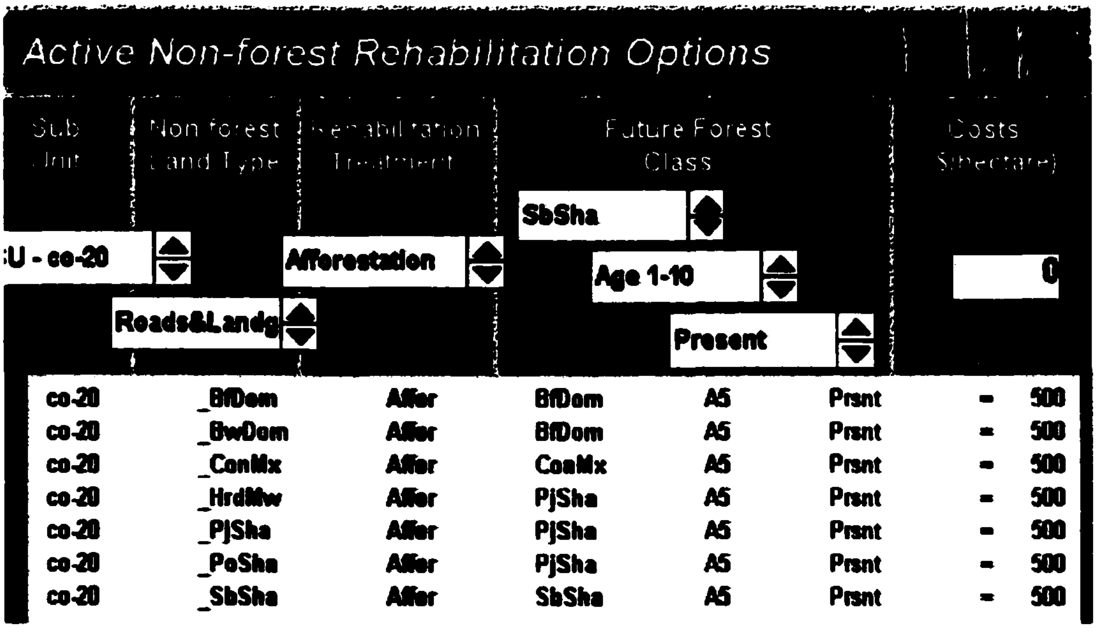
			Proportion Transferred to Future Fores						
		Cost ($/ha)	SbSha	PjSha	PoSha	BwDom	BfDom	ConMix	HrdMw
SbSha	Exten	50	1.00						
	Basic	100	1.00						
	Basc2	120	0.50	0.30				0.20	
	Inten	140	1.00						
	Intn2	160	0.50	0.30				0.20	
PjSha	Exten	50		1.00					
	Basic	100		0.90				0.10	
	Basc2	120	0.70	0.10				0.20	
	Inten	140		0.90				0.10	
	Intn2	160	0.70	0.10				0.20	
PoSha	Exten	50					0.60	0.10	0.30
	Basic	100			1.00				
	Basc2	120	0.80	0.10				0.10	
	Inten	140			1.00				
	Intn2	160	0.80	0.10				0.10	
BwDom	Exten	50	0.80					0.20	
	Basic	100				1.00			
	Basc2	120	0.30				0.70		
	Inten	140				1.00			
	Intn2	160	0.30				0.70		
BfDom	Exten	50	0.80					0.20	
	Basic	100					1.00		
	Basc2	120		0.20	0.30			0.50	
	Inten	140					1.00		
	Intn2	160		0.20	0.30			0.50	
ConMix	Exten	50						1.00	
	Basic	100		0.60					0.40
	Basc2	120	0.20	0.10				0.70	
	Inten	140		0.60					0.40
	Intn2	160	0.20	0.10				0.70	
HrdMw	Exten	50			0.80				0.20
	Basic	100							1.00
	Basc2	120	0.60	0.10					0.30
	Inten	140							1.00
	Intn2	160	0.60	0.10					0.30

Appendix II-7 Mid-rotation Tending Treatment & Partial Harvest Options



co-20	SbSha	A35	Prsnt	CmThin	SbSha	A35	Prsnt	=	400
co-20	PjSha	A35	Prsnt	CmThin	PjSha	A35	Prsnt	=	400
co-20	PoSha	A35	Prsnt	CmThin	PoSha	A35	Prsnt	=	400
co-20	BwDom	A35	Prsnt	CmThin	BwDom	A35	Prsnt	=	400
co-20	BfDom	A35	Prsnt	CmThin	BfDom	A35	Prsnt	=	400
co-20	ConMx	A35	Prsnt	CmThin	ConMx	A35	Prsnt	=	400
co-20	HrdMw	A35	Prsnt	CmThin	HrdMw	A35	Prsnt	=	400

Appendix II-8 Active Non-forest Rehabilitation Options



co-20	_BfDom	Affor	BfDom	A5	Prsnt	=	500
co-20	_BwDom	Affor	BfDom	A5	Prsnt	=	500
co-20	_ConMx	Affor	ConMx	A5	Prsnt	=	500
co-20	_HrdMw	Affor	PjSha	A5	Prsnt	=	500
co-20	_PjSha	Affor	PjSha	A5	Prsnt	=	500
co-20	_PoSha	Affor	PjSha	A5	Prsnt	=	500
co-20	_SbSha	Affor	SbSha	A5	Prsnt	=	500

Appendix III

Table 16-1. Error Distribution of Stumpage Revenue by Planning Terms

Error Distribution of Stumpage Revenue(%) in SFMM (Species Cases)							
Err_Spe_FRI	-30	-20	-10	0	10	20	30
T1	78.5	62.63	70.88	0	20.37	9.95	-8.12
T2	76.47	61.76	66.67	0	20.78	6.89	-7.7
T3	77.31	62.54	69.36	0	21.23	6.48	-7.06
T4	76.65	61.77	68.48	0	20.51	3.91	-7.18
T5	77.5	62.28	69.07	0	20.03	3.12	-6.85
T6	75.47	61.87	68.5	0	20.39	2.38	-7.47
T7	73.2	59.83	67.67	0	19.68	1.01	-9.33
T8	79.75	67.95	73.79	0	19.6	2.29	-8.23
T9	84.44	68.08	72.46	0	23.53	5.29	-6.08
T10	78.74	64.6	67.75	0	21.98	5.44	-5.85
T11	77.88	58.05	72.76	0	28.11	11.44	-4.72
T12	68.91	44.01	64.25	0	20.41	8.57	-4.11
T13	54.34	33.67	58.64	0	21.04	10.34	-2.14
T14	42.21	28.63	49.82	0	17.47	8.38	-1.85
T15	47.88	32.63	47.47	0	23.11	8.62	-2.59
Total	1067.4	830.3	989.55	0	316.24	96.1	-87.26
Average	71.16	55.35	65.97	0	21.08	6.41	-5.82
Range	42.23	39.45	26.32	0	8.64	10.43	7.48

Table 16-2 Two Factor Analysis Between Terms (Rows) and Between Species Error Classes (Columns)

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	1947.836	14	139.1311	2.917967	0.001216	1.811298
Columns	96716.33	6	16119.39	338.0684	1.32E-56	2.208552
Error	4005.191	84	47.68085			
Total	102669.4	104				

Table 17. Error Distribution of Silviculture Expenditure in SFMM (Species cases)

SILVICULTURAL EXPENDITURES ERRORS IN SFMM							
	-30	-20	-10	0	10	20	30
T1	48.71	37.63	50.11	0.00	2.28	-4.56	5.43
T2	59.42	49.46	61.63	0.00	16.81	-13.57	3.37
T3	58.38	49.15	60.15	0.00	11.91	-10.82	-2.68
T4	53.84	45.14	55.68	0.00	10.85	-10.98	-6.60
T5	51.37	42.86	54.40	0.00	10.19	-12.37	-7.26
T6	53.81	46.84	57.30	0.00	11.76	-11.95	-6.94
T7	21.27	16.05	25.12	0.00	1.52	-9.34	-20.69
T8	56.65	15.69	24.96	0.00	8.49	-27.02	0.40
T9	46.37	40.75	51.61	0.00	3.28	-15.56	-14.00
T10	43.94	38.97	48.87	0.00	31.15	-15.29	-12.71
T11	48.00	38.13	54.81	0.00	12.76	-12.84	-5.14
T12	41.38	29.32	49.86	0.00	9.45	-11.94	-7.19
T13	34.88	22.63	49.53	0.00	10.06	-9.61	-3.57
T14	30.22	19.95	44.49	0.00	6.94	-8.62	-4.09
T15	32.10	22.28	44.96	0.00	12.08	-9.01	-3.45
Total	680.34	514.86	733.48	0.00	161.54	-183.48	-85.11
average	45.36	34.32	48.90	0.00	10.77	-12.23	-5.67
Range	38.15	33.77	36.67	0	29.63	22.46	26.12

Table 17-1 Shannon Weiner Index Errors

Shannon Weiner Index Error Distribution by Terms							
Err_Spe_FRI	-30	-20	-10	0	10	20	30
T1	-10.67	-27.21	-28.01	0.00	3.32	8.13	7.25
T2	-10.52	-24.17	-25.25	0.00	1.59	5.89	6.18
T3	-13.09	-21.46	-23.86	0.00	2.33	4.01	5.10
T4	-12.35	-19.01	-22.40	0.00	2.38	1.67	5.24
T5	-13.97	-18.82	-23.03	0.00	1.36	-0.06	1.88
T6	-14.67	-17.17	-21.17	0.00	1.37	1.40	3.52
T7	-12.58	-15.06	-18.36	0.00	1.38	-0.04	2.89
T8	-12.25	-15.21	-17.71	0.00	1.05	-0.22	1.61
T9	-11.98	-14.11	-16.98	0.00	0.54	-0.78	1.27
T10	-11.27	-12.89	-15.82	0.00	0.42	-1.20	0.74
T11	-10.21	-11.75	-14.68	0.00	0.48	-1.38	0.42
T12	-9.52	-10.89	-13.67	0.00	0.66	-1.46	0.26
T13	-8.78	-10.11	-12.72	0.00	0.82	-1.62	0.28
T14	-8.24	-9.40	-12.16	0.00	0.95	-1.72	0.39
T15	-7.99	-9.01	-11.57	0.00	0.90	-1.66	0.31
T16	-7.45	-8.55	-10.99	0.00	1.08	-1.55	0.36
Total	-175.54	-244.82	-286.36	0.00	20.64	9.41	37.70
Average	-11.08	-15.30	-17.90	0.00	1.29	0.59	2.36
Range	7.22	18.66	15.02	0	2.9	9.85	6.99

Appendix IV. Statistical Test Between terms and Between Cases

	Between Cases		Significant	Between Terms		Significant
RESEARCH ITEMS	F_col	F_col_a		F_row	F_row_a	
Total Forest Area	23.73144	2.007635	y	1.396056	1.745189	n
Harvested Volume	31.98167	2.012655	y	2.095013	1.775032	y
Stumpage Revenue	46.93262	2.012655	y	0.351197	1.775032	n
Silviculture Expenditure	14.93889	2.012655	y	2.422336	1.775032	y
Shannon Weiner Index	40.05278	2.012655	y	0.693687	1.775032	n
Wildlife Habitat Area	14.9309	2.012655	y	3.324415	1.775032	y

Appendix V

Table 26. Error Distribution of Harvested Volume by Terms and Stocking Error Classes

(Stocking Cases)

Err_sto_FRI	-20	-15	-10	-5	0	5	10	15	20
T1	-21.26	-15.43	-10.78	-4.01	0.00	9.70	15.76	19.76	23.33
T2	-21.25	-15.45	-10.88	-3.98	0.00	9.77	15.87	19.79	23.41
T3	-21.23	-15.47	-10.98	-3.94	0.00	9.84	15.99	19.82	23.48
T4	-21.22	-15.49	-11.08	-3.90	0.00	9.92	16.11	19.85	23.56
T5	-21.21	-15.52	-11.19	-3.86	0.00	10.00	16.23	19.88	23.64
T6	-21.20	-15.54	-11.30	-3.82	0.00	10.08	16.36	19.91	23.73
T7	-21.18	-15.57	-11.41	-3.78	0.00	10.17	16.49	19.95	23.81
T8	-21.17	-15.59	-11.52	-3.74	0.00	10.25	16.63	19.98	23.90
T9	-21.01	-15.81	-12.06	-3.54	0.00	10.54	15.92	19.62	24.18
T10	-20.97	-15.79	-12.18	-3.49	0.00	10.66	16.01	19.62	24.27
T11	-20.60	-15.10	-12.65	-2.58	0.00	11.40	16.63	21.07	24.03
T12	-20.59	-15.05	-13.65	-2.57	0.00	10.93	16.49	20.87	23.94
T13	-20.47	-15.57	-13.39	-2.42	0.00	9.33	16.52	20.40	24.04
T14	-19.79	-15.80	-13.73	-1.59	0.00	6.67	17.36	21.20	23.80
T15	-23.83	-19.35	-14.54	-1.64	0.00	4.90	11.53	15.16	17.49
Total	-316.98	-236.62	-181.24	-48.88	0.00	146.37	239.91	296.88	350.62
Average	-21.13	-15.77	-12.08	-3.26	0.00	9.76	15.99	19.79	23.37
Range	4.04	4.3	3.76	2.42	0	6.5	5.83	6.04	6.78

Table 27. Error Distribution of Stumpage Revenue by Terms andstockingError Classes

	Stocking Cases								
	-20	-15	-10	-5	0	5	10	15	20
T1	-21.91	-14.38	-9.55	-3.69	0.00	9.17	14.28	19.50	22.39
T2	-22.01	-14.51	-9.30	-4.38	0.00	7.98	13.10	18.62	21.37
T3	-21.01	-14.32	-10.01	-4.30	0.00	8.84	13.91	19.07	21.97
T4	-21.30	-14.37	-9.68	-4.38	0.00	8.68	14.00	19.37	22.05
T5	-21.84	-14.50	-9.90	-4.33	0.00	9.25	14.40	19.68	22.76
T6	-21.82	-14.88	-10.24	-4.92	0.00	8.33	13.75	18.94	22.21
T7	-20.93	-14.36	-10.53	-4.69	0.00	8.69	13.97	18.21	22.15
T8	-21.21	-14.45	-10.90	-5.32	0.00	9.09	15.15	18.15	20.68
T9	-20.79	-13.94	-10.25	-3.86	0.00	10.63	13.10	18.54	23.82
T10	-20.57	-14.35	-10.57	-4.02	0.00	10.68	12.73	17.88	24.09
T11	-20.20	-13.72	-11.89	-2.80	0.00	10.83	13.45	17.22	22.32
T12	-19.97	-13.88	-12.76	-2.78	0.00	9.82	13.37	18.72	23.54
T13	-19.47	-15.25	-12.90	-2.05	0.00	5.54	13.97	18.00	23.16
T14	-17.75	-16.26	-13.05	0.23	0.00	5.30	15.70	18.30	22.77
T15	-20.39	-16.28	-13.30	0.01	0.00	5.52	12.98	14.78	18.81
Total	-311.16	-219.45	-164.83	-51.50	0.00	128.35	207.87	271.16	334.08
Average	-20.74	-14.63	-10.99	-3.43	0.00	8.56	13.86	18.08	22.27
Range	4.26	2.56	4	5.55	0	5.53	2.97	4.9	5.28

Table 28. Error Distribution of Silviculture Expenditure by Terms and stocking Error Classes

	(Stocking Cases)								
Err_sto_FRI	-20	-15	-10	-5	0	5	10	15	20
T1	-19.41	-14.28	-10.91	-3.84	0.00	3.49	10.76	12.77	13.75
T2	-17.79	-12.28	-1.39	-1.32	0.00	15.87	11.89	24.82	29.82
T3	-17.04	-12.32	-9.19	-2.96	0.00	8.89	12.94	16.39	18.89
T4	-16.82	-12.12	-8.85	-2.89	0.00	8.80	12.86	16.30	18.62
T5	-16.24	-11.49	-8.64	-2.64	0.00	9.13	13.05	15.64	18.69
T6	-16.55	-11.97	-9.06	-3.04	0.00	8.68	12.92	15.48	18.72
T7	-13.77	-10.14	-7.62	-2.70	0.00	6.56	10.00	12.10	14.64
T8	-12.79	-8.97	-6.53	-2.52	0.00	7.51	10.50	12.41	14.46
T9	-25.95	-17.21	-18.73	-13.23	0.00	-2.77	8.47	22.66	6.26
T10	-16.79	-12.02	0.60	-3.62	0.00	9.54	11.26	35.67	19.12
T11	-16.13	-11.05	-9.07	-2.38	0.00	10.78	12.18	15.27	18.50
T12	-16.31	-10.90	-10.23	-3.09	0.00	9.55	11.62	15.02	17.89
T13	-15.66	-12.16	-9.46	-2.14	0.00	6.66	12.24	14.68	18.91
T14	-14.55	-13.97	-10.46	-0.72	0.00	5.05	13.55	16.03	17.70
T15	-18.97	-16.16	-11.41	-0.23	0.00	1.96	8.56	10.19	10.90
Total	-254.77	-187.05	-130.96	-47.33	0.00	109.70	172.82	255.44	256.86
Average	-16.98	-12.47	-8.73	-3.16	0.00	7.31	11.52	17.03	17.12
Range	13.16	8.24	19.33	13	0	18.64	5.08	25.48	23.56

Table 29. Error Distribution of Shannon-Weiner Index by Terms andstockingError Classes

(Stocking Cases)									
Err_sto_FRI	-20	-15	-10	-5	0	5	10	15	20
T1	-0.30	-0.32	-0.36	-0.16	0.00	-1.09	-0.13	-1.01	-1.16
T2	-0.54	-0.40	-0.09	0.02	0.00	0.02	0.03	0.05	0.01
T3	-0.68	-0.45	-0.16	0.00	0.00	0.18	0.16	0.20	0.10
T4	-0.67	-0.51	-0.20	-0.01	0.00	0.27	0.24	0.21	0.13
T5	-0.42	-0.41	-0.09	-0.04	0.00	0.08	0.14	0.04	-0.02
T6	-0.31	-0.27	0.04	-0.05	0.00	-0.13	-0.03	-0.09	-0.11
T7	-0.35	-0.33	0.04	0.19	0.00	-0.33	-0.20	-0.07	0.27
T8	-0.47	-0.42	-0.14	-0.05	0.00	-0.05	0.04	0.03	-0.04
T9	-0.40	-0.39	-0.14	-0.04	0.00	-0.03	0.05	0.01	-0.05
T10	-0.36	-0.41	-0.15	-0.04	0.00	-0.04	0.07	0.01	-0.08
T11	-0.29	-0.37	-0.15	-0.03	0.00	0.01	0.10	-0.02	-0.11
T12	-0.28	-0.37	-0.16	-0.03	0.00	-0.01	0.09	-0.06	-0.15
T13	-0.29	-0.35	-0.16	-0.05	0.00	0.02	0.09	-0.08	-0.17
T14	-0.29	-0.37	-0.16	-0.06	0.00	-0.01	0.07	-0.09	-0.18
T15	-0.24	-0.32	-0.16	-0.05	0.00	0.00	0.10	-0.07	-0.15
Total	-5.91	-5.68	-2.04	-0.41	0.00	-1.14	0.82	-0.93	-1.70
Average	-0.39397	-0.38	-0.14	-0.03	0.00	-0.08	0.05	-0.06	-0.11
Range	0.44	0.24	0.4	0.35	0	1.36	0.44	1.22	1.43

Table 30. Error Distribution of Wildlife Habitat Area by Terms andstockingError Classes

(Stock Cases)									
Err_sto_FRI	-20	-15	-10	-5	0	5	10	15	20
T1	1.05	1.70	2.21	1.09	0.00	6.14	0.59	5.84	6.64
T2	-0.57	0.70	-0.07	0.00	0.00	3.07	1.94	2.63	0.82
T3	-0.63	0.09	-1.57	0.06	0.09	4.81	3.08	3.41	1.82
T4	-1.08	-1.32	-2.40	-0.41	0.00	3.39	3.61	2.20	-0.02
T5	0.37	-0.55	-1.70	0.25	0.00	4.57	3.28	1.82	1.68
T6	0.11	-0.79	-1.48	0.26	0.00	3.67	2.88	1.21	1.29
T7	0.34	-0.28	-1.48	-0.53	0.00	3.53	2.66	0.55	-0.43
T8	0.29	0.14	-0.89	-0.71	0.00	2.92	1.69	1.32	0.12
T9	0.43	0.87	0.28	-0.87	0.00	2.89	1.44	1.03	0.29
T10	0.05	0.58	0.73	-0.79	0.00	2.29	0.25	0.73	0.85
T11	-0.65	0.11	0.70	-1.03	0.00	2.57	-0.02	0.09	0.55
T12	-1.46	-0.25	-0.31	-1.46	0.00	2.04	-0.69	-0.17	-0.48
T13	-1.54	-0.49	-0.22	-1.44	0.00	1.79	-0.11	0.09	0.47
T14	-2.18	-3.00	-0.55	-1.43	0.00	0.36	-0.69	-0.29	-0.20
T15	-1.32	-2.62	-0.56	0.00	0.00	-0.44	1.15	0.42	-0.14
Total	-6.79	-5.12	-7.31	-7.00	0.00	43.60	21.27	20.85	13.25
Average	-0.45	-0.34	-0.49	-0.47	0.00	2.91	1.42	1.39	0.88
Range	3.23	4.7	4.61	2.55	0	6.58	4.3	6.13	7.12

Apendix VI

Appendix VI-1 Two Factor Analysis of Stocking Cases (Rows: Planning Terms, Column: Stocking Error Classes)

Total Forest Area Errors

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	0.036655	15	0.002444	1.707718	0.057976	1.750497
Columns	0.018064	8	0.002258	1.577964	0.138377	2.016428
Error	0.171714	120	0.001431			
Total	0.226433	143				

Harvested Volume Errors

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	89.40188	14	6.385848	6.388876	4.44E-12	1.78105
Columns	31653.13	8	3956.642	5197.708	3.5E-140	2.022091
Error	85.25755	112	0.761228			
Total	31827.79	134				

Stumpage Revenue Errors

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	21.96978	14	1.56927	0.994481	0.46387	1.78105
Columns	27695.53	8	3461.941	2193.907	2.7E-119	2.022091
Error	176.7337	112	1.577979			
Total	27894.23	134				

Silviculture Expenditure Errors

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	713.9554	14	50.99681	5.231671	1.61E-07	1.78105
Columns	19267.98	8	2408.497	247.0834	1.93E-67	2.022091
Error	1091.743	112	9.74771			
Total	21073.68	134				

Shnnon-Weiner Index Errors

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Rows	1.414344	14	0.101025	3.651188	5.38E-05	1.78105
Columns	3.009455	8	0.376182	13.59581	1.29E-13	2.022091
Error	3.098923	112	0.027669			
Total	7.522721	134				

Wildlife Habitat Area Errors

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Rows	93.36562	14	6.668973	6.432313	2.47E-09	1.78105
Columns	170.0152	8	21.2519	20.49774	8.25E-19	2.022091
Error	116.1207	112	1.036792			
Total	379.5015	134				

Appendix VI-2 Regression Equations of Various Errors for stocking Cases

	Regression and coefficients			Ta	Tb	Ta_c	Tb_c
Error Items	a	B	R				
Har_Vol	2.503835	1.121955	0.977854	2.013765	11.39171	0.09068	2.74E-05
Stu_Ren	1.442222	1.1062	0.997097	3.498835	34.64569	0.010009	4.33E-09
Sil_Exe	1.293333	0.919567	0.994	2.5807	23.68834	0.036435	6.07E-08
NPV	3.879589	1.487856	0.995192	4.725964	22.72024	0.005215	3.07E-06

f	fa	std. Errora	std.Errorb
129.771	0.001	0.603	0.047
1200.324	4.33E-09	0.412201	0.031929
561.1373	6.07E-08	0.501156	0.038819
516.2094	3.07E-06	0.82091	0.065486

APPENDIX VII

Appendix VII-1-1 Comparisons Between Error FRI Classes and Total Forest Area Errors in SFMM (Combination Cases Including Case 9)

ANOVA

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Rows	11.97704	15	0.79847	1.921968	0.02718	1.750497
Columns	276.1039	8	34.51298	83.075	2.87E-45	2.016428
Error	49.85324	120	0.415444			

Appendix VII-1-2. Statistical comparison between FRI error Classes and SFMM total forest area by dropping cases 9 (Combination cases)

ANOVA

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Rows	12.74808	15	0.849872	3.31045	0.000154	1.762658
Columns	8.296913	7	1.185273	4.616918	0.000156	2.098005
Error	26.95601	105	0.256724			
Total	48.001	127				

Appendix VII-2-1. Error Comparison of Harvested Volume by Terms (Combination Cases)

ANOVA

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Rows	71.75305	14	5.125218	0.641339	0.825146	1.78105
Columns	24401.83	8	3050.228	381.6873	1.58E-77	2.022091
Error	895.0405	112	7.991433			
Total	25368.62	134				

Appendix VII-2-2. Regression Summary of Harvested Volume Errors in SFMM (Including case 9).

Regression Statistics

Multiple R	0.82844
R Square	0.68632
Adjusted R Square	-1.28571
Standard Error	8.53750
Observations	1

ANOVA

	Df	SS	MS	F	Significance F
Regression	9	1116.377	124.0419	15.31613	0.006
Residual	7	510.223	72.88899		
Total	16	1626.6			

Coefficients

		Unstandardized Coefficients		Standardized Coefficients		Sig.	95% Confidence Interval for B	
Model	.	B	Std. Error	Beta	t	Significance	Lower Bound	Upper Bound
1	(Constant)	-3.881	2.846	-1.364	.215	-1	0.610	2.848
	Er_class	.863	.220	.828	3.914	.006	.341	1.384

a Dependent Variable: Harvested Volume Area Error.

Appendix VII-3-1 Statistic Comparison of Stumpage Revenue Errors between Terms

ANOVA

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Rows	106.9013	14	7.635806	0.458997	0.949766	1.78105
Columns	26165.22	8	3270.652	196.6027	3.11E-62	2.022091
Error	1863.215	112	16.63585			
Total	28135.34	134				

Appendix VII-3-2. Regression Analysis of Stumpage Revenue Errors (Combination cases, Terms Average) (Excluding Case 20%)

Regression Statistics	
Multiple R	0.987886
R Square	0.975919
Adjusted R Square	-1.33333
Standard Error	2.638935
Observations	1

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	8	1693.355	211.6693	243.159	0.006
Residual	6	41.78366	6.96398		
Total	14	1735.138			

Appendix VII-4-1. Two Factor Analysis Of Silviculture Expenditure Error by terms (Combination Cases)

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	2619.503	14	187.1074	4.871487	5.89E-07	1.78105
Columns	13590.93	8	1698.866	44.23132	3.13E-31	2.022091
Error	4301.772	112	38.40868			
Total	20512.21	134				

Appendix VII-4-2 Regression between silviculture expenditure errors and combination errors.

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.739054
R Square	0.546201
Adjusted R Square	-1.28571
Standard Error	7.665082
Observations	1

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	9	495.0179	55.00199	8.425338	#NUM!
Residual	7	411.2744	58.75348		
Total	16	906.2923			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept							0	0
X Variable 1	0.195313	7.665082	0.025481	0.980383	-17.9297	18.32034	-17.9297	18.32034

Appendix VII-5-1 Two Factor Analysis of Shannon Weiner Index Error by Terms and by error classes (Combination Cases)

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	39.82084	14	2.844346	2.956676	0.000727	1.78105
Columns	320.1949	8	40.02436	41.60502	3.97E-30	2.022091
Error	107.7449	112	0.962008			
Total	467.7606	134				

Appendix VII-6-1. NPV Error Regression Analysis

Regression Statistics	
Multiple R	0.988607
R Square	0.977343
Adjusted R Square	-1.28571
Standard Error	2.457713
Observations	1

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	9	1823.921	202.6579	301.9561	0.08
Residual	7	42.28247	6.040352		
Total	16	1866.203			

Coefficients

Variable	B	SE B	Beta	T	Sig T
VAR00001	1.102700	.063458	.988607	17.377	.0000
(Constant)	-2.456667	.819238	-2.999	.0200	

Appendix VIII

Table 40. Total Forest Area Errors by Survey Factors and Error Classes

Total Forest Area Error												
Error Class	-30.00	-20.00	-15.00	-10.00	-5.00	0.00	5.00	10.00	15.00	20.00	30.00	
Species	4.81	6.48		9.39		0.00		0.70		14.05	37.20	Area Weighted
	-24.22	-23.36		-12.84		0.00		2.84		4.82	16.00	Algbra Mean
Age		0.72	0.70	0.57	0.54	0.00	0.26	0.45	0.70	2.68		
Stock		0.03	0.02	0.03	0.01	0.00	0.04	0.02	0.01	0.01		
Combine		0.89	0.78	0.60	0.70	0.00	0.33	0.57	0.94	-4.36		
Total		8.12	1.50	10.59	1.25	0.00	0.63	1.74	1.65	12.38	37.20	
Average		2.03	0.38	2.65	0.31	0.00	0.16	0.44	0.41	3.10	9.30	

Table 42. Harvested Volume Errors by Survey Factors and Error Classes

Harvested Volume Error											
Error Class	-30	-20	-15	-10	-5	0	5	10	15	20	30
Species	75.11	63.42		78.22		0		16.33		-16.72	-10.13
Age		-4.88	-1.2	-2.29	-2.45	0	3.54	2.55	1.19	-20.85	
Stock		-21.13	-15.77	-12.08	-3.26	0	9.76	15.99	19.79	23.37	
Combine		-23.62	-21.67	-15.15	-5.86	0	5.82	15.83	13.2	-3.49	
Total		-49.63	-38.64	-29.52	-11.57	0	19.12	34.37	34.18	-0.97	
Average		-16.54	-12.88	-9.84	-3.857	0	6.373	11.46	11.39	-0.323	

Table 43. Anova: Two-Factor Analysis for Harvested Volume Errors.(95% confidence)

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	165.2155	2	82.60774	0.791466	0.470142	3.633716
Columns	2491.786	8	311.4733	2.984231	0.029877	2.591094
Error	1669.969	16	104.373			
Total	4326.97	26				

Table 46. Stumpage Revenue Errors by Survey Factors and Error Classes.

Stumpage Revenue Error											
Error Class	-30	-20	-15	-10	-5	0	5	10	15	20	30
Species	76.16	55.35		65.97		0		21.08		6.4	-5.82
Age		-8.54	-5.87	-7.03	-8.44	0	2.12	-0.97	-2.12	-20.8	
Stock		-20.7	-14.6	-11	-3.43	0	8.56	13.86	16.08	22.27	
Combine		-26.4	-21.5	-18	-8.69	0	5.22	13.88	13.26	-2.12	
Total		-55.7	-42	-36.1	-20.6	0	15.9	26.77	29.22	-0.61	
Average		-18.6	-14	-12	-6.85	0	5.3	8.923	9.74	-0.2	

Table 47. Stumpage Revenue Error Two Factors Analysis (95% confidence)

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	278.4937	2	139.2468	1.576981	0.237078	3.633716
Columns	2549.466	8	318.6833	3.609112	0.013852	2.591094
Error	1412.794	16	88.29964			
Total	4240.754	26				

Table 49. Silviculture Expenditure Error by Survey Factors and Error Classes

Silviculture Expenditure Error											
Error Class	-30	-20	-15	-10	-5	0	5	10	15	20	30
Species	45.36	34.32		48.9		0		10.77		-12.23	-5.67
Age		-5.64	1.94	2.03	-0.08	0	3.3	1.45	-2.41	-20.85	
Stock		-16.98	-12.47	-8.73	-3.16	0	7.31	11.52	17.03	17.12	
Combine		-18.44	-15.99	-9.07	-3.01	0	5.99	12.75	7.67	-6.26	
Total		-41.06	-26.52	-15.77	-6.23	0	16.6	25.72	22.29	-9.99	
Average		-13.69	-8.84	-5.257	-2.077	0	5.533	8.573	7.43	-3.33	

Table 50. Silviculture Expenditure Error Statistic Analysis (85% confidence)

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	104.0745	2	52.03727	0.574345	0.575798	2.179085
Columns	1352.562	7	193.2232	2.132642	0.107914	1.875243
Error	1268.438	14	90.60273			
Total	2725.075	23				