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Even-aged Boreal Forest Management Planning Models: An Overview

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EVEN-AGED BOREAL FOREST MANAGEMENT PLANNING MODELS: AN OVERVIEW

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INTRODUCTION

Potential users of planning models face a bewildering range of choices, making it difficult to decide which products will best serve a particular application. To the uninitiated, each product holds great promise in terms of providing useful insights into difficult forest management problems, but in terms of usability these expectations are often diminished by a lack of data to run the models, applicability to specific problems or issues, and by a lack of product documentation.

Models are used to simulate a variety of management decisions. Results from these simulations are then used by resource managers to select the most appropriate actions required to best meet the desired management objectives. A common requirement of resource managers is the setting of a long-term, even-flow sustainable harvest level.

OBJECTIVE

The objective of the study was to compare and analyze current, even-aged, boreal forest planning models. The intent was to assess the relative strengths and weaknesses of the models using a specified set of forest management planning objectives common to the boreal forest.

The models tested were FORMAN (version 2.3), GLFC-FORMAN, NORMAN, CROPLAN (FORMANCP), FORMAN+1, HSG, and SFMM (Strategic Forest Management Model). The evaluation also incorporated the use of two ancillary data generators: PCNFCS (PC NORMAN-FORMAN File Creation System), and the Canadian Forest Service's data generator for FORMAN+1. Table 1 provides a chronological overview of each of the models studied.

Table 1. An historical overview of the models and tools included in this study.

Year	Models and tools	Description
1987	FORMAN 2.1	Volume-based simulation model with intensive and extensive silvicultural options.
1988	FORMAN 2.3	Final update to FORMAN 2.1.
1988	MADCALC	Area based simulation model, easier to use than predecessors - WOSFOP[1] AND OWOSFOP. Used in this study as a bench mark against which to compare the other models (Hall 1977).
1989	GLFC FORMAN	An enhanced version of FORMAN 2.1 adapted for use on DEC VAX computer systems.
1989	NORMAN	An improved FORMAN 2.3 that allows for intensive, basic, and extensive silvicultural options, with improved output reports (Hauer 1989).
1991	CROPLAN	Based on FORMAN 2.1, it provides assistance in preparing input files, and has some economic analysis capabilities (Willcocks et al. 1990).
1991	FORMAN+1	Provides additional flexibility with silvicultural treatment options and improved species reporting, and allows for succession of older stands (Vanguard Forest Management Services Ltd. 1991, Wang et al. 1987).
1994	HSG	Provides a stand-level approach to modelling that allows results to be spatially displayed, has improved options for succession of older stands, and improved query and graphing capabilities (Dendron Resource Surveys et al. 1993).
1994	PCNFCS	Aggregates stand information and prepares input files for the FORMAN-type models. Provides numerous helpful reports and can be used as a volume generator (Lindquist 1994).
1995	SFMM	An optimization model that allows greater flexibility in defining and regulating forest management activities. It has improved graphing and reporting options.
1995	CFS-DG[2]	Aggregates stand information and prepares input files for the model. Also provides a capability for incorporation of fixed and variable harvesting costs and volume effects due to insect defoliation, and provides for limited spatial differentiation of simulation-generated results (Andersen et al. 1994).

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[1] Hall, T.H. 1977. WOSFOP: Instruction manual. New Brunswick Dept. of Natural Resources and Energy, Fredericton, N.B. Unpublished.

[2] Canadian Forest Service FORMAN+1 data generator. The prototype data generator was used for research purposes with FORMAN+1, as was GLFC-FORMAN. These programs were developed for use on VAX VMS-based computer systems and UNIX-based work stations.

CASE STUDY AREA

For this study, a forest being managed by Avenor Inc. in northwestern Ontario was used as the case study area. Harvesting and silvicultural operations on the forest date back to the early 1940s.

This study area was selected because many forest management problems common to the boreal forest occur here. In-kind help from Avenor staff provided additional support for this project and offered realistic planning scenarios.

SCENARIOS MODELED

The design of the case studies took into account the results of a questionnaire that was sent to model users as well as some follow-up interviews. The following is an overview of the goals of each of three case studies that were analyzed.

Case Study 1

The goal in Case Study 1 was to compare the output from each of the six simulation models using the same inputs to determine the long-term, even-flow sustainable harvest level. Runs were made to examine how each of the models performed using different harvest rules. Additional runs were made to determine the effect of altering the curve Y factors for the FORMAN-based models.

Case Study 2

Many resource managers rely on historical depletion data to determine the percentage of the land base that is lost to reserves, fires, and insect and disease attacks, among others. This depletion information was then used in simulation models to project future losses.

The goal in Case Study 2 was to compare the assumptions commonly used in determining the area lost to riparian reserves versus actual losses, and to determine the impacts of these assumptions on the long-term sustainable conifer harvest level.

Case Study 3

This case study examined some of the options in evaluating timber supply and costs. It was broken down into several sections. The first examined how the allowable harvest level for an individual species such as spruce can be determined, while maintaining the overall objective of maximizing the even flow, sustainable conifer harvest level. Section two briefly examined one way of incorporating spatial considerations such as haul costs (Lockwood and Moore 1993). Section three examined the impacts of natural succession (as opposed to post-renewal succession) on the allowable harvest level, and the final section looked at the impacts of the different silvicultural investments on harvest levels.

PREPARATION OF LAND BASE INFORMATION

In preparation for modelling, the following steps were taken to prepare the land base information:

1) Records for the areas that had been declared free-to-grow were appended to the original forest resource inventory (FRI) stand inventory file.

2) A geographic information system (GIS) was used to determine stand areas and to determine the area of cutover that had not been declared free-to-grow. It should be noted that stand areas generated by the GIS were generally slightly smaller in size than those initially estimated in the original FRI stand descriptions. It is not known if the reduction in area is typical of all FRI inventories or not—it depends on the method and accuracy used to determine original FRI areas. The stand description information from the FRI database was joined to the GIS area database using the map sheet and stand number to join the two tables .

3) The cutover area that had not been declared free-to-grow (approximately 80 000 ha) was divided into four 5-year age classes and given a species composition based on historical silvicultural treatments. Historical free-to-grow and 5-year survey results supported this treatment of the cutover information .

4) To prepare the database for modelling, several other steps were taken:

a) stands less than one hectare in area were dropped from the inventory database;

b) modelling was not required for several working groups (red pine, white pine, cedar, other conifer, ash, and other hardwood); and

c) barren and scattered stands were changed to productive forest land, and assigned a stand description based on historical survey work for the 19-year-old inventory. This step dramatically reduced the number of yield curves required by the models.

SETUP USING PC NORMAN-FORMAN FILE CREATION SYSTEM (PCNFCS)

PCNFCS was used to create the land base files and the volume and cost curves to be used by FORMAN 2.1, FORMAN CP, NORMAN, and SFMM models. The conversion program in FORMAN+1 was used to convert the FORMAN 2.1 files for use with FORMAN+1. This conversion worked well, and because the basic, intensive, and extensive curves were included by PCNFCS in the FORMAN 2.1 files, this information was also incorporated into the FORMAN+1 file conversion.

The edited land base was sorted using the FORMAN Management Unit option provided by PCNFCS. This option allowed for the separation of upland and lowland spruce stands, which requires a breakdown by species composition as well as by site class and working group. Also, a conifer mixedwood FORMAN Management Unit was developed so that a more intensive silviculture strategy could be applied to these areas.

The primary species curve information used by Avenor Inc. was entered into PCNFCS. This yield information was primarily based on normal yield tables (Plonski 1974), with minor adjustments made for local conditions. Because some models do not allow for the conversion of older stands to different working groups, no attempt was made to do so at this early stage of the comparisons. The stand information was then aggregated.

The user should be aware that PCNFCS develops a curve for each age class specified in the aggregation. To reduce the number of curves developed, a 20-year age class aggregation was used for this scenario. For example, with ten FORMAN Management Units, if a five year age class aggregation criteria was used, the program would develop 240 additional curves (24 additional age classes x 10 FORMAN Management Units).

Present volume, future volume, and cost curves were developed by PCNFCS based on the aggregated stand information and the silvicultural card information. PCNFCS allowed for easy editing of all the parameters for the aggregated stands.

Operability limits, often confused with rotation ages, are used by volume-based models to assign the minimum volume required for the model to consider the area for harvest. It was felt that the minimum conifer volume required before an area could be considered operable was 30 m^3/ha. The ages used in FORMAN+1, HSG and SFMM are not rotation ages, they are the age at which the minimum operable volumes are met. This was done to make a fair comparison of the models.

OVERVIEW OF MODELS TESTED

In their day, all of the models examined played a role in increasing resource managers' understanding of forest dynamics, and contributed in a particular way to improved forest management.

To properly use these models a great deal of care and effort is required when planning the inventory. All of them need accurate, up-to-date inventory information. Using these models is not difficult, but it is very precise work and mistakes can be easily made and go unnoticed. When interpreting the results of simulations it is necessary to be aware of the inherent and implied assumptions.

FORMAN 2.3, GLFC-FORMAN, and NORMAN

All three of these models work in a similar fashion and can be learned quickly. They are in the public domain and are available free of charge. FORMAN 2.3 is not used much because of its relatively poor reporting abilities and the fact that it only handles two levels of regeneration treatments (extensive and intensive).

GLFC-FORMAN has a certain advantage, in that it is more user-friendly and operates in a UNIX environment. However, because development of this model ended in 1991 it fails to include the corrections and improvements incorporated in the development of FORMAN Version 2.3.

Of these three programs, NORMAN is the best overall. It has good reporting abilities, and for many situations can handle the desired task. The model should be updated to handle 20 management units. Apparently, NORMAN has this capability, but this fact was never published because when it appeared many personal computers could not handle the array size.

CROPLAN (FORMANCP)

CROPLAN was developed to assist resource managers to better understand the financial implications of various levels of silviculture treatments. It was also developed to assist in the preparation of the required input files. The model meets these goals. While not tested in this study, the model has the ability to examine thinning as a means to meet anticipated wood shortages.

Results from this project suggest that CROPLAN may be less accurate than are other models that use 10-year age classes for the yield curve input.

FORMAN+1

FORMAN+1 is a model available for purchase from Pearson Timberline in Alberta. The model has many capabilities, such as how it harvests, regenerates, and maintains the forest. It also has the ability to model natural succession. While it takes more time to understand and use this model, its extended capabilities are worth the effort. Currently, the biggest drawback with this model is that it will only simulate forest activities for up to 100 years. The next version to be released was to allow modelling up to a 200 year time frame. Pearson Timberline also offers good support of their product and are very helpful to users.

HSG

A qualitative, not quantitative, comparison between FORMAN and HSG was warranted because there are substantial differences in model design. Although Table 2 compares the quantitative results of the various models, the purpose of this discussion is to highlight the design features that differ between the FORMAN and HSG models.

Design Rationale and Inventory Inputs

The HSG design rationale is to (a) store Ontario inventory data at the stand level, (b) queue the harvest based upon individual species volumes, and c) produce a simulation answer that can then be classified into descriptive forest classes for the user. HSG requires that each stand description be stored and altered throughout the simulation according to a set of state table definitions. All assumptions regarding natural succession and regeneration must be explicit in the state table. This can be a formidable task for forests that are complex and diverse.

The FORMAN-based models, on the other hand, are premised on the laws of averaging: accepting that an aggregate description of conceptual "forest classes" best describes an otherwise complex forest. Admittedly, any two stands described by the same forest class may differ, but when examining numerous stands of that same forest class, the average condition can be more readily measured. This average condition and development assumptions are expressed in the "class present yield curves".

Model Inputs

HSG requires Ontario FRI inventory format to operate. An HSG module called FRITTER is used to convert this FRI format into HSG-compatible format. A user must ensure that the input inventory file format complies with the FRI standards exactly, prior to using FRITTER. HSG uses fully stocked, pure species yield curves to calculate volumes at a given age. A total stand volume is calculated by considering each species component within each unique stand, referencing each species yield curve, and prorating that value according to the stand's stocking level. Users should be aware that FRITTER has a maximum capacity of five species per stand.

The inventory can be simulated and redescribed according to the state table; therefore the possibility of uneven-aged stand components exists. The complex scenarios of partial logging may be described, where residual mature species succeed in association with even-aged regeneration. This, however, is not considered as a normal application of HSG, and would be quite a complex procedure. One other distinction between the design of HSG and the FORMAN-based models is that HSG does not allow for an "area factor" (the net forest land base to be included in the simulation after reserves have been excluded). For example, FRI input can be altered using a database to reduce individual stand area by 15 percent prior to using it in HSG, if no other spatial means are available for coding reserves. Ideally, the FRI inventory would be coded spatially using a GIS to reflect these anticipated reserves, but a GIS is not always available. If an average riparian reserve is 50 metres in width, then the selected pixel size should ideally be 0.5 hectares to match this resolution. Small pixel sizes create very large data files that may overload some computers.

Simulation of Queuing Mechanisms and Harvest Rules

HSG queues are based on species volume targets only. Multiple species may contribute to one harvest target, as in the general case for conifers. Timber volumes by species are calculated for each stand: if the stand's volume components are sufficient to meet the harvest rule, the stand is then queued. An example of a harvest rule target would be Sb/Sw/Pj/B[3] = 145 000 m3. No additional secondary targets can be defined.

Instantaneous Rates of Change: State Tables

The HSG model uses stand breakup as a mechanism to define dynamic succession. If the user desires, the stand stocking and species composition can be redescribed by species at intervals, using the state table. However, by default, the total inventory is continuously being redescribed, with or without any harvest activity. Natural successional pathways are defined in the state table. Of the FORMAN-based models, only FORMAN+1 allows for natural succession. A breakup age can be defined, and when this age is reached the area is directed to a new curve at a user-defined age. SFMM works in a similar fashion.

Silviculture

HSG and the other models provide the user with sufficient capacity to examine silvicultural treatments. All models provide equal resolution for the definition of assumptions relating to silvicultural succession. HSG uses a treatment table to rank inventory sites that are referenced to intensive, extensive, basic, or natural regeneration states. Each regeneration description is found in the state table. If desired, regeneration can be redescribed after the juvenile and maturing stages using a juvenile breakup age. HSG allows the user to

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[3] Sb = black spruce (*Picea mariana* [Mill.] B.S.P.), Sw = white spruce (*P. glauca* [Moench] Voss), Pj = jack pine (*Pinus banksiana* Lamb.), B = balsam fir (*Abies balsamea* [L.] Mill.)

specify the maximum allowable area for silvicultural treatment throughout the simulation. A user-defined upper budget limit for silviculture could be translated into the cost.

Data Storage

HSG controls the size of the simulation intervals using the STEP command. The step intervals can vary throughout the full simulation, and at each interval a different harvest target and harvest rule can be specified. The land base is adjusted and the volumes are recalculated at each step. A 5-year interval step was used to coincide with the FORMAN model. The step size can make a significant difference to the long term sustainable harvest level. The SNAPSHOT command records a copy of the inventory database for the current simulation, with the redescribed state and adjusted volumes. The SNAPSHOT file is as large as the original inventory file, therefore frequent use of SNAPSHOT may consume large amounts of disk space. If the user wishes to generate a map query of a particular time period, a snapshot must be taken at that time period.

In FORMAN-based models, queries relating to any particular time period must be solved by interpreting the hard copy tabular reports. Only one copy of the forest classes is stored for the FORMAN-based models, which requires little disk space.

Outputs

Three forms of output are provided by HSG simulations: tables, graphs, and maps (where a digital inventory exists).

The most significant difference between HSG and the other models is that diverse queries can be made of the HSG simulation results to enhance the interpretation of simulation activities. In contrast, the FORMAN-based outputs are tabular only, and no queries of the simulation results are possible. The ability of HSG to query the simulation results (with or without a digital inventory) affords the user tremendous latitude to interpret the effects of simulation. Suitability matrices can be defined to classify stand data output into descriptive classes. The suitability matrix can be easily modified to reclassify the output. In contrast with the other models, the entire inventory would require re-aggregating into new forest classes and preparing the associated yield curves if the classification parameters changed.

If the goal of a modelling exercise is to explore the full range of simulation effects upon the forest and to classify stand data output into more readily interpreted classes, HSG is the preferred tool. If these effects require a spatial context then HSG is also the better model.

User Skill and Ease of Use

Generally speaking, HSG requires a higher degree of skill to effectively operate and take advantage of its output capacities. HSG requires the user to explicitly define forest development assumptions (the state table) in advance. This can be time consuming, as all possible states must be identified, therefore casual users of modelling software may find this difficult. In contrast, the other models require the user to define generalized forest classes and yield curves. The querying capacity of HSG is very advantageous, but also requires skill and experience to utilize.

HSG Functionality in Applications

HSG functions as a wood supply tool without the need for a digital forest inventory. However, a digital inventory should be used to augment the interpretive capacity of the model. Although the quality of the spatial output provided by HSG/IDRISI is inferior to that produced by workstation-based GIS software, it is nonetheless valuable to the analyst. Spatial output is also an asset when communicating results to others.

A digital inventory can be rasterized using other available software, including ARC/INFO. Techniques to complete this rasterization process will differ with each package. A unique record number must first be assigned to each stand in the forest prior to rasterization. This unique record number will relate to the inventory file containing the stand FRI attributes. The HSG GRIDDER module is then used to reformat a noncompressed ASCII grid file into IDRISI raster file format. IDRISI is limited to 32 767 unique stand records, which are dependent upon the forest area and the selected raster cell size, which is a possible limiting factor. These operations should be performed by computer-literate individuals.

Adaptive Management and Tradeoff Analysis

HSG is designed as a simulation tool to be used in the context of adaptive resource management. Source data is input, harvest targets are specified, and then queries are made of the simulation results to determine future simulation modifications. The user can examine the simulation results and determine if they are compatible with the defined objectives for the forest. Common forest objectives can be expressed in terms of sustainability, industrial opportunities, and costs. A selected simulation result will be determined after various tradeoff analyses have been carried out.

Economics

Unlike the other models, HSG cannot queue the harvest using cost as a factor. It can, however, fully analyze the economic implications of the simulation results and classify the output in terms of cost. HSG links a rule file, containing economic parameters, to the schedule of harvest and silvicultural treatments so as to calculate economic values and costs. These cost rule files can be defined in a broad or fine resolution depending upon the circumstances. Simple HSG menus allow the user to calculate and query the net present value of simulation results. More complicated harvesting and transportation cost analysis is possible, but this was not explored because the required input was not fully available.

Wildlife Habitat

HSG is effective in simulating wildlife habitat availability, because it maintains the stand level inventory resolution along with a spatial context. Suitability matrices can be designed to describe specific levels of habitat quality and to store the value in a new category. This category can then be queried spatially, and examined for broad local or landscape patterns. The suitability matrix can then be adjusted, if warranted, and a second simulation will show how sensitive the description of habitat is in relation to the adjusted variable.

Decision Communication

HSG provides detailed simulation results and maps to communicate results. This is particularly important when potential land use conflicts exist. The importance of having the capability to link a spatial component to otherwise abstract simulation results cannot be understated. The goal of this study is not to compare the mapping output of HSG to other mapping software, but to other wood supply software.

In reference to the questionnaire used for this study, HSG is seen as an effective tool to examine (a) timber harvest by species, (b) forest succession, c) economic impacts, and (d) wildlife habitat issues. Although a 'secondary product' definition capacity is not available in HSG, most questionnaire respondents preferred to rely upon historic estimates and experience for this, rather than upon simulation results.

STRATEGIC FOREST MANAGEMENT MODEL (SFMM)

Testing the SFMM was incorporated into the project in the last two months of the study, and the authors readily admit that not all capabilities of this model were examined. In many instances, to make a fair comparison with the other models, additional restrictions and constraints were placed on the SFMM.

SFMM is an optimization model, and so reacts differently to the assumptions and targets used. The model is easy to use, but is harder to understand than some of the others. When using this model it is important to start with a basic run, and then add assumptions one at a time to see how the model reacts. Overall, the model is very flexible and can be used in a wide variety of situations.

The AIMMS Windows version tested provides an excellent user-friendly interface, and changes in assumptions can be efficiently made. Input graphs and tables allow the user to visualize the assumptions and identify and correct any input errors. Outputs in the form of graphs, tables, and reports are excellent, and options allow the user to save cases and make comparisons between runs without a lot of manual effort.

Overall, the model stands head and shoulders above all of the other models. The only drawback with this model is the cost of the AIMMS linear program and the high capacity of the personal computer that is required.

PCNFCS

PCNFCS is very handy for a wide variety of purposes. It is recommended that the program be upgraded to handle the required inputs for FORMAN+1 and SFMM (some work has been started on SFMM inputs). To the new user, this program offers a wide variety of options to prepare the required inputs for modelling. The program is set up in four stages: file check and preparation, forest class aggregation, yield curve development, and file export. The comments that follow deal specifically with each stage of the program.

File Check and Preparation

This stage of the program is easy to use, works well, and can be useful for a variety of purposes. The error check capability identified mistakes in the original FRI database that had gone unnoticed for years. The search and edit features allow the user to easily search out errors and make the required changes.

A wide variety of reports and summaries are available, and the author has assisted the user by formatting some of the reports for inclusion into timber management plans. Reports can be saved in a file, or exported directly to a printer. Reports sent directly to a printer have been formatted for a wide page printer. This is a drawback with the program, but the user may be able to avoid this by exporting the report files to some other software program and printing from there, or by setting up the printer to print from DOS.

The option of exporting the corrected "stanf" (a standard OMNR database of stand forest inventory) file in the proper format avoids the necessity of making corrections in more than one database. While not the fault of the program, the user should be cautioned that to incorporate free-to-grow and cutover information into the stanf database, the required format must be followed. For example, eastern larch (*Larix laricina* [Du Roi] Koch) and balsam fir should be identified by "L" and "B", and the correct number of spaces left between the working group and percent composition (e.g., B_ _6BW_3L_ _1)[4].

Forest Class Aggregation

The forest class aggregation stage of the program allows the user to define the parameters needed to model the required scenarios. There is great flexibility in setting these parameters, but care and planning are required to avoid creating too many curves. When setting the number of Forman Management Units and setting the aggregation criteria for the working groups and site classes, the total number of curves generated by the program is almost exponential. Even some of the simplest scenarios can generate 200 to 300 curve sets, which is greater than the capacity of most models.

The selection and running of aggregation criteria also sets up the silvicultural cards (silvicultural treatment regimes) for the next step of the program. Again, it is cautioned that planning is required to avoid creating too many silvicultural cards. If there are no real differences between silvicultural treatments required to regenerate a site, and the user feels comfortable with averaging the volumes among site classes, it is advisable to group whenever possible. This will reduce the number of curves and give the user enough flexibility to better model more important criteria. For example, the user may decide to group all three site classes for the white birch (*Betula papyrifera* Marsh.) working group because the silvicultural treatment required to regenerate these stands (i.e., leave for natural regeneration) are similar, and because white birch is not usually a primary or secondary product. This would allow the user to further refine the definition between upland and lowland black spruce sites, which in this case is a primary species and requires quite different silvicultural treatments based on the site type.

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[4] BW = birch white, i.e., white birch (*Betula papyrifera* Marsh.)

Yield Curve Development

This stage involves entering the information required for the silvicultural cards, pure species curves, product percent table, and site class cross reference table. The format for this data entry has been well thought out and is user-friendly. If the user is not satisfied with the silvicultural card setup developed in the aggregation stage, he must back-up, re-enter, and run the aggregation criteria. The model would function better if the bank of silvicultural treatment cards could be re-used for different aggregation runs, thus avoiding the need to enter the information each time (i.e., similar to the cross reference table, pure species curves, and product percent tables).

File Export

The last stage of the program involves the preparation of the files required by NORMAN, FORMAN CP, and FORMAN 2.3. Note, however, that because FORMAN+1 has a built-in conversion program to accept FORMAN 2.1 files, PCNFCS can also be used to prepare, in part, some of the curve information required by FORMAN+1. File export is straightforward. In the March 31, 1994 version of PCNFCS, two problems were encountered in the file export stage:

• In the NORMAN cost files there are two places where a space is missing in the file. These required manual editing before the program would accept the file.

• In the transfer of information for CROPLAN, the cost data did not transfer to the FORMAN CP files (it did on earlier versions).

CANADIAN FOREST SERVICE FORMAN+1 DATA GENERATOR

Prototype copies of the FORMAN+1 DATA GENERATOR, Version 1.0 have been completed and tested to date. The FORMAN+1 data generator was developed with the intent of facilitating FORMAN+1 simulations by automating much of the input files data preparation process. The data generator was developed within the context of a specific simulation design. The intent of the simulation was to provide spatial representation at the level of compartments (e.g., map sheet aggregates) or working circles within a designated management unit, or group of management units. The temporal projection was envisioned as encompassing a 20 to 30 year planning horizon. Representation of forest cover types was designed to allow for differentiation by selected working group, site class, and age class categories. To process cover type aggregations comparable to PCNFCS-generated data files, the user will require a compatible FORTRAN compiler, must be familiar with FORTRAN programming, and ultimately, be prepared to undertake the task of modifying the source code.

CONCLUDING COMMENTS

Because of the time that has elapsed between carrying out the above research and publishing the results, some of the evaluations may be outdated. For example, the Strategic Forest Management Model has evolved considerably since this investigation was conducted, and a number of recommendations from this project were in fact incorporated into subsequent versions of the model (e.g., refinement of the inventory data into more age classes to improve the accuracy of the results).

This report should be of value for those just starting to use models because it makes clear:
• the historical context in which the models were developed and used,
• the need for up-to-date inventory information to properly use all the models,
• that forest inventory information must be sorted and manipulated into forest units that represent a number of aspects of forest management, for example, harvesting, silvicultural treatments, succession, wildlife habitat, and others,
• that assumptions must be introduced in an orderly fashion, and the user must know how models handle the information,
• in some situations where rough approximations are required, some to the early models, such as FORMAN or MADCALC, may be useful.

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DISCLAIMER

The views, conclusions and recommendations are those of the Authors and should not be construed as either policy or endorsement by Natural Resources Canada or the Ontario Ministry of Natural Resources.

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