Growth and Yield Modelling: Applications of SYMFOR to evaluate silvicultural systems.

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Abbreviations.

BFMP	Berau Forest Management Project
DFID	Department For International Development (UK)
GIS	Geographic Information System
PCT	Potential Crop Tree thinning treatment
PSP	Permanent Sample Plot
RIL	Reduced Impact Logging
RKL	Five year operating plan.
STREK	Silvicultural Treatments for Regeneration of logged over forest in East Kalimantan.
SYMFOR	Sustainable Yield Management for Tropical Forests. (DFID, Growth model)
TPTI	Indonesian Selective Logging and Replanting silvicultural system
TPTJ	Indonesian Strip cutting and replanting silvicultural system.
YSS	Yield Simulation System (BFMP Concession scale growth and yield model)

1 Introduction

1.1 Applications of growth and yield modelling for forest management.

1.1.1 The growth of a forest described the change in number of stems, volume or basal area in a forest stand over time. Yield described the amount of products (e.g. timber) that can be obtained from the forest when harvested. Growth and yield modelling is a tool that can be used for forest management to assess the likely productivity of a forest concession. The application modelling can also be extended to assess if forest management practices are likely to meet set management objectives for example linked to the concept of indicators of sustainable forest management (van Gardingen & Phillips, 1999).

1.1.2 This training document aims to introduce users to the SYMFOR growth and yield model so that they can develop and run applications to support the development of a management plan for the Labanan concession of PT Inhutani I in East Kalimantan.

1.2 Growth and yield modelling using SYMFOR.

1.2.1 Conventional forest growth and yield modelling ranges from simple statistical stand models linking average diameter or height with stand age; through to models which use a knowledge of inter-tree distances, site indices and stand basal areas to empirically simulate the inter-tree competition for resources of light, water and nutrients (Vanclay, 1994; Adlard, 1995; Alder, 1995).

1.2.2 Complex tropical forests have three characteristics making yield modelling difficult: a) several hundred tree species may be present, b) the forest covers a wide range of growth habitats and c) tree age is often irrelevant to growth potential and is usually unknown. This means that species must be grouped into classes of similar growth type and volume relationships based on factors like tree diameter (diameter at breast height, dbh) rather than age. Simple dbh-based stand growth models or yield tables have been used in the tropics, but, in addition to the problems of species categorisation, they tend to ignore the great influence of tree density on future growth. Over the years, whole-stand models, diameter-distribution models, distance-independent individual tree models and, finally, distance-dependant individual tree models have been developed (Wan Razali, Chan & Appanah, 1989; Mohren & Burkhart, 1994; Vanclay, 1994; Ong & Kleine, 1995).

1.2.3 SYMFOR (Sustainable Yield Modelling for Tropical Forests) was developed to enable forest managers to explore the impact of alternative management practices on growth and yield for mixed tropical forest (Young & Muetzelfeldt, 1998). To do this, its design is based on a detailed representation of the forest composition and spatial structure. This gives it considerable advantages over other commonly-used methods, such as yield models, diameter-class projection models, matrix models, cohort models and gap models, that are much less able to capture spatial relationships, including those relating to logging, that are so crucial to forest dynamics.

1.2.4 SYMFOR represents a one-hectare patch of forest (though this is readily changed) normally obtained from a network of permanent sample plots (PSP). This one hectare is taken as representative of some larger area, assuming uniformity with respect to species composition, soil characteristics, past management practices, and other factors which might be thought to affect tree growth relationships. SYMFOR is thus a stand-level model, modelling the dynamics of one management unit, rather than a forest-level model (such as DIPSIM (Ong & Kleine, 1995)), modelling a whole set of management units.

1.3 SYMFOR Model Structure

1.3.1 SYMFOR is in fact not a single model, but rather a modelling framework within which models can be constructed and their behaviour investigated. This gives considerable flexibility in allowing alternative modelling assumptions to be explored, models to be refined incrementally as more information becomes available, and alternative silvicultural methods (e.g. logging) to be explored. A multiple-run facility allows the user to perform repeated simulations in order to obtain estimates of the mean and variance of their results, that naturally arises from the Monte Carlo modelling of stochastic (random) processes used in several components of the models, for example tree mortality.

1.3.2 All SYMFOR models work on yearly time-steps, with several functions being carried out each year. The principle forest processes that are modelled are:

- individual tree growth;
- natural mortality;
- seedling and sapling ingrowth;
- damage resulting from natural disturbance (tree falls);
- logging and its associated disturbance.

1.4 Structure of the training course.

1.4.1 SYMFOR is a tool to support users in their evaluation of silvicultural systems for forestry in lowland dipterocarp forests in Indonesia. The model's predictions on the growth and yield of these types of forests can also be used for more general management planning when combined with concession-wide growth and yield modelling, economic modelling and an environmental (GIS) framework for the concession.

1.4.2 The training course will take potential users through a set of skills that are required in order to run SYMFOR simulations and analyse results from the simulations. One worked example is presented illustrating an analysis of the conventional TPTI silvicultural system. Participants in the training workshop will then used this example as a starting point to assess alternative management options.

1.5 Outputs from the training course.

1.5.1 At the end of the training course, the participants will have developed the skills required to apply SYMFOR to contribute to management planning for a concession.

1.5.2 The participants will have used these skills in a case study for management of the Labanan concession of PT Inhutani I in East Kalimantan.

2 Single simulations

2.1 Introduction

2.1.1 SYMFOR models simulate growth and yield using data from individual permanent sample plots. The simplest example of a growth simulation with SYMFOR involves a single simulation. This section will describe such an application to compare different silvicultural treatments in SYMFOR.

2.2 Getting started

2.2.1 SYMFOR has already been installed on the computers to be used in the workshop. Participants will be given a CD-ROM version of the latest version of SYMFOR. This standard installation of SYMFOR (and the version downloaded from the web) does not include some of the data files and simulation instructions used for the training workshop and this simulation. A list of the modified and additional files is presented as Appendix 4. These will be included on a separate CD-ROM containing a summary of the material presented at the workshop.

2.2.2 Several options are available to users once SYMFOR is running. Select the **`New single run`** option from the **`Start run`** menu.

2.2.3 The model prompts for information about the Tree-Data table. Use the settings shown in Table 1.

Parameter	Setting
Database type	Visual Foxpro .dbf files
File name	c:\program files\symfor\STREKplots
Database table name	R4P12RU2C1.DBF

Table 1. Settings used to select data describing the individual trees used for a single simulation in SYMFOR.

2.2.4 These settings select the file containing information about trees in the plot used in the simulation. These data come from the STREK plots from Inhutani I's Labanan concession. The coding (sequentially) shows that these data are from RKL 4 (R4), Plot 12 (P12), recording unit 2 (RU2) and measurement campaign 1 (C1). It is necessary to press the **`Set`** button after selecting a file after browsing a directory. Press **`OK`** once the file has been selected.

2.2.5 After selecting the stand data, SYMFOR will prompt for a file containing information about the stand. Use the settings shown in Table 2. These settings select a file describing unlogged plots in the STREK trial.

Parameter	Setting
Database type	Text
File name	c:\program files\symfor\Stands
Database table name	nologging.csv

Table 2. Settings used to select data describing the stand used for a single simulation in SYMFOR.

2.2.6 SYMFOR will next display the Run settings options dialog box (Figure 1)

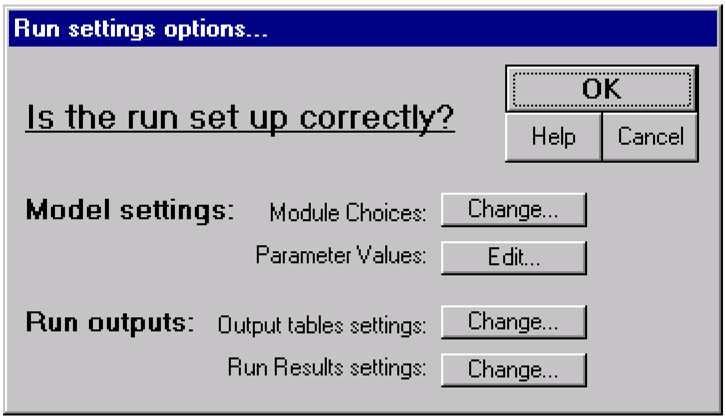


Figure 1. SYMFOR's Run settings option window.

2.2.7 The first example will run SYMFOR to simulate the standard TPTI silvicultural system. SYMFOR needs to be given appropriate settings to describe the system. These are set using the **Module choices** and **Parameter values** dialog boxes. You can press the **Help** button to display information about the window, model settings, modules and parameters.

2.2.8 Select **Module choices** to display the following window (Figure 2)

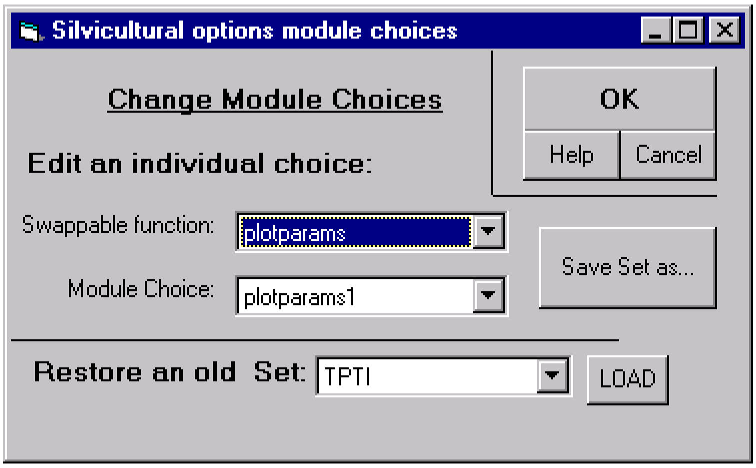


Figure 2. Module choice window.

2.2.9 Select the TPTI entry under **Restore an old Set:** and then click the **Load** button. This will load an existing set of modules for the model. Click **OK** to return to the run settings options. You should then select the **Parameter values** window (Figure 3).

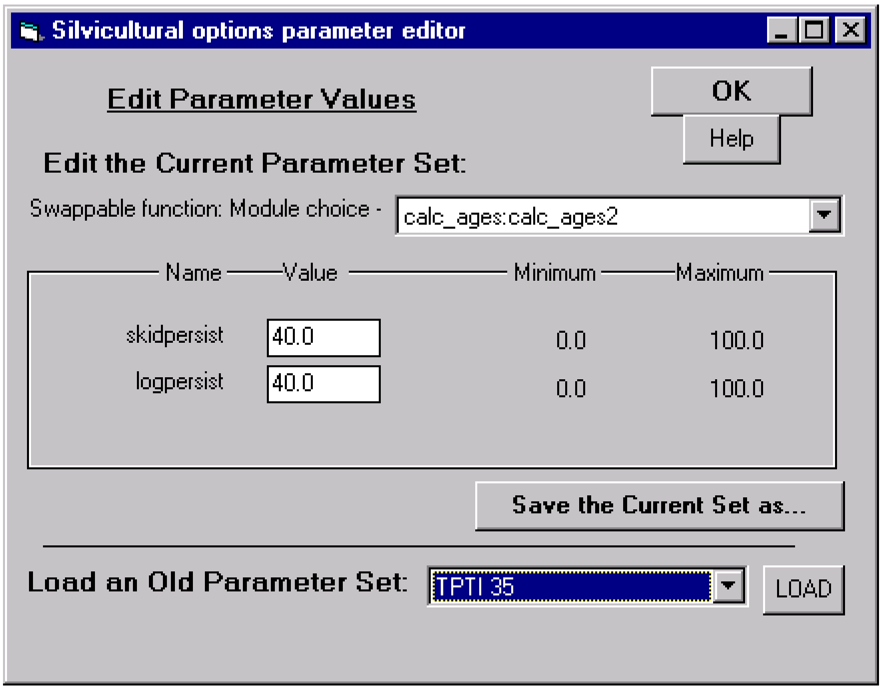


Figure 3. Silvicultural options parameter editor.

2.2.10 Select the **TPTI 35** entry for **Load an Old Parameter Set:** and then click the **Load** button. These parameters will set the model to simulate the implementation of TPTI.

2.2.11 You can examine the settings of the silvicultural options by selecting any of the entries in the **Swappable function: Module choice** menu. The entries shown in Table 3 are the key parameters used to define the TPTI system. (Do not change any of the settings yet)

Module	Parameter name	Value
calc_treatment:calc_treatment	firstlogging	0
	loggingcycle	35
felling:undirectional	-	-
logqualify:qualify1	dbhthreshold	50 cm for commercial dipterocarp groups
	qualitylimit	0.3
planskidtrails:straight	accesspointx	50
	accesspointy	0

Table 3. Parameter settings used to describe the TPTI silvicultural system.

2.2.12 These settings set the model to log the plot at the start of the run (year 0) and then at 35 year intervals. The harvesting of trees does not use directional techniques. The trees to be harvested are selected from commercial groups when their diameter is greater than 50 cm. The quality limit of 0.3 is used to represent the rejection of a proportion of the trees that have poor stem quality. The value of 0.3 used in this example means that 70 % of commercial trees with diameter greater than 50 cm will be harvested. Note that trees rejected for harvesting cannot be reselected during subsequent harvests. The straight skidtrials are used to represent conventional logging techniques where these are not planned to minimise damage to the residual stand.

2.2.13 Once you have finished examining the parameters, you should press the **OK** button to return to the **Run settings** dialog box. The run has now been set up correctly so click the **OK** button to load the data. The **Run** dialog box (Figure 1) should now be displayed.

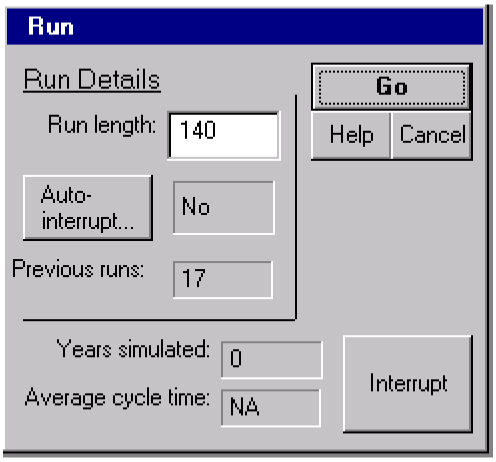
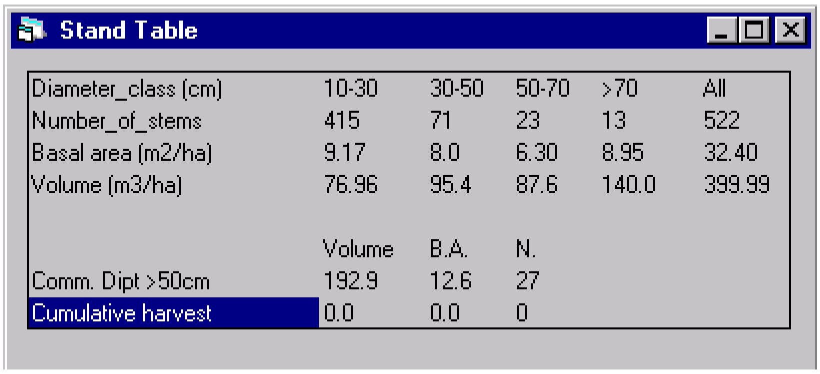


Figure 4. Run settings dialog box.

2.3 Displays

2.3.1 Before you start to run the model you should select a number of displays to show information about the stand as the model runs. From the Displays menu you should select Stand table (Figure 5), Plan view (Figure 6) and Time series plot of run results (Figure 7).



Stand Table

Diameter_class (cm)	10-30	30-50	50-70	>70	All
Number_of_stems	415	71	23	13	522
Basal area (m2/ha)	9.17	8.0	6.30	8.95	32.40
Volume (m3/ha)	76.96	95.4	87.6	140.0	399.99
	Volume	B.A.	N.		
Comm. Dipt >50cm	192.9	12.6	27		
Cumulative harvest	0.0	0.0	0		

Figure 5. Stand table display at the start of a single simulation.

2.3.2 The stand table shows a summary of the stand in terms of the number of stems and their basal area and volume according to size class. The lower part of the window displays information describing commercial dipterocarps that are larger than the 50 cm diameter cutting limit and cumulative harvest from the simulation (0 at the start of the run)

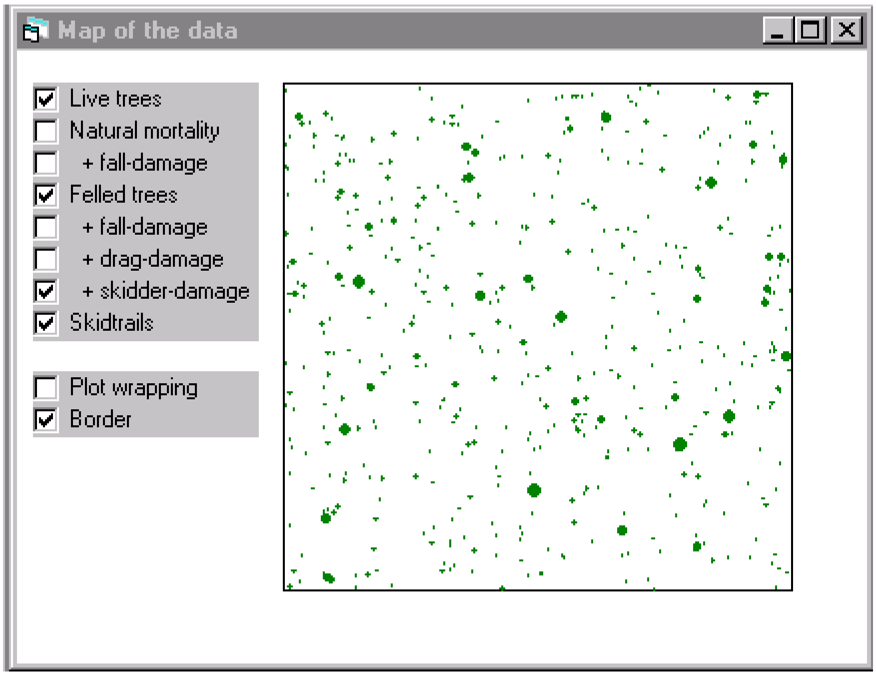


Figure 6. Map (Plan view) display showing the location of individual trees at the start of the simulation. The diameter of each circle is proportional to the diameter of the tree.

2.3.3 The plan view of the data presents a map showing trees and skidtrails. You should select (check) the checkboxes for Felled trees, skidder damage and skidtrails as shown above. The diameters of the circles on the map are proportional to the diameter of each tree represented in the model.

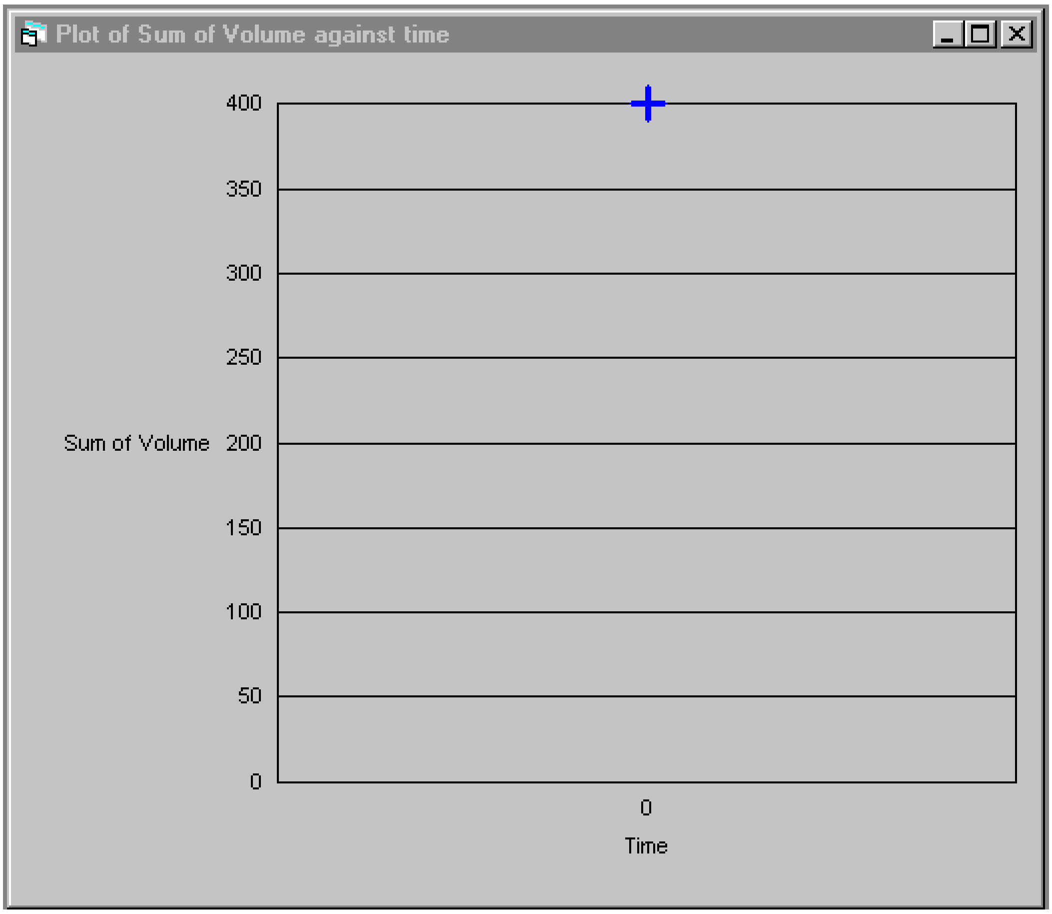


Figure 7. Plot view (default settings) to display changes in stand volume with time.

2.3.4 The plotter window (Figure 7) is used to present a graphical representation of changes in the status of the stand as the simulation proceeds. It contains no data at the start of the run.

2.4 Running the model

2.4.1 You may need to resize the windows to fit onto your computer screen before you start to run the model. When you are ready click **Go** in the **Run** window. The model will now start to simulate the growth and yield of the forest.

2.4.2 The displays are updated at the end of every ten-year interval of the simulation. You can click the **Interrupt** button in the **Run** window to pause the simulation allowing you to examine the results.

2.5 Results

2.5.1 The following examples of the display windows were obtained at year 20 of a sample simulation. You should note that you will not have the same information. This is because SYMFOR models many processes that involve components of chance. For this reason no two runs will produce identical results. The implications of this aspect of modelling will be considered later.

Stand Table

Diameter_class (cm)	10-30	30-50	50-70	>70	All
Number_of_stems	475	60	13	2	550
Basal area (m2/ha)	9.64	7.3	3.50	0.87	21.30
Volume (m3/ha)	79.37	88.0	48.4	13.0	228.80
	Volume	B.A.	N.		
Comm. Dipt >50cm	39.8	2.7	9		
Cumulative harvest	152.2	9.9	20		

Figure 8. Stand table showing a summary of data at year 20 of a simulation of the TPTI silvicultural system.

2.5.2 Figure 8 shows that 20 stems were harvested with a total volume of 152.2 m^3. The stand at this stage has a further 9 stems of commercial dipterocarp species with diameter greater than 50 cm.

2.5.3 The map display (Figure 9) shows the location of the trees that were felled (red circles), the direction that the stem fell (red lines) and the skid trails (thick yellow lines). It can be seen from this display that trees fall in random directions in relation to the skidtrails. The skidtrails all radiate from a single access point at the bottom of the plot.

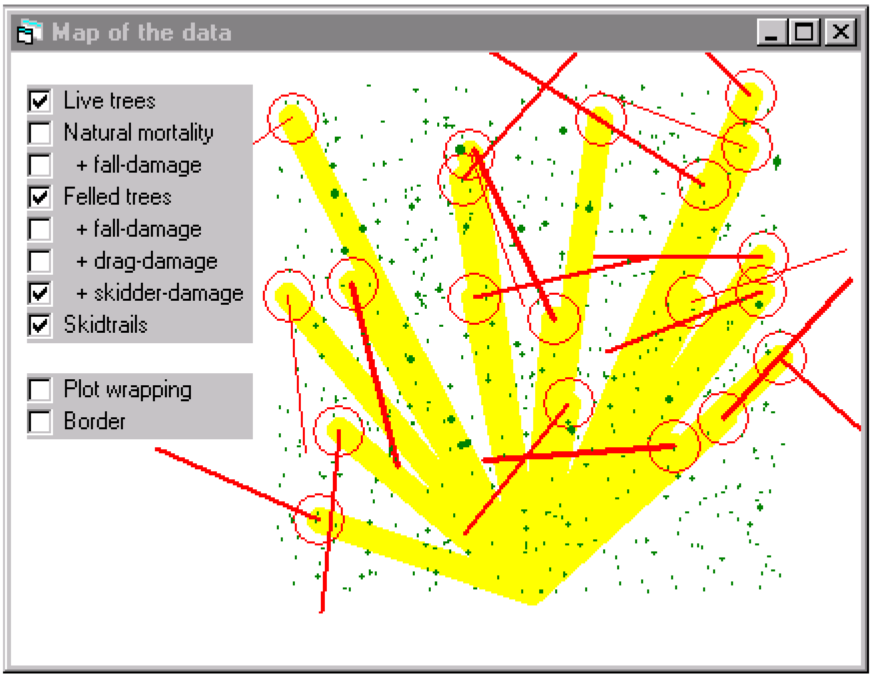


Figure 9. Map display at year 20 of a simulation of the TPTI silvicultural system. The red circles mark the location of logged trees and associated skidder damage. Red (thin) lines show the location of felled trees and the (thick) yellow lines are skid trails.

2.5.4 The plot display (Figure 10) shows the change in stand volume. There is an initial drop in volume associated with logging followed by a gradual increase over the following twenty years of the simulation.

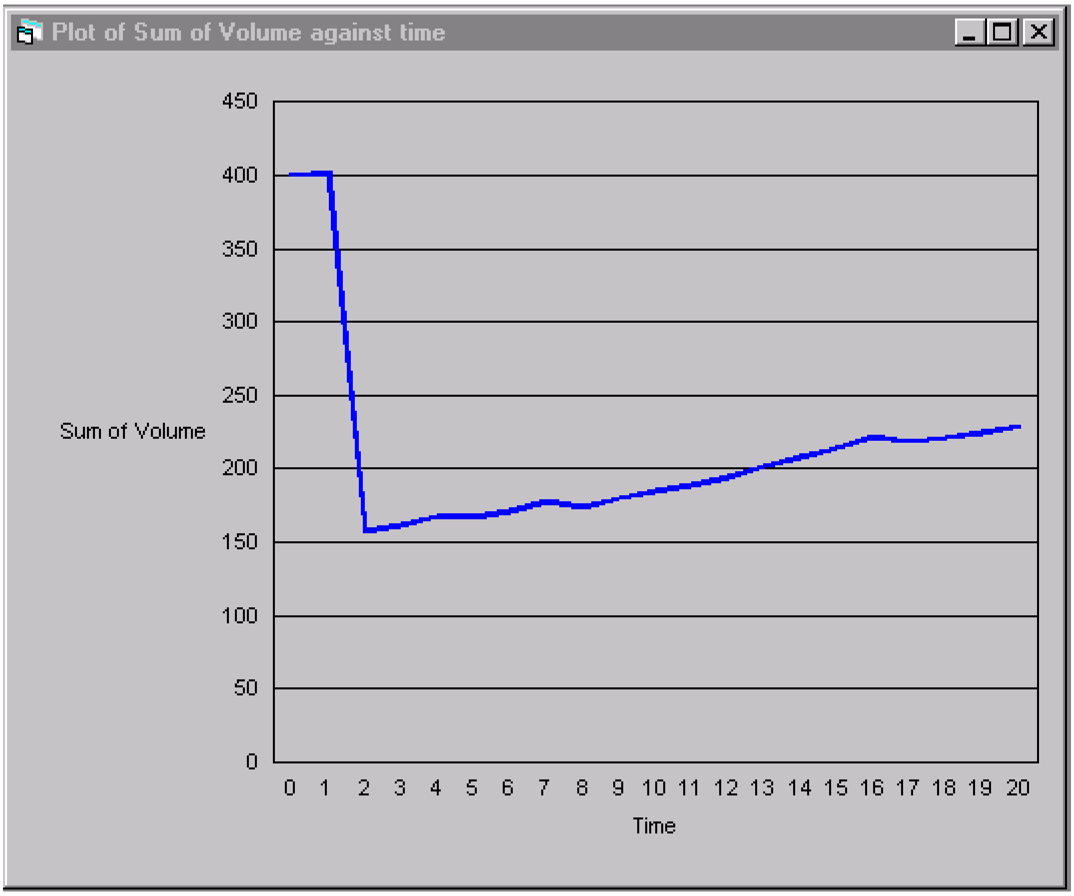


Figure 10. Plot display at year 20 of a simulation of the TPTI silvicultural system.

2.5.5 The run can be restarted by clicking the **Go** button in the **Run** window. The simulation will run for a total of 140 years. The displays will be updated every ten years of the simulation.

2.5.6 The results can be examined in more detail at the end of the simulation. The plot display shows changes in total stand volume over the course of the simulation (Figure 11).

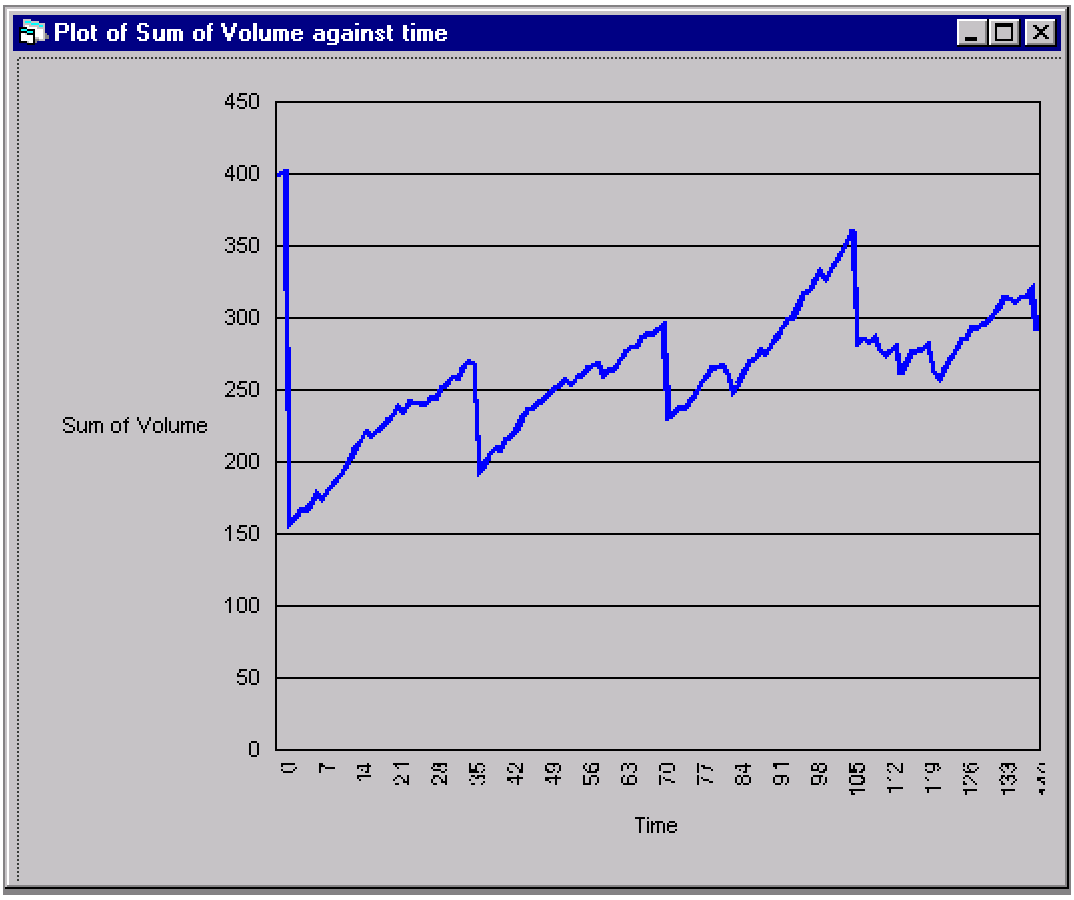


Figure 11 Graph of stand volume against time for a 140 year simulation of the TPTI silvicultural system. Logging is simulated at 35 year intervals.

2.5.7 Double clicking on the plotter display of the time series data (Figure 11) will display the plotting options editor (Figure 12) which allows you to examine other summary data for the simulation. As an example, select the option **Vol of felled trees** and click **Ok**. The plotter display will change to display the cumulative volume of trees felled during the simulation (Figure 13).

2.5.8 The plotter display shows the total volume harvested in one simulation of the TPTI system with a 35 year cutting cycle. Figure 13 shows that the second and subsequent simulated harvests are significantly smaller than the first harvest from primary forest.

2.5.9 This completes the first example run using SYMFOR. The next section considers ways of implementing alternative silvicultural treatments in SYMFOR.

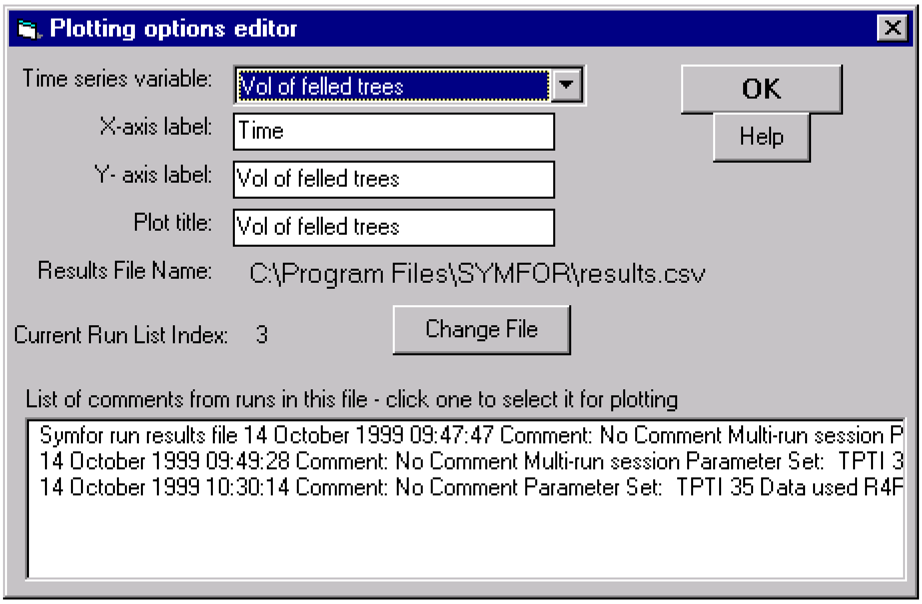


Figure 12. Plotting options editor.

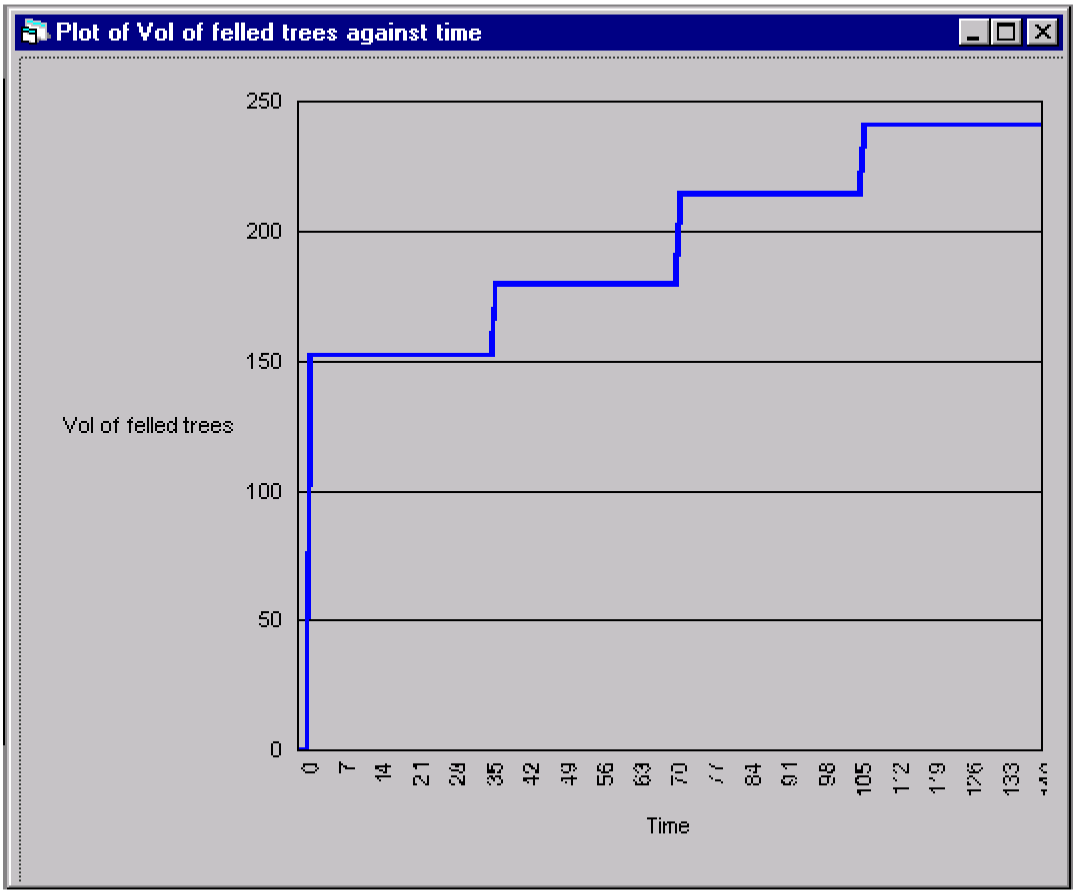


Figure 13. Plot of the cumulative volume of trees felled (harvested) over a 140 year simulation of the TPTI silvicultural system.

3 Simulating Silviculture in SYMFOR

3.1 Introduction

3.1.1 SYMFOR was designed to examine the effects of various silvicultural management options on the status of the forest stand and commercial productivity. In this section we will describe how these options are modified for individual runs using SYMFOR.

3.1.2 SYMFOR is fully documented through interactive help pages linked to a series of web (Hypertext) documents. Display the **`SYMFOR help pages`** from the main **`Help`** menu. The sections describing the **`SYMFOR Users Manual`** and **`Model Components`** will help you to understand the next exercises.

3.2 Modules choices and Parameter Values

3.2.1 The way that SYMFOR simulates growth and silviculture is determined by the choice of modules within the model and the values of parameters within each module. A module can be considered to describe one way of completing or simulating a task. An example would be the module used to create skidtrails. One option is to create straight trails that all radiate from a central access point. This simulates conventional logging, which does not use planned skidtrails. The alternative module simulates planned trails by constructing a branched network of trails to minimise total length and area of disturbance.

3.2.2 Within each module a number of parameter values may be used to modify or control how the task is completed. Using the previous example of the skidtrails, parameters are used to determine the access point, the width of the trails.

3.2.3 The help page for **`SYMFOR 99 Model components`** provides information about swappable functions, module choices and model parameters.

3.2.4 Two examples will be presented in this exercise. In the first, the TPTI system will be modified to examine the effects of increasing the length of the logging cycle. In the second example the logging prescription will be changed.

3.2.5 The most important silvicultural module choices for the SYMFOR model are summarised in Table 4 and silvicultural model parameters are summarised as Table 5.

Swappable Function	Module	Description
calc_treatment	calc_treatment1	Decides when to implement silvicultural treatments
treatment	TPTI RIL TPTJ	Activates modules to apply silvicultural treatments. Note that TPTI and RIL have essentially the same module choices
logqualify	qualify1 TPTJqualify	Selects trees for logging according to diameter and stem quality limits
logselect	Select1	Implements restrictions on the volume or number of stems harvested
felling	undirectional directional	Select directional module to activity directional felling
dragdamage	dragdamage1	Simulates damage to stand from log extraction
skidprepdamage	skidprepdamage1	Simulates damage to the stand when preparing to skid the bole
planskidtrails	straight branched	Select branched to simulate planned skidtrails
calcskidcorners	nocorners sharpcorners	Used to simulate the damage from skidding a felled tree around a corner
skidtrails	skidtrails1	Used to simulate the damage resulting from the construction of skidtrails.
createstrips	createstrips1	Creates cleared strips for TPTJ
replantstrips	replantstrips1	Replants strips for TPTJ

Table 4. Silvicultural model choices in SYMFOR.

Parameter	Module	Swappable Function	Description
firstlogging	calc_treatment1	calc_treatment	When to do the first silvicultural operation
loggingcycle	calc_treatment1	calc_treatment	How often to repeat the operation
dbhcrit	qualify1	logqualify	Minimum diameter to qualify for logging
qualitylimit	qualify1	logqualify	Minimum stem quality for logging
nlogmax	select1	logselect	Maximum number of logs to extract
maxextract	select1	logselect	Maximum timber volume to extract
minextract	select1	logselect	Minimum timber volume for any logging
cutdirection	directional	logging	Felling angle relative. to skidtrail (directional felling)
joinangle	branched	planskidtrails	The angle at which skidtrails meet
skidwidth	skidtrails1	skidtrails	The width of a skidtrail
skidpersist	calc_ages1	calc_ages	The time that skidtrails remain usable for
skidprepradius	skidoreodamage1	skidprepdamage	The area damaged by the skidder manoeuvring to attach to the bole.

Table 5. Silvicultural parameters in SYMFOR

3.3 Changing the length of the cutting cycle.

3.3.1 The first example of changing a silvicultural prescription simply involves changing the length of the cutting cycle. This is controlled by the model parameter **`loggingcycle`** in the module **`calctreatment1`** (Table 5).

3.3.2 Start a **`New single run`** of SYMFOR (**`Start Run`** menu item). Use the same input files as you used in section 2. Choose edit parameters when the run settings options dialog box (Figure 4) is displayed. You should choose the entry for the swappable function: module choice of **`calc_treatment:calctreatment`** and then edit the entries as shown in Figure 14. This will programme the model to log first in year zero of the simulation and then at 45 year intervals. You should next click **OK** to accept you changes and return to the run settings dialog. Click **OK** to load the data and display the **Run** window.

3.3.3 Select any display windows and then run the model. You should compare the results with those obtained previously using a 35 year cutting cycle.

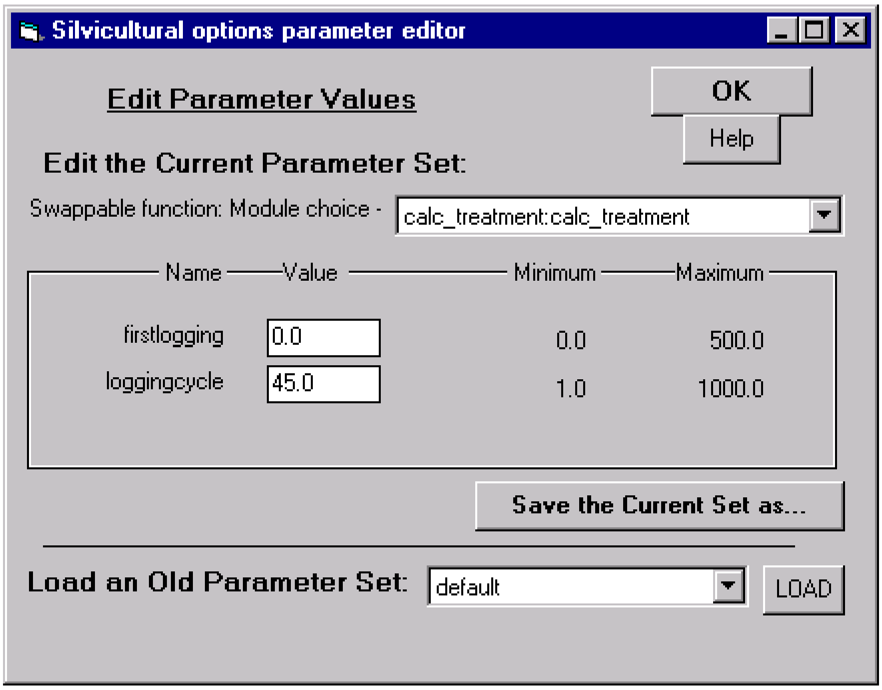


Figure 14. Silvicultural options for a 45 year cutting cycle.

3.4 Changing the logging prescription.

3.4.1 The selection of trees for simulated logging is determined by a sequence of prescriptions that specify diameter limits by species group, a stem quality limit, minimum and maximum volumes for logging and a maximum number of stems that can be logged. The logging prescription is controlled by the swappable functions **`logqualify`** and **`logselect`**. The TPTI prescription uses the modules **`qualify1`** and **`select1`**.

3.4.2 In this exercise, you will first reset the system to use the default TPTI silvicultural prescription and then change parameters to increase the diameter limits to 55 cm with a maximum of 8 stems being harvested.

3.4.3 Start a new single run of SYMFOR and select the same default input files. Choose Edit parameter values when the **Run settings options** dialog box is displayed. Select the module choice logqualify:qualify1 (Figure 15).

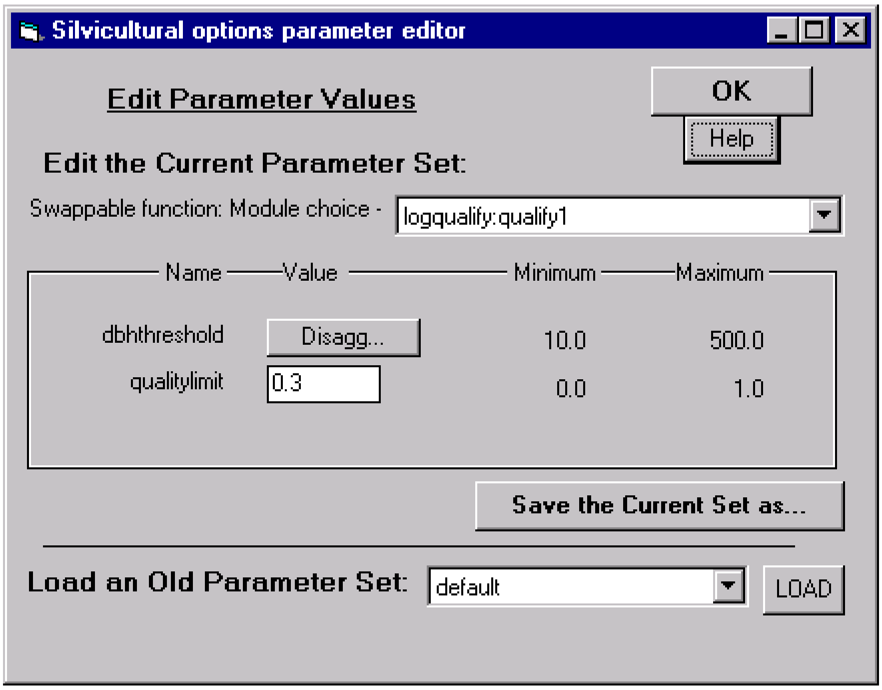


Figure 15. Parameter set for Logqualify module.

3.4.4 The quality limit of 0.3 specifies refers to an estimate of stem quality. Trees will only be selected for logging if the stem quality exceeds 0.3. Quality values are normally assigned to the dataset at random with values between 0 and 1. A value of 0.3 therefore means that 70 % (1-0.3) of the trees will be harvested. Trees that have been rejected once will not be available for subsequent harvests. Leave the setting as 0.3 for the current run.

3.4.5 The dbhthreshold parameter is set according to a species utilisation group. Click the **Disagg** button to display a dialog box to edit the threshold for each utilisation group. The STREK data have been provided with two species groupings. The utilisation groups are based on the BFMP species groupings (Appendix 1, (Rombouts, 1998)). An ecological species grouping (Appendix 2, (Phillips & van Gardingen, 1999)) is used to simulate growth and other ecological processes.

3.4.6 The DBH thresholds should be edited as shown in Figure 16 so that trees in groups 1-3 (Commercial Dipterocarps, Appendix I) are available for logging when their diameter exceeds 55 cm. It should be noted that this condition is combined with the quality assessment only trees which has a stem quality greater than 0.3 *and* exceeding the DBH limit will be available (qualify) for logging.

3.4.7 Once the changes to the DBH limits have been completed press the **Finish Editing** button to return to the parameter editor. You should now display the parameters for the **Logselect:select1** module (Figure 17). These should be edited as shown in Figure 17. These settings mean that logging will only take place if a minimum volume (**minextract**) of 20 m^3 is available (qualifies) for logging. The simulated harvest will extract a maximum of 8 stems per hectare. The eight largest qualifying trees will be harvested. The value of 500 m^3 for **maxextract** is used to set no upper volume limit on the selection. Once the changes have been completed, click **OK** to return to the run settings dialog and then **OK** again to display the run window. Click **Go** to run the model.

How do the results compare with previous runs?

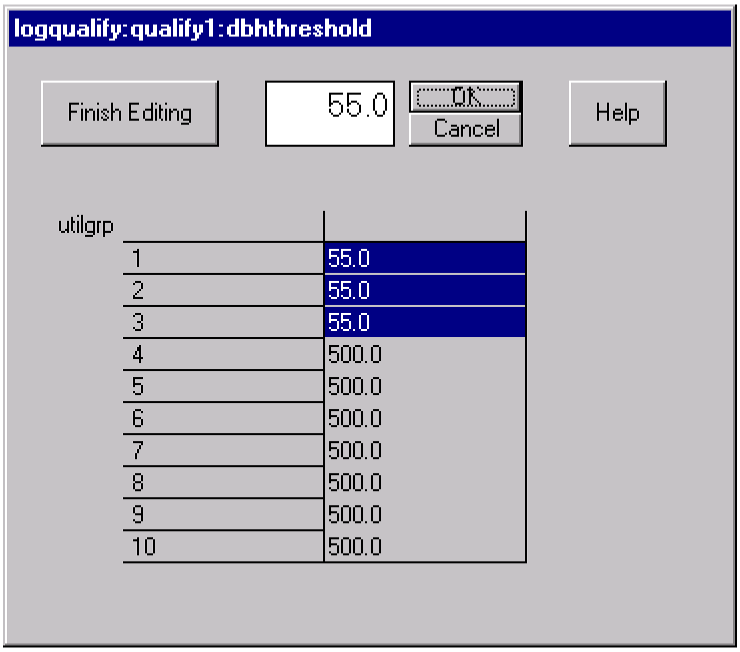


Figure 16. DBH threshold dialog box. This is used to set the logging diameter limit for each timber utilisation group.

3.4.8 SYMFOR stores information about every runs in a session and itis possible to compare runs using the time series display at the end of a run. You should display the time series plotter and then double click in the plot window. The **plotting options editor** dialog box (Figure 12) includes a list of comments from previous runs. Click on one to select it and then click **OK** to display data from one of the earlier runs.

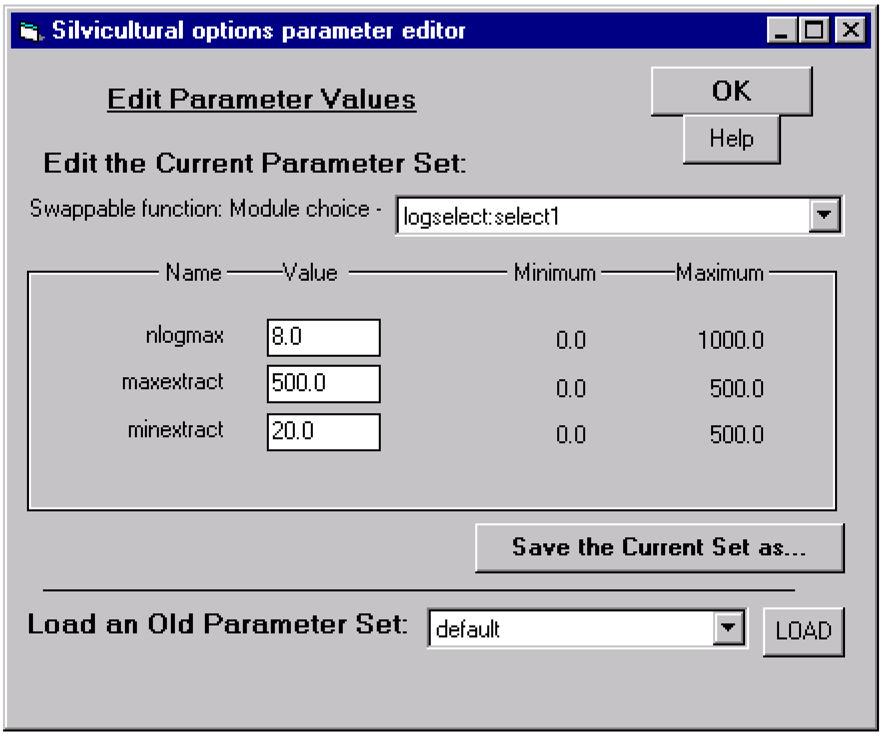


Figure 17. Parameters for selection of stems for logging.

4 Displaying, saving and restoring module and Parameter settings.

4.1 Introduction

4.1.1 The previous sections have shown how individual simulations are controlled by the choice of modules and parameters. SYMFOR has a number of features designed to aid users to display the structure of the model and to save frequently used settings.

4.2 Displaying the model.

4.2.1 The structure of the silvicultural and ecological models can be displayed using the **`model viewer`** option under the **`Silvicultural options`** and **`Ecological model`** menu items. Select the model viewer for silvicultural options (Figure 18).

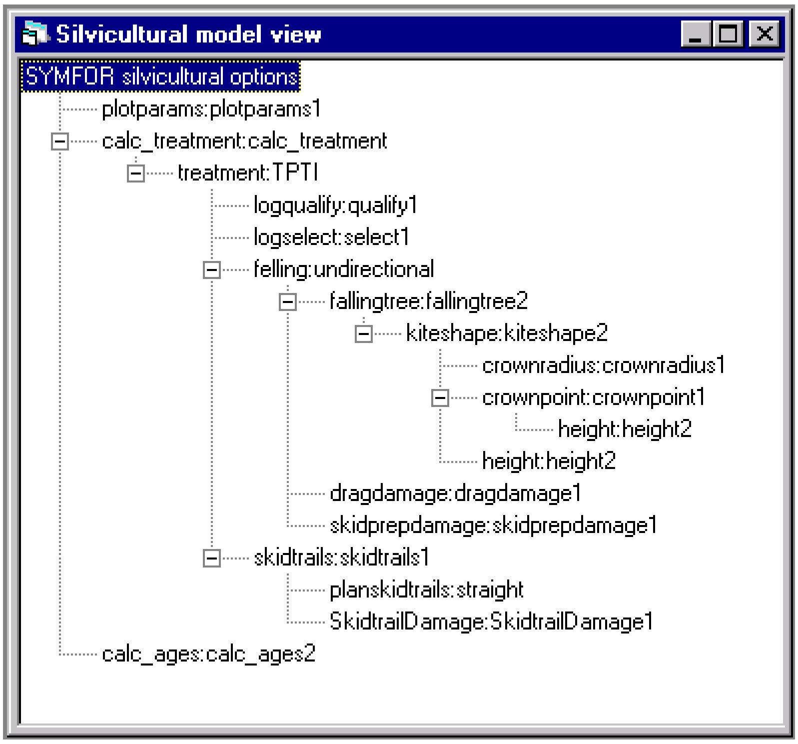


Figure 18. Model viewer for the Silvicultural model. An equivalent display is available for the ecological model.

4.2.2 The TPTI model shown in Figure 18 summarises the TPTI module and parameter sets used in the earlier examples. The individual parameters can be displayed and edited using as the parameter editor.

4.3 Restoring module and parameter sets.

4.3.1 The module choice (Figure 2) dialog box has an option to restore old (previously stored) module set. An equivalent option in available for the parameter editor (Figure 3). A number of sets have been provided for your use and are summarised as (Table 6). It should be noted that the parameter sets should only be used with the appropriate module set.

4.3.2 The module or parameter sets should be selected from the dialog boxes and then click `load` to restore the set. These sets are also used when making multiple simulation runs. The information is stored in the pars.txt initialisation file in the SYMFOR program directory.

Module Set	Parameter set	Description
default	default	Same as TPTI and TPTI-35
TPTI	TPTI-35	TPTI, 50 cm diam. limit, 35 year cycle.
RIL	RIL 8 Stems	Reduced impact logging. Max. 8 stems ha^{-1}
RIL	RIL 50cm	Reduced impact logging. 50 cm diam. limit
RIL	RIL 60cm	Reduced impact logging. 60 cm diam limit
TPTJ	TPTJ	TPTJ system (**NOT CALIBRATED**)
nologging	nologging	no logging

Table 6 Stored module and parameter sets.

4.4 Saving module and parameter sets.

4.4.1 The module choice dialog box has an option to save the current set of module choices. Click the "`Save the current set as`" button to save your current settings. You will be asked to provide a label (name) to give the new module set. Note that it is not possible to re-use an existing name. The same procedure is used to save parameter sets.

4.4.2 You should try to make a new set of silvicultural parameters (section 3) and save the set. Test that you can use the new sets with sample runs.

5 Statistical modelling and analysis.

5.1 Introduction

5.1.1 SYMFOR is a *stochastic* model, which means that some events are modelled according to chance or probability. Examples include the death or recruitment of individual trees and assigning stem quality to existing and new trees. For this reason no two runs will produce identical results and it is necessary to run multiple simulations to generate statistics describing the results. This section will introduce the concept of variation between runs and then describe simple statistics that can be used to summarise results.

5.2 Comparing several single runs

5.2.1 You will work in groups to illustrate the variation between multiple runs of SYMFOR. Each group will run SYMFOR using the same data file and module and parameter settings for the standard TPTI specification of the model. The groups will then repeat the process with two alternative reduced impact logging silvicultural regimes.

5.2.2 Start a new single run in SYMFOR (**2.2**) using the same individual tree and stand data files (Table 1). Restore the **`TPTI`** module and **`TPTI-35`** parameter sets (**4.3**). Bring up the **`Run`** window (**2.2**) and the stand table and map displays. Check that the simulation will use the default length of 140 years. When you are ready click **`Go`** to start the simulation. At the end of the 140-year simulation you should record the volume, basal area and number of stems for the cumulative sum of the harvests from the stand table display in Table 7 (below).

5.2.3 Repeat the runs with the **`RIL`** module and **`RIL 50cm`** parameter sets using the same data files. These settings use the same 35 year cutting cycle and 50 cm cutting limits as TPTI, but differ in having planned skid trails. Enter the results of these runs in Table 7. Finally repeat the process with the **`RIL`** module and **`RIL 8 stems`** parameter sets. These settings programme the model to harvest a maximum of eight trees at each harvest. This is one form of simple yield regulation suggested as an improvement to TPTI (van Gardingen *et al.*, 1998a; van Gardingen *et al.*, 1998b).

5.2.4 You should note the differences in skid trail design and layout when using the RIL module for planned (branched) skid trails. You can use the map display to examine the design of the skidtrail network. You can use the time series plotter display (**2.3**) to show the total area of skid trails as a proportion of the total plot.

Silviculture	Run	Volume	Basal Area	Number of stems
TPTI 35 years	1			
	2			
RIL 50 cm	1			
	2			
RIL 8 Stems	1			
	2			

Table 7. Results from individual runs of SYMFOR simulations using three different silvicultural prescriptions.

5.3 Simple statistical analysis

5.3.1 It is necessary to use statistics to compare the results between treatments. You have been provided with a simple Excel spreadsheet to assist you to analyse the results from the replicate runs. The file "**SYMFOR summary 1.xls**" is stored in the **Analysis** directory under the main **SYMFOR** directory on your hard disk (normally c:\program files\symfor). This file will calculate the mean and standard error for each treatment.

Mean

5.3.2 The mean is defined as:

$$\bar{x} = \frac{\sum x}{n}$$

Equation 1

5.3.3 In Excel the mean of a range of cells *aa:bb* can be calculated by entering the function **=AVERAGE(***aa:bb***)** into a cell.

Standard error

5.3.4 The standard error measures the variation in the data and is used to compare means. It is calculated from the standard deviation of the population (σ_{n-1}) as:

$$s.e. = \frac{\sigma_{n-1}}{\sqrt{n}}$$

Equation 2

5.3.5 In Excel the standard error of a range of cells *aa:bb* can be calculated by entering the function **=STDEV(***aa:bb***)/SQRT(COUNT(***aa:bb***))** into a cell.

Using the EXCEL spreadsheet

5.3.6 You should now enter your results into the table provided in the Excel spreadsheet (Table 8). When you have data from all groups you should be able to compare the results using the means and standard errors (**5.4**).

	Group 1		Group 2		Group 3		Group 4		Summary			
TPTI Harvesting	Run 1	Run 2	Run1	Run2	Run1	Run2	Run1	Run2	Mean	s.e.	Min	Max
Volume												
Basal Area												
Number of stems												
RIL 50 cm												
Volume												
Basal Area												
Number of Stems												
RIL 8 Stems												
Volume												
Basal Area												
Number of Stems												

Table 8. Excel spreadsheet for analysis of multiple runs of SYMFOR.

5.4 Comparing means

5.4.1 A simple rule can be used to compare means using their standard errors. Means are usually significantly different when their standard errors do not overlap. They can be compared graphically or else by calculation. In most cases with SYMFOR it will be found that differences between treatments are small and require more sophisticated statistical analysis.

5.4.2 The data analysis options in EXCEL (`Tools>Data analysis`) can use used to compare the treatments. You can compare two results using a t-test. Select the t-test for Two-samples assuming unequal variances (Figure 19). To compare the total cumulative harvested volume between the conventional TPTI and RIL 50cm treatments you should select the cells for TPTI as variable 1 and those for the RIL treatment as variable 2 (as shown in Figure 19). The resulting analysis will indicate if the treatments have produced significantly different yields over the 140 year simulation.

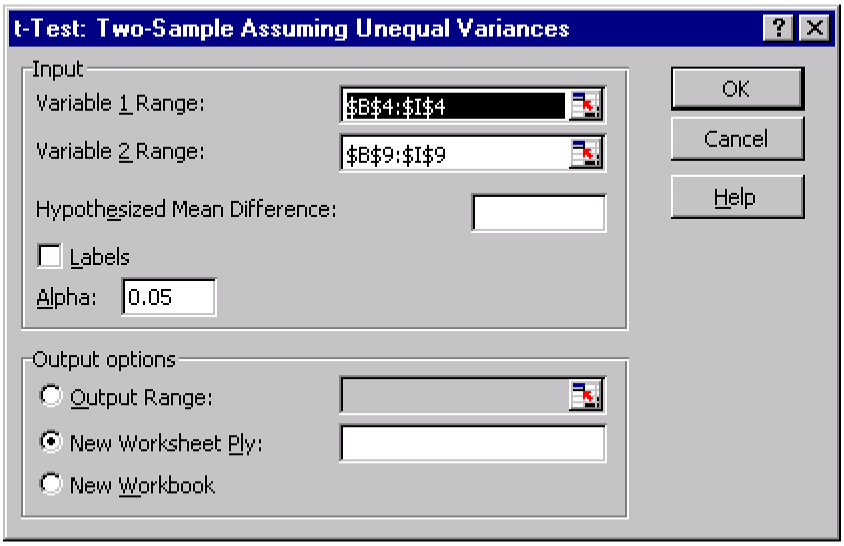


Figure 19. t-Test for two samples using EXCEL.

6 Multiple simulations.

6.1 Introduction

6.1.1 The previous sections discussed the importance of running multiple simulations using SYMFOR. SYMFOR has been designed to simplify this process using a multiple run option to step through a sequence of simulations. The results are saved in one or more output files. This powerful feature is an essential tool required when using SYMFOR to examine differences between silvicultural treatments or types of forest stands.

6.1.2 This section introduces the multiple run facility in SYMFOR through an exercise to analyse the number of stems, volume and basal area harvested under the TPTI and RIL silvicultural treatments.

6.2 Starting a multiple run.

6.2.1 Select the **`Multiple run`** option under the **`Start run`** menu on SYMFOR to display the Multiple Runs Manager (Figure 20). Click the **`Create New Instruction`** button to display the **`Run Instruction Editor`** (Figure 21) and start creating a multiple run instruction.

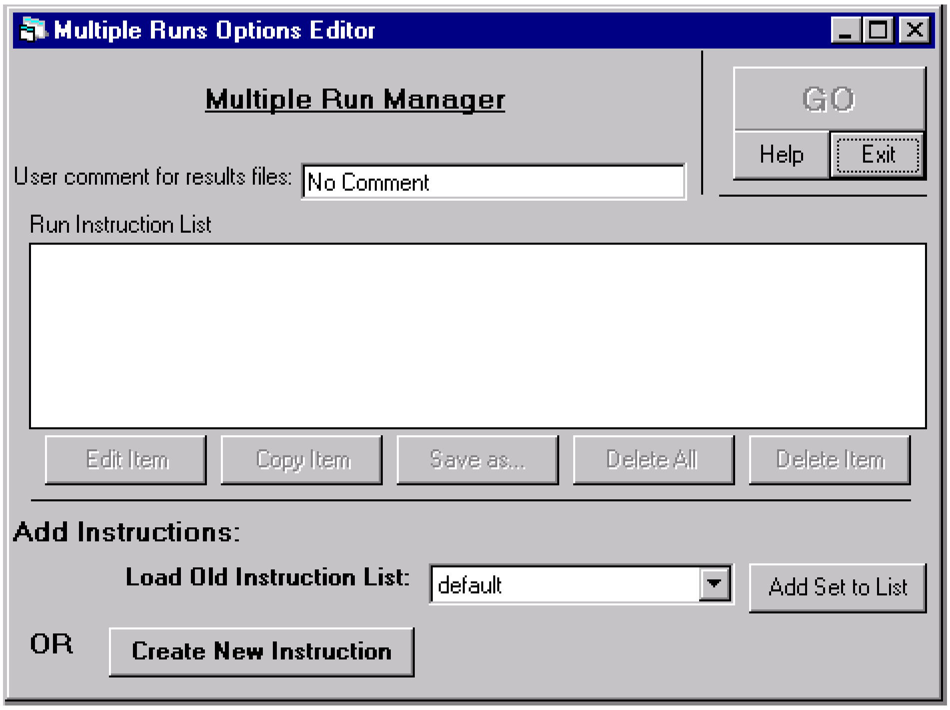


Figure 20. Multiple Runs Manager

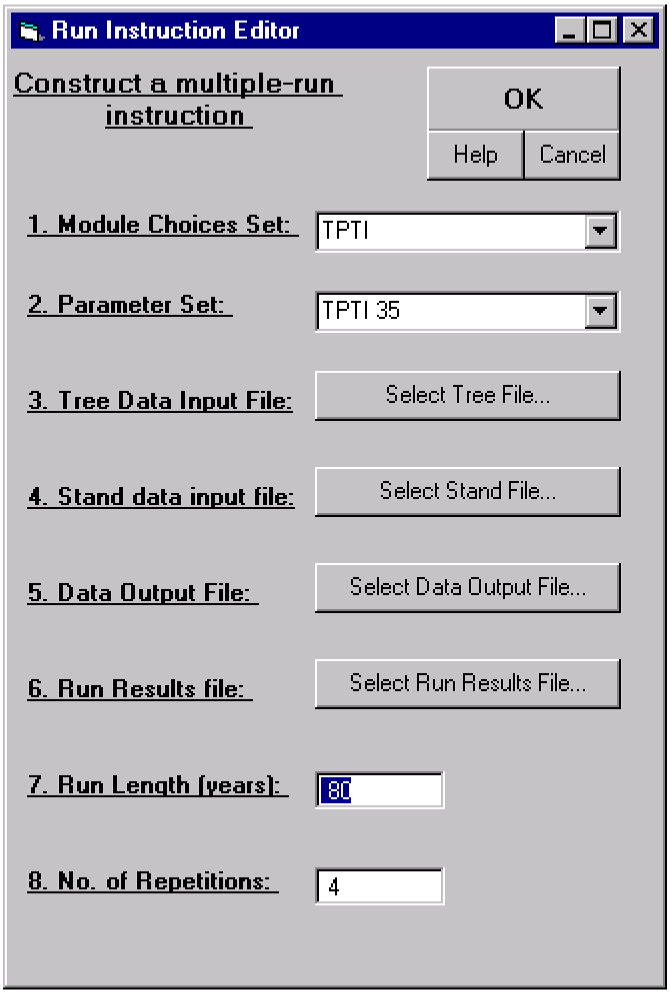


Figure 21. Multiple run instruction editor.

6.3 Selecting module and parameter sets and input data for a multiple run.

6.3.1 Module and parameter sets can be selected from drop down lists (1 & 2, Figure 21). These stored sets will be used to configure the model and parameters for the run.

6.3.2 You should next click on the **`Select Tree File`** button and select a tree data input file. It is suggested that you use the same file as in earlier examples (Table 1).

6.3.3 You next need to set the stand file to be used in the simulations. Click on the **`Select Stand File`** button and then select a stand file. You should use the unlogged stand file (Table 2).

6.4 Creating a data output file

6.4.1 You should always define a data output file to be used to store results from a multiple run. Click on the **`Select Data Output File`** button to display the Output Data Editor (Figure 22). Click on the **`New Output Table`** button to display the dialog box to select the output database file (Figure 23). This window is used to specify the database file for output and when data are to be saved. The window has options for a number of different output events such as at the start or end of a run, before and after logging and at set intervals during the simulation.

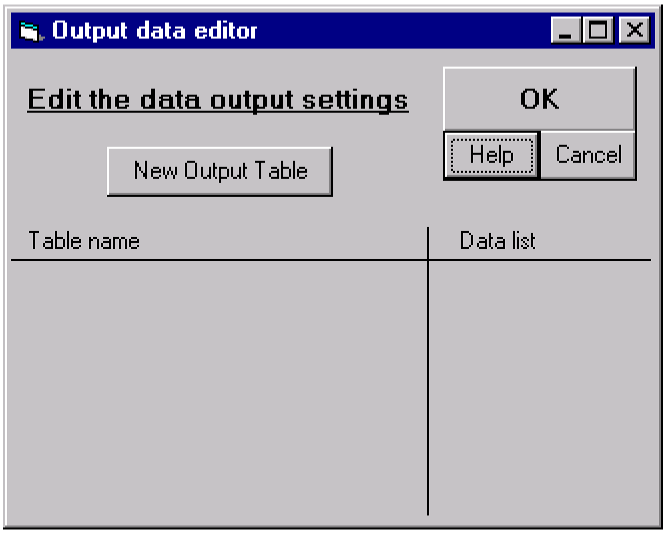


Figure 22. Output data editor.

6.4.2 For the current example you should edit the entries as shown in Figure 23. These options will create a text file with data stored at the end of the simulation. You need to enter the .csv suffix for the file name. It is important to set the entry for output style. The default action is to overwrite any exiting data in the file. After you have specified the output file you should click **`OK`**. The system then displays a window used to select the data to be included in the output file (Figure 24).

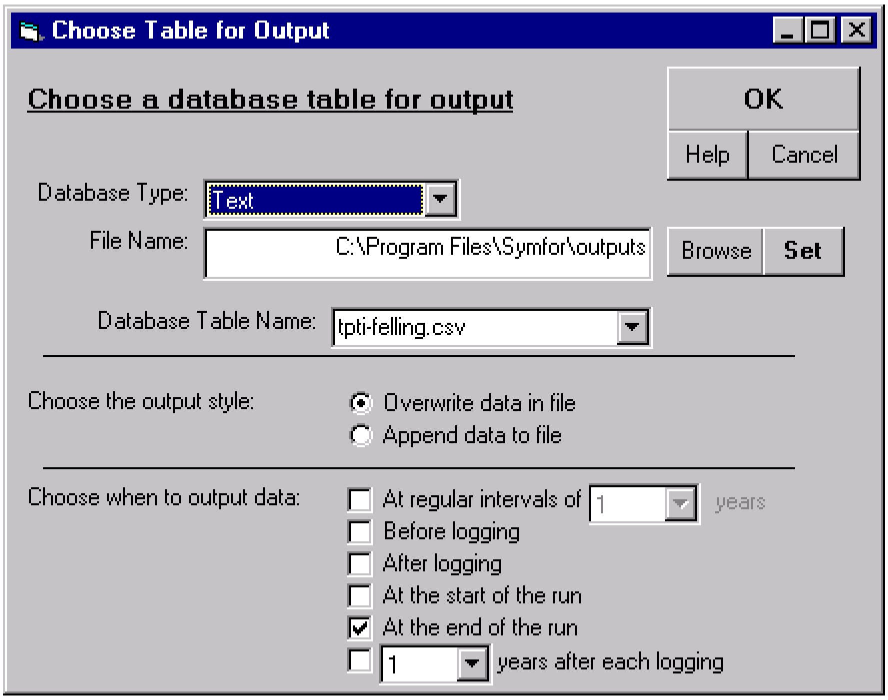


Figure 23. Data output options.

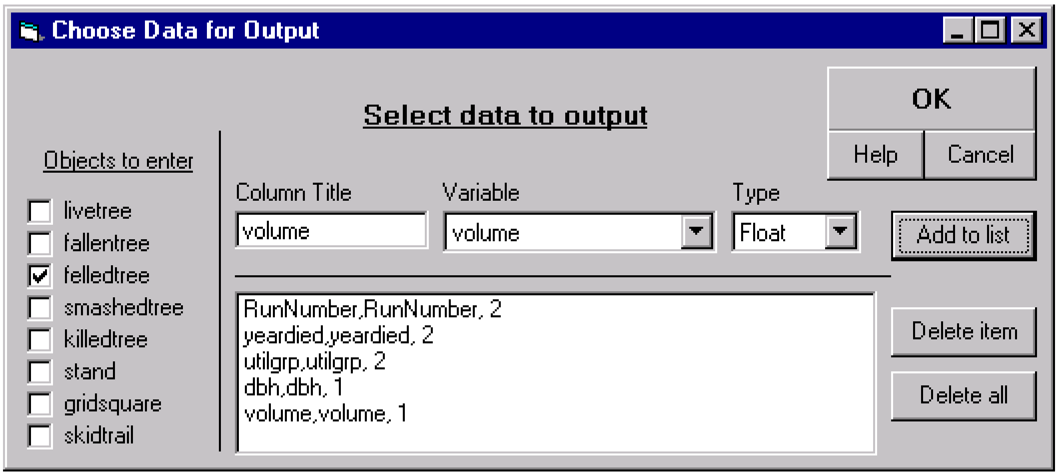


Figure 24. Selecting data for output.

6.4.3 The data output dialog box (Figure 24) presents you with a number of options for data output. You need to specify the type of object (e.g. livetree, felledtree) to be outputted as well as the variable and data type. The datatype can be either integer or float (real number). Each variable has a default column label. You should not normally change these. The following instructions will set the system for the current example.

6.4.4 Select data for **`felledtree`** objects (checkbox).

6.4.5 Select data type **`integer`**.

6.4.6 Select **`runnumber`** from the dropdown list of variables. Click the **`add to list`** button to add this variable to the output list. You should next repeat these actions to add the **`year died`** and **`Utilgrp`** variables.

6.4.7 Change the data type to **`float`** and add the **`dbh`** and **`volume`** variables. Your entries should now look identical to those shown as Figure 24. Click **`OK`** to return to the output data editor and then **`OK`** again to return to the run instruction editor.

6.4.8 You now need to specify the length of the runs and number of replicates. This example uses a 80 year run length with 4 replicate runs. You have now finished specifying your first multiple run instruction. Click **`OK`** to return to the multiple runs options editor.

6.5 Copying and editing existing instructions.

6.5.1 There should now be one instruction in the Run Instruction List. This instruction will now be used as the template to create two new instructions. Click on the instruction to select it. Click on the **`Copy Item`** button ***twice*** to create two new entries.

6.5.2 Click to select the second item in the Run Instruction List. Click on the **`Edit Item`** button to display the Run Instruction Editor. Change the module choice to **`RIL`** and parameter set to **`RIL 50cm.`** Bring up the output data file and edit the table name to be **`RIL50cm_felling.csv`**. You not change any of the other settings for this run. Click OK.

6.5.3 Click to select the third item in the Run Instruction List. Click on the **`Edit Item`** button to display the Run Instruction Editor. Change the module choice to **`RIL`** and parameter set to **`RIL 8 stems.`** Bring up the output data file and edit the table name to be **`RIL_8_stem_felling.csv`**. You not change any of the other settings for this run. Click OK.

6.5.4 You have now created a set of run instructions. These can be saved by using the **`Save as`** button and old instructions can be reloaded using a drop down list and the **`Add set to list`** button.

6.6 Running the multiple simulations.

6.6.1 Click on the **`GO`** button to start the multiple runs. The system will now run a sequence of twelve (3 instructions * 4 replicates) simulations. The runs will take up most of the resources of your computer until they are completed. Large complex run sets may take several hours to be completed. *Now is a good time to take a coffee break!*

6.7 Examining and analysing results.

6.7.1 Each of the output files can be opened in Excel as a **`CSV`** file. Many other database and statistics packages can also read this format. Within the file, the **`RunNumber`** column will identify the run. There will be up to three harvests per run and these can be separated by the **`yeardied`** column.

6.7.2 You should take some time to compare the results between harvests, between runs and between silvicultural treatments.

(Hint, split the data into harvests and use the SUM() function in EXCEL)

7 Post Processing Analysis

7.1 Introduction.

7.1.1 The output from SYMFOR needs to be processed for analysis and comparison of treatments. The output files from a multiple run are intended to be transferred to spreadsheets, databases and statistical packages for further analysis. In addition a number of specific post-processing programs are being developed in conjunction with the main SYMFOR program.

7.1.2 In this section the use of post-processing analysis will be introduced using data from earlier multiple simulations and a SYMFOR post processor.

7.2 SYMFOR post processors.

7.2.1 The post processor used for this training sessions (**`postp1.exe`**) was designed to summarise the total volume basal area and number of stems harvested in a simulation and to summarise the structure of the stand at intervals during the simulation.

7.3 Data output specification for the post processor(`postp1.exe`)

7.3.1 The post processor requires data to in a specific format. An example of this is included as the output specification for the **`TPTI RKL4`** multiple run set. Two output files are required, one with information about all felled trees after each harvest and the second describing all live trees at intervals during the simulation. The minimum specification for the felled trees is shown as Table 9 and for live trees as Table 10.

7.3.2 The post processor requires that data are saved as text files in a comma separated value (CSV) format.

OBJECT type	**felledtree**	
Output data events	**At end of run**	
Variables	Name	Type
	outreason	integer
	dumpnumber	integer
	runnumber	integer
	yeardied	integer
	species	integer
	utilgrp	integer
	dbh	float
	basalarea	float
	volume	float

Table 9. Specification of output file format for live trees required to the SYMFOR post-processor.

OBJECT type	**Livetree**	
Output data events	**before logging** **after logging** **20 years after each logging**	
Variables	Name	Type
	outreason	integer
	dumpnumber	integer
	runnumber	integer
	species	integer
	utilgrp	integer
	quality	float
	dbh	float
	basalarea	float
	volume	float

Table 10. Specification of output file format for felled trees required to the SYMFOR post-processor.

7.4 Running the post processor.

7.4.1 The post processor should be run and the fields edited as shown in Figure 25. This example uses output from the earlier multiple run simulation using the TPTI specification. The following entries influence the analysis.

Title and treatment

7.4.2 Text comments that will be included as the header of the analysis output.

Diameter limit

7.4.3 The diameter limit used in the analysis of live tree data that describe the status of the stand during the simulation. The setting of 50 cm will result in an analysis showing only trees above a 50 cm diameter (cutting) limit. You should set this entry to 10 cm to obtain a summary of all trees in the stand. This entry does not affect the analysis of harvested trees.

Quality limit

7.4.4 The quality limit is used in the analysis of live tree data. The setting of 0.3 will result in an analysis that includes only trees with a stem quality of greater than 0.3 (70 % of the original stand). When combined with the diameter limit, these settings give a total (in stand) potential commercial volume. You should set this entry to 0.0001 to obtain a summary of all trees in the stand. This entry does not affect the analysis of harvested trees.

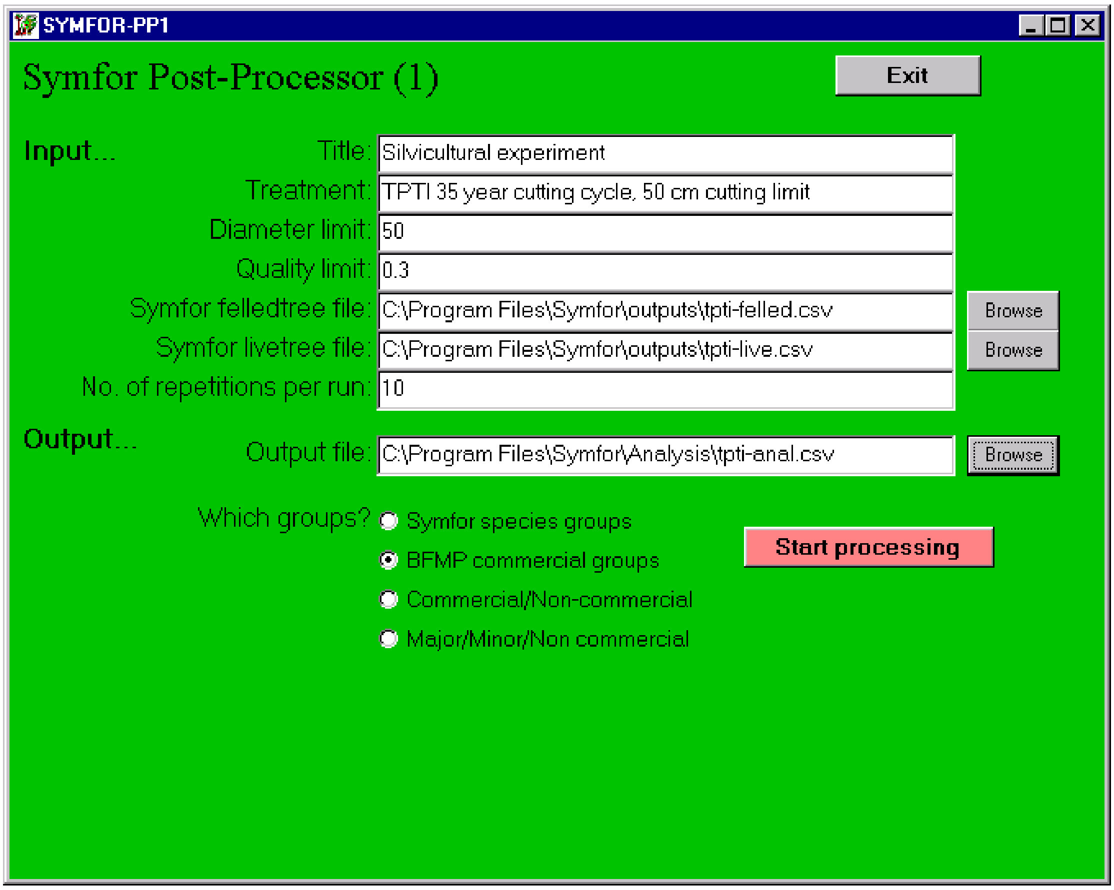


Figure 25. SYMFOR post processor.

SYMFOR felledtree and livetree files.

7.4.5 These fields define the output files from SYMFOR that contain the results to be analysed by the post processor

No of repetitions per run.

7.4.6 This entry must be set to be equal to the number of repetitions per plot that was used in the multiple run instruction set. NOTE that all plots must have equal replication (number of repetitions).

Output file.

7.4.7 This entry specifies the location and file name for the text file used to store the results of the post processing analysis. This file is saved in CSV format and you should add the **`.csv`** suffix.

Species groups

7.4.8 The post-processor will analyse the individual tree data (live trees) according to one of four species groupings. The first is the ecological grouping used by SYMFOR (Appendix 2), whilst the remaining three groupings are based on the BFMP commercial groupings (Appendix 1). You must choose one.

Running the post processor.

7.4.9 Click on the **`start processing`** button to start the analysis. Analysis of a large result set may take several minutes. At the end of the analysis the post-processor will report on the number of plots found. You should check that this is the same as the number you used in the original SYMFOR simulations.

Changing settings.

7.4.10 You can change any of the settings for the post processor and then re-run the analysis. Examples would be to examine the effect of changing the quality or diameter limits and using a different species grouping.

7.4.11 One useful ecological analysis can be obtained using the SYMFOR species group with a diameter limit of 10 cm and quality limit of 0.0001 to select all trees. These settings will show the changes in non commercial species such as pioneers following logging.

7.5 Examples of analysis

7.5.1 The post processor analyses the data and creates a text file as output. This can be read into EXCEL as a comma separated value (CSV) file. These results can then be incorporated into reports in the form of tables or figures.

7.5.2 The first section of the analysis report presents information on the harvested trees (Figure 26). data are presented for each species group followed by the total of all groups for each individual harvest.

Title	Silvilcultural experiment.						
Treatment	TPTI, 35 year cutting cycle						
Diameter limit	50						
Quality limit	0.3	(Minimum stem quality of .3 gives 70% of initial stand with dbh above 50cm					
Simulated logging results	BFMP groups	Volume	s.e.	Basal Area	s.e.	Number of	s.e.
Harvest number 1	Meranti	38.64795	22.68681	2.494512	1.449912	5.1	2.91376
Note this will not change	Fast growing other dipterocarps	1.60124	2.483464	0.111104	0.171197	0.325	0.472802
if the above diameter limit is	Slow growing other dipterocarps	52.58503	29.78401	3.423833	1.899409	7.225	3.180703
changed	Non-dipterocarp major commerci	0	0	0	0	0	0
	Non-dipterocarp minor commerci	0	0	0	0	0	0
	Protected	0	0	0	0	0	0
	Non-commercials/unknown/other	0	0	0	0	0	0
	Total	92.83422	37.52261	6.029449	2.395685	12.65	4.339403

Figure 26. Sample output from post processing of harvest data.

7.5.3 The results for the individual tree data are presented as a series of tables for each species group, followed by one table for all species. Data within the table are presented as a sequence of events (Output Reason) which are controlled by the original output instructions (e.g. Before logging, after logging and a set interval after logging). The user will need to refer to the multiple run instruction from SYMFOR in order to decide when each event took place. An example of output for the individual tree data is shown as Figure 27.

Simulated state of the forest								
Meranti	Output Number	Output Reason	Volume	s.e.	Basal Area	s.e.	Number of	s.e.
	1	Before Logging	40.49688	23.89682	2.612585	1.524336	5.316667	3.010768
	2	After Logging	0	0	0	0	0	0
	3	Interval after logging	5.124262	3.031061	0.354267	0.210236	1.333333	0.749815
	4	Before Logging	15.10029	5.766074	1.009896	0.382556	3.333333	1.234459
	5	After Logging	0.914431	1.028367	0.062025	6.97E-02	0.225	0.268095
	6	Interval after logging	13.86794	5.320959	0.933658	0.349025	3.375	1.18682
	7	Before Logging	26.40311	9.552797	1.737599	0.613764	5.141667	1.695808
	8	After Logging	0.307273	0.457097	2.05E-02	3.07E-02	6.67E-02	0.10274
	9	Interval after logging	11.70756	3.349925	0.801283	0.229026	3.008333	0.873173
	10	Before Logging	21.75851	6.920819	1.453239	0.460942	4.575	1.499514
	11	After Logging	0.584475	0.670409	3.87E-02	4.50E-02	0.116667	0.157233
	12	Interval after logging	11.23934	2.61039	0.766197	0.179193	2.841666	0.665155
	13	Before Logging	23.64269	5.518044	1.572296	0.37197	4.891666	1.323164
	14	After Logging	0.553268	0.720986	3.74E-02	4.83E-02	0.125	0.158771

Figure 27. Sample output from post processing of individual tree data.

7.6 Statistical analysis.

7.6.1 Results from the multiple run output or post-processor can be further processed through statistical analysis. The exact methods will depend on the design of the simulation experiment and is beyond the scope of this document.

8 Management options: Silviculture.

8.1 Introduction.

8.1.1 As a user of SYMFOR, you should now have the basic skills required to start addressing issues of importance to forest management. The previous sections of this document have discussed how to use SYMFOR as a tool to examine and evaluate different silvicultural management systems suitable for Indonesian dipterocarp forests.

8.1.2 The successful application of a management tool such as SYMFOR requires that users have clearly defined questions. These questions should be framed within the context of documented management objectives for the forest resource.

8.2 Objectives for sustainable forest management.

8.2.1 Sustainable forest management requires an approach that balances a number of potentially conflicting economic, social, biological and environmental constraints. In practice the most appropriate way to achieve sustainable management is likely to be managing concessions as a mosaic of resources, for example areas identified for production, watershed and environmental protection.

8.2.2 Sustainable forest management should aim to ensure the following:

- The area of the permanent forest estate maintained.
- Forest products sustained.
- Conservation and protection of environmental and biological resources.
- Socio-economic status of *all* stakeholders. Enhancing livelihoods of local communities.

8.2.3 Management objectives should meet the criteria of being both quantitative and timebound (Fixed time scale). As such the following points could be considered when developing a silvicultural management plan for a concession.

Objective	Comment
1. Maintenance of area of permanent forest estate.	Avoid forest conversion and clear felling
2. Target productivity of timber products.	Sustainable commercial yield
3. Environmental standards for the harvesting operation.	e.g. Protection of soil and water resouces
4. Target productivity of non-timber forest products.	Often for local communities
5. Standing volume and species composition of permanent forest estate.	Quantify current conditions and identifies targets at set time scales.
6. Maintenance of ecosystem structure	Biodiversity.

Table 11. Management objectives of relevance to silviculture.

8.2.4 Defining management objectives for management units has the advantage of stating what the manager hopes to achieve in a concession and this will permit regular review of how this is realised in practice. If one or more objective is observed to be unobtainable, management can then be adapted to address this issue or to new opportunities. It may for example be necessary to review the target productivity of the system in order to achieve environmental standards.

8.2.5 The management objectives listed in Table 11 present the forest manager with an opportunity to state how they expect the concession to perform, and to predict the status of the areas of production forest in the future. The first objective defines the total area of forest and states that this should be maintained. This implies that conversion or clear cutting should not be used to maintain overall commercial production from the concession.

8.2.6 Objective 2 defines target productivity for commercial timber products. In practice this will first be set for an entire concession. The total area of the concession and length of management (cutting) cycle will then determine the target productivity for individual management compartments. Silvicultural management is effective at the level of a compartment.

8.2.7 Objective 3 defines environmental standards for the forest management. It is now accepted in Indonesia that reduced impact logging standards should be applied to protect the soil and water environment. These standards will require indicators of good forest management. It has been suggested that the length or area of skid trails may be a suitable indicator. Forest management systems can thus be evaluated against these standards.

8.2.8 Objective 4 addresses the productivity of non-timber forest products. These are often a important source of income for local communities. The management objectives for a concession should state if these products are expected from areas of protection forest.

8.2.9 Objective 5 addresses the status and structure of the forest resource. This should state a target stocking for the entire concession at a set time in the future. This is required to ensure that the long-term status of the forest is protected. This prevents the management option of maintaining short-term productivity through excessive harvesting that reduces that stocking of the forest.

8.2.10 Objective 6 addresses the issues relating to maintenance of biodiversity. The establishment of appropriate management objectives for biodiversity requires further work to define appropriate operational biodiversity indicators. At present it may be adequate to compare the proportions of different ecological groups or indicator species in the forest.

8.3 Silvicultural options.

8.3.1 The choices of silvicultural options available to the manager of dipterocarp forests in Indonesia are relatively simple. They relate to the method of logging, number or volume of stems removed at each harvest, choice of species, post harvesting treatments such as replanting or thinning and the length of cutting cycle. These are all specified with the standard TPTI system of silviculture. Alternatives such as the Line clearing and planting system (TPTJ) can also be considered.

8.3.2 SYMFOR has been designed to allow forest managers to evaluate the likely benefits of these options in terms of yield from the forest. These however need to be linked to appropriate economic analysis to determine how appropriate they may be for any concession.

8.3.3 The main options are considered below.

Method of logging

8.3.4 Conventional logging may result in considerable damage to the residual forest stand, soil and water resources. Reduced impact logging has been accepted as a method to minimise these problems. It has been suggested based on results from the STREK trial, that reduced impact logging will only be effective when combined with a limit to the number or volume of stems extracted (Sist *et al.*, 1998).

Yield regulation

8.3.5 The conventional TPTI system regulates yield through diameter limits and a specification of the structure of the stand following logging. Alternatives to this include specifying a maximum number of stems or volume to be extracted. Previous studies have suggested that a limit of eight stems per hectare may be appropriate for Indonesian dipterocarp forests (Sist *et al.*, 1998; van Gardingen *et al.*, 1998a).

Choice of species

8.3.6 Changes in the structure of the forest or market conditions may make changes in the composition of harvested species necessary or desirable.

Post harvesting treatments.

8.3.7 The TPTI system defines a complex and comprehensive series of post harvest treatments. These include clearing and tending, replanting and thinning. These have been reviewed by the BFMP project (van Gardingen, 1998; van Gardingen, 1999). It is likely that some of these treatments have minimal benefit in terms of yield from the forest and may consequently have negative economic benefits (Dadang Fadilah, 1999).

Alternative silvicultural systems.

8.3.8 Alternative systems such as TPTJ can be considered, but at present there are few data available to support the system. SYMFOR has been programmed to simulate the TPTJ system, but any results should be treated with extreme caution as the system has not been calibrated.

Primary and logged-over forest.

8.3.9 It is likely that different management objectives and systems will need to be applied in logged-over forest compared with primary forest. It is likely that a modified TPTI system can be applied successfully in areas of high quality logged-over forest. Many areas of forest are degraded and hence will have much lower productivity or else require some form of rehabilitation. In extreme cases it may be necessary to retire compartments which can no longer support commercial production. These choices are summarised in Figure 28.

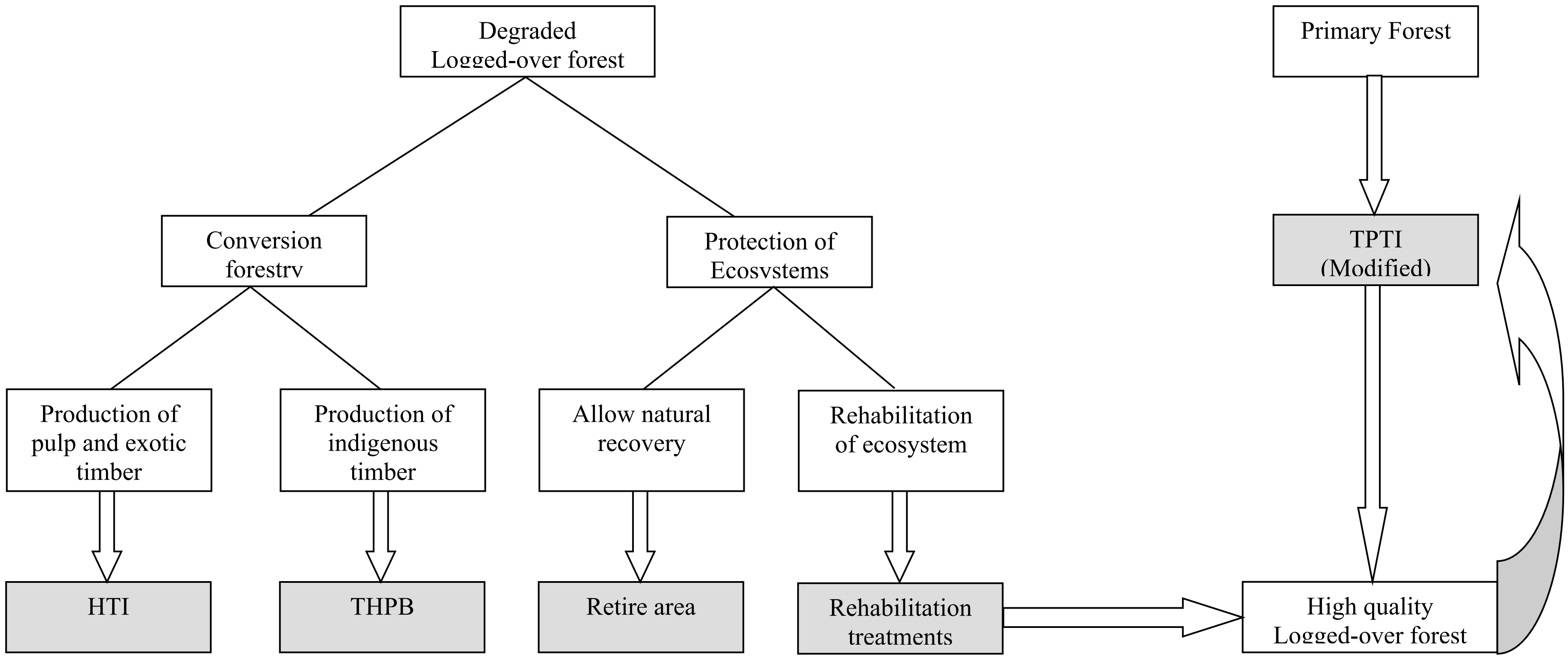


Figure 28. Choices of silvicultural systems for areas of primary and logged-over forest in Indonesia.

8.4 Linkage to economic analysis.

8.4.1 Output from SYMFOR or any other system for predicting the growth and yield of forests needs to be linked to suitable economic models to assess its likely performance and profitability. The BFMP project is working with the SYMFOR project to link output from SYMFOR into the BFMP concession model.

8.5 Summary.

8.5.1 The evaluation of silvicultural systems using SYMFOR requires a statement of management objectives. Once these have been established the system can be used to examine the effects of different options such as yield regulation or length of cutting cycle. The results would then need to be processed and analysed as described in sections **7** and **7**. These results would then need to be linked with appropriate economic analysis.

9 Evaluating Silvicultural Treatments.

9.1 Introduction

9.1.1 The previous sections have shown how to program SYMFOR to simulate difference silvicultural systems and use multiple runs to generate data for statistical analysis and comparison. This is the way that SYMFOR should normally be used.

9.1.2 The version of SYMFOR used in this training course includes one example definition of a multiple run set used to evaluate the standard TPTI silvicultural system. This will be used to demonstrate the way that SYMFOR should be applied to evaluate silvicultural options.

9.2 Designing an "experiment".

9.2.1 A simulation experiment needs to have sufficient replication to ensure that differences between plots and individual simulation runs are described. The experiment which has been programed into SYMFOR will be used to compare silvicultural options for primary (unlogged) forest in the Labanan concession of PT Inhutani I. The experiment will be defined in terms of the number of plots and number of replicate runs per plot.

Plot Data (STREK Logging Trial).

9.2.2 The data used in the experiment come from the first pre-logging measurement of the STREK logging trial in RKL-4. The STREK project set up 12 separate 4 ha permanent sample plots in RKL 4. Each plot was subdivided into 4*1 ha recording units. One recording unit was selected at random from each plot for the simulation experiment. These are summarised as Table 12 and have been loaded onto your computers for the training sessions.

Plot	Recording Unit	Filename
1	2	R4P01RU2C1.DBF
2	2	R4P02RU2C1.DBF
3	4	R4P03RU4C1.DBF
4	1	R4P04RU1C1.DBF
5	4	R4P05RU4C1,DBF
6	4	R4P06RU4C1.DBF
7	3	R4P07RU3C1.DBF
8	1	R4P08RU1C1.DBF
9	1	R4P09RU1C1.DBF
10	1	R4P10RU1C1.DBF
11	3	R4P11RU3C1.DBF
12	1	R4P12RU1C1.DBF

Table 12 Plots and recording units used for the silvicultural simulations.

9.3 Replicate runs.

9.3.1 The system was programmed to run ten replicate simulations for each plot.

9.4 Restoring a multiple run set to define an experiment.

9.4.1 Start a new multiple run and then load the old instruction set **TPTI RKL4**. This set has twelve instructions to run simulations of the TPTI system on each of the plots selected in Table 12.

9.4.2 Select the first instruction and click on the **Edit item** button to examine the instruction. The first instruction uses data for plot 1.

9.4.3 Examine the output instructions by clicking on the **Select Data Output File** button. Two output files are defined, one to store information on felled trees and the second to store information on all live trees at intervals during the 150 year simulation. The structure of the data list for these files meet the specifications required for post processing analysis (Section 7). The first output instructions have been set to **overwrite** existing data in the file. If you examine the instructions for plots 2 to 12 you will find that these have been set to **append** to the existing data in the file.

DO NOT RUN THIS EXAMPLE

9.4.4 It would take several hours to run this simulation and for this reason this example has been completed and the results stored in the **outputs** directory. These will be used to demonstrate post processing analysis in the next section.

9.5 Editing a multiple run set to implement a new silvicultural system.

9.5.1 An existing multiple run instruction set can be edited to implement an alternative silvicultural system using the same plots.

9.5.2 Each instruction needs to be edited to change the choice of **module choice set** and **parameter set**. Select the **RIL** module set and **RIL 8 Stems** parameter set.

9.5.3 At the same time you should select the **Data output file** and change the names of both output files. Change the name of the first output table to **RIL8-felled.csv** and the second to **RIL8-live.csv**.
It is important to make the same changes to all entries in the multiple instruction set.

9.5.4 Make these changes to all of the entries in the multiple instruction set, check them and then save the new instruction set as **RIL 8 stems RKL4**.

9.5.5 Other applications (simulation experiments) may require you to select different data input files for individual tree or stand data.

9.6 Summary

9.6.1 The sequence of events described in this section represents the basic procedures used to create multiple instruction sets used to compare silvicultural treatments. Once a number of sets have been completed it is possible to load several into the multiple run options editor and then execute them all in sequence. This is best done overnight as large multiple runs will require many hours to be completed.

It is important to check that you have sufficient space available on your computer's hard disk before starting a large run. The instruction set described above will create output files exceeding 40 Mb in size.

9.6.2 You will use these instructions when you start to compare silvicultural treatments to produce your report for the workshop.

10 Producing reports: An analysis of the TPTI system

10.1.1 The output from the post processor can be used to produce tabular or graphical presentations using EXCEL or other software packages. The results from the example given above have been copied into the SIGMAPLOT scientific graphics package to illustrate the end results of the application of SYMFOR and the post processor.

10.1.2 Changes in the total volume of harvested timber under the TPTI system are shown as Figure 29 for a cutting cycle of 35 years. It can be seen that most of the simulated harvest for RKL4 would come from the Meranti and slow growing dipterocarp commercial groups. The initial harvest from primary forest has the highest yield. The second harvest is the smallest and then subsequent harvests (3 through 5) yield a total volume of around 40 m^3 ha^{-1}. It should be noted that this volume is effective commercial volume before skidding extraction and yarding. These volumes could be reduced by a further 40 % by these practices.

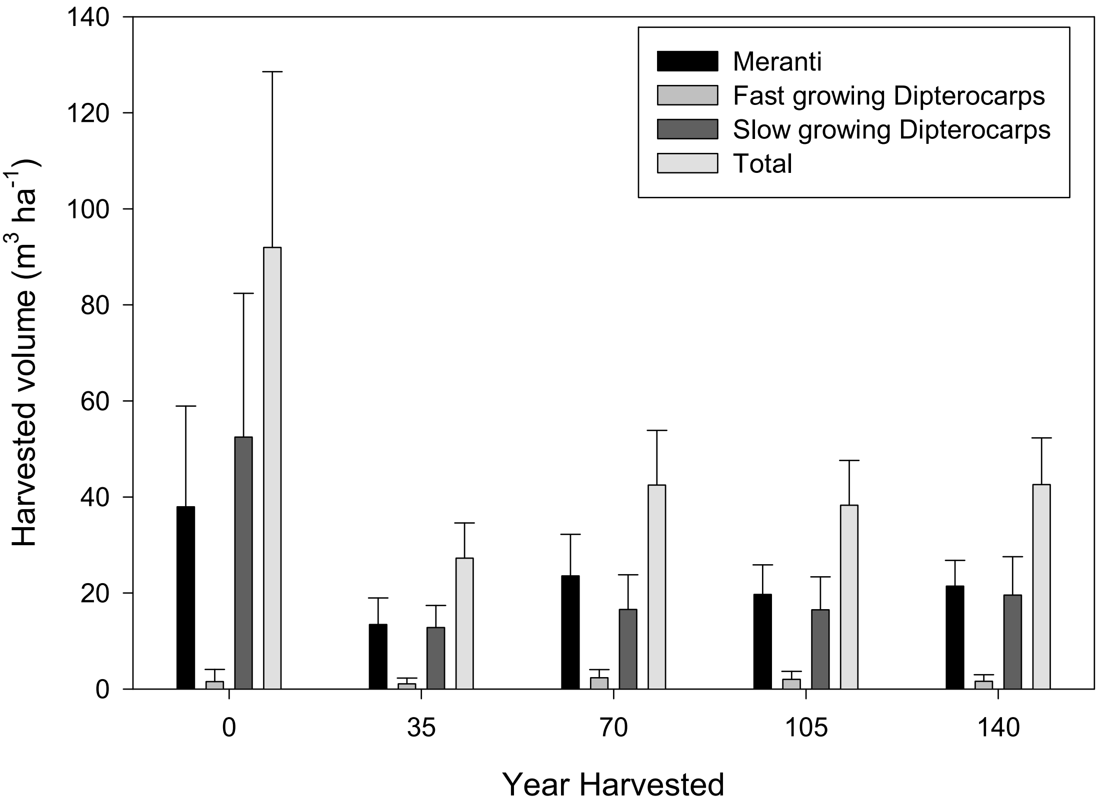


Figure 29. Harvested volume for a sequence of harvests simulated using a specification for the TPTI silvicultural system and a 35 year cutting cycle. The simulation used twelve plots of primary forest from RKL 4 (Table 12). Year 0 represents a simulated harvest on primary forest. Data are the mean ± 1 standard error calculated from data resulting from the simulations. Ten replicate runs were completed per plot and the average of these were used to calculate the means in this figure (n=12).

10.1.3 The variation between harvests is inefficient and potentially costly for concession holders. Good management should aim to maintain the level of production. The relatively low yield from the second harvest suggests that the first harvest may have been too intensive and that the cutting cycle may need to be extended for TPTI to be more effective. These are options that could be examined in this workshop.

10.1.4 The yield from the second and subsequent harvests will be determined mainly by the growth of commercial trees above the 50 cm cutting limit. Individual tree data can be used to examine the regrowth of the forest. This has been done for the TPTI analysis and presented as Figure 30 for the Meranti and slow growing dipterocarp groups.

10.1.5 The data show significant increases in commercial volume for these species averaging 0.6 $m^3 ha^{-1} yr^{-1}$ for the Meranti group and 0.5 $m^3 ha^{-1} yr^{-1}$ for the slow growing dipterocarps. When combined these data exceed the 1 $m^3 ha^{-1} yr^{-1}$ often assumed for the TPTI system in Indonesia. It should also be noted an allowance has already been made for stem quality rejecting stems with a quality of less than 0.3.

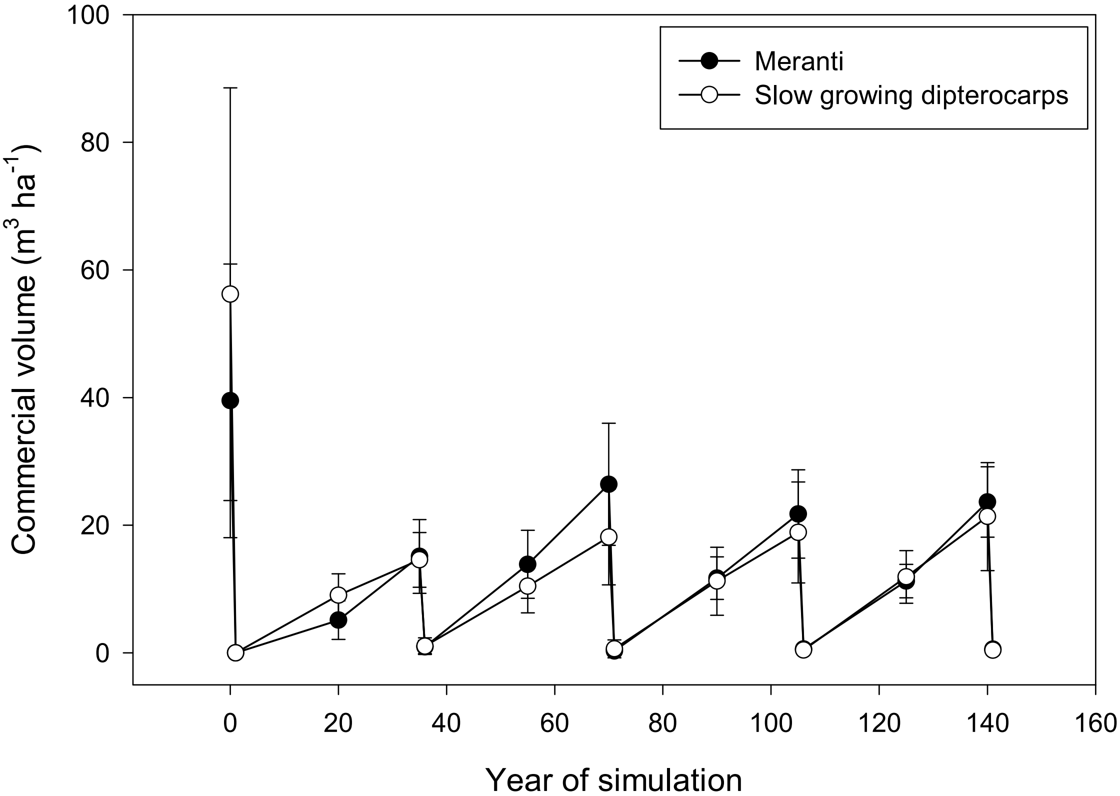


Figure 30. Commercial volume for the Meranti and Slow growing dipterocarp groups. Commercial volume was defined as the total volume of all stems with DBH greater than 50 cm and a stem quality greater than 0.3. (70 % of the initial stand). Other details as for Figure 29.

10.1.6 The rate of volume increment shown in Figure 30 has not slowed before each harvest and in some instances appears to be increasing (e.g. years 36 to 70 for the Meranti group. This suggests that it would be useful to consider extending the length of the cutting cycle.

10.1.7 Ecological aspects of the growth of the forest over the simulation can be examined using the SYMFOR ecological species group selecting all trees (dbh>10 cm, quality 0.0001). The results of this analysis are shown as Figure 31. The volume of the pioneer species groups of *Anthocephalus* and *Macaranga* species increase in significance following the initial heavy harvest in primary forest. The proportion of pioneers is lower after subsequent harvests presumably because of lower total harvest intensities. Throughout the simulation, the most important groups in this forest type were the slow growing dipterocarps and the general group of small non-commercial species.

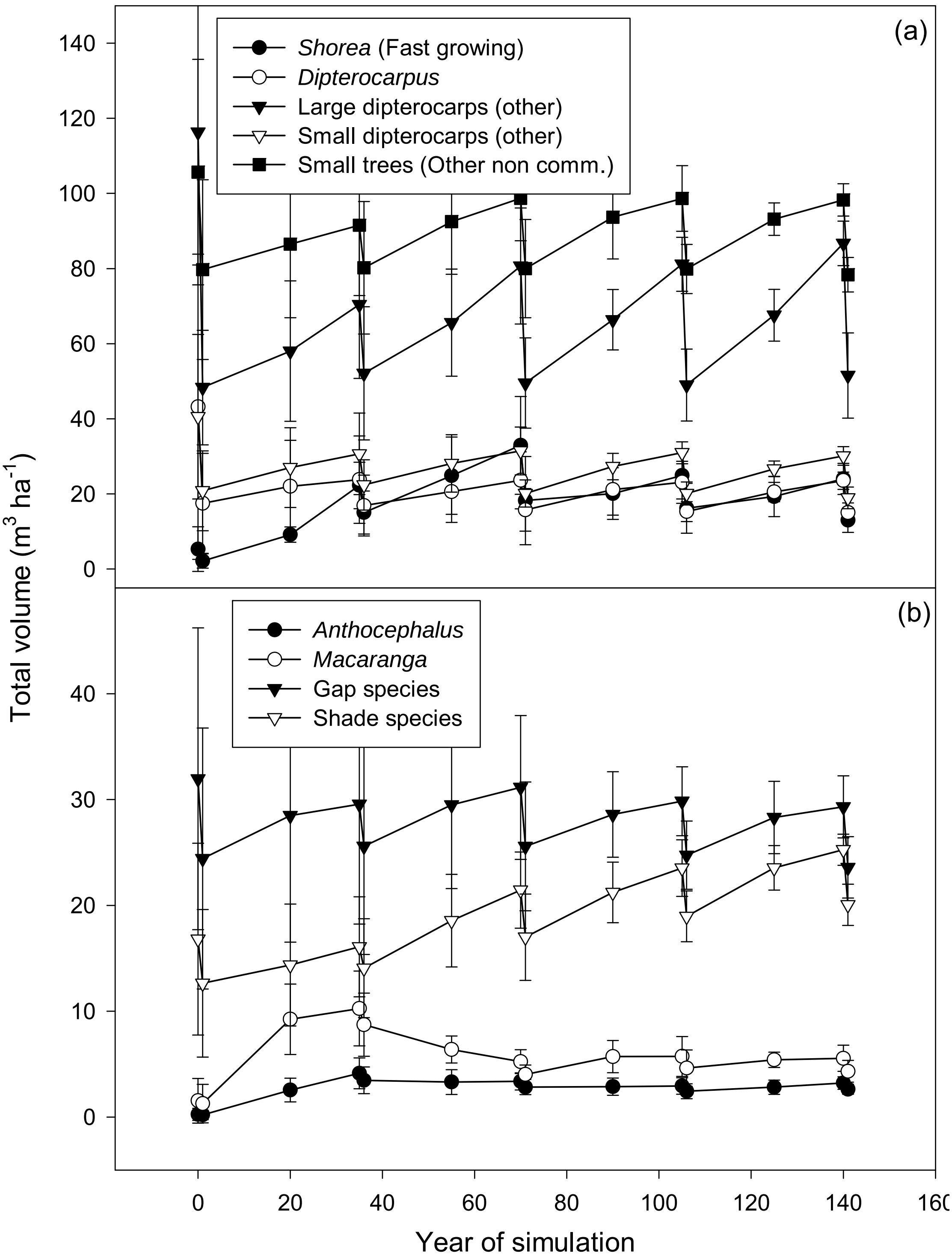


Figure 31. Total volume of SYMFOR ecological species groups following the application of the TPTI system with a 35 year cutting cycle. All trees with DBH greater than 10 cm are included. Other details as for Figure 29.

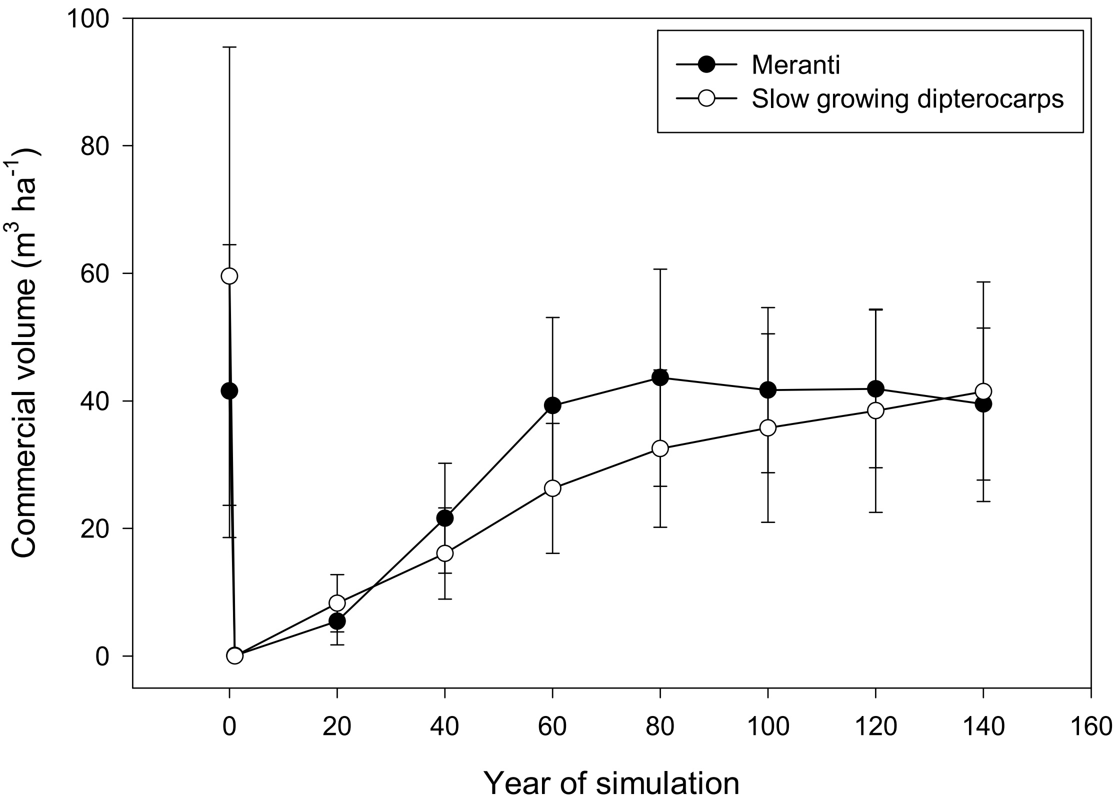


Figure 32. Commercial volume of the Meranti and Slow growing dipterocarp groups following a single harvest in year 0. Other details as for Figure 29 and Figure 30.

10.1.8 The first step towards considering the optimal length of cutting cycle is to examine the simulated regrowth of the forest stand following a single harvest. This has been completed and the commercial volume change of the Meranti and slow growing dipterocarp BFMP groups is shown as Figure 32. This figure shows that volume increment starts to decline after year 60 of the simulation. This result suggests that a cutting cycle of between 40 and 60 years may be optimal for this location and forest type.

10.1.9 Changes in the SYMFOR ecological groups are shown as Figure 33 over the same 140 year simulation. The pioneer species (*Anthocephalus* and *Macaranga*, Figure 33b) increase in importance over the first forty years of the simulation and then start to decline over the period between years 40 and 60. The fast growing *Shorea* species (Figure 33a) increase rapidly in proportion up to year 60 and then gradually decline in importance. These observation suggest that the heavy logging was promoting the regeneration of light demanding species such as the pioneers or *S. johorensis* and *S. leprosula*. It might be expected that different patterns of change would emerge if the logging intensity was lower. The results also suggest that it will take over 140 years following logging for the forest to reach a state that approaches that of the primary forest before logging.

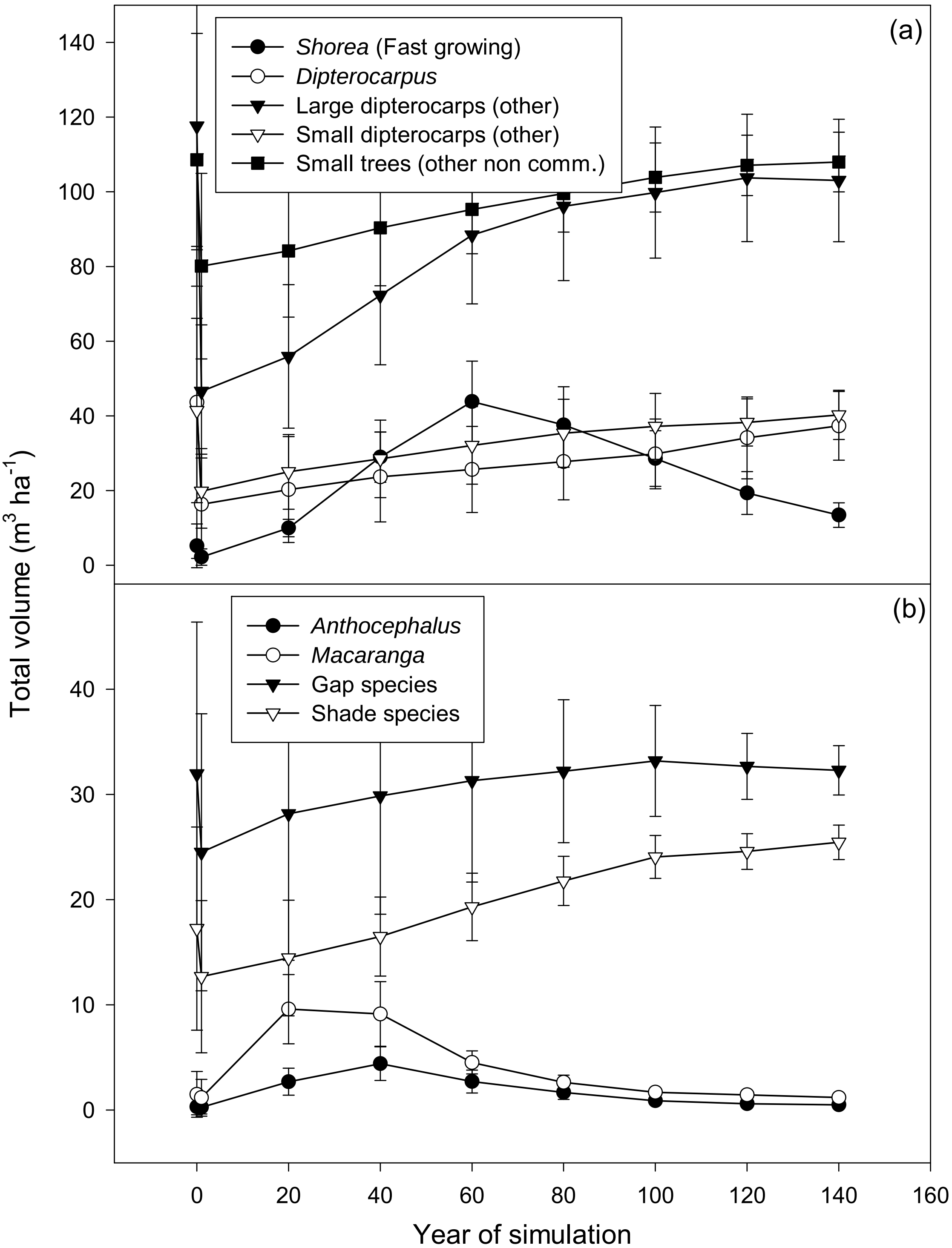


Figure 33. Total volume of SYMFOR ecological species groups following a single harvest in year 0. All trees with DBH greater than 10 cm are included. Other details as for Figure 29.

11 Silvicultural component of the management plan for the Labanan concession of Inhutani I

11.1 Introduction.

11.1.1 Yield scheduling using growth and yield models is one aspect of the processes required to plan sustainable harvests for a concession. These are illustrated diagrammatically as Figure 34. SYMFOR is a tool that permits forest managers to consider the implications of silvicultural management options. This needs to be combined with concession wide yield scheduling using a tool such as the BFMP Yield Simulation System (YSS) (Rombouts, 1998) and an economic model of the concession.

11.1.2 The simulation of the conventional TPTI silvicultural system in section **8** showed that this system resulted in low yields from the second and subsequent harvests of logged-over forest. It is now suggested that this should be compared with a modified TPTI system including reduced impact logging and combinations of yield regulation to limit the intensity of the initial harvest and a longer cutting cycle. This will form the first set of applications for participants in the workshop. Each group should run and analyse two modified systems of TPTI. The modified prescriptions will be defined by the participants.

11.1.3 An example comparing prescriptions is presented in Table 13 and Table 14. The conventional TPTI prescription is here compared with a prescription for reduced impact logging with the yield regulated to 8 stems per hectare at each harvest. Both of these systems have been programmed and are available for use in SYMFOR. These specifications should be used as starting points for the work programme of the workshop.

11.1.4 The majority of the area of most forest concessions in Indonesia consists of logged-over forest that may have first been logged up to 30 years previously. The method and intensity of earlier logging were often very different from current practice. These areas of forest have subsequently been managed with various degrees of success resulting in a range of current forest condition.

11.1.5 Results from SYMFOR simulations starting with primary forest are not directly relevant to the very important questions relating to the management of existing logged-over forest. For these questions it is necessary to have data from permanent sample plots in areas of logged-over forest. At present this is only available from the STREK logging trials. The BFMP project is currently modifying the inventory procedures to implement additional sample plots across the concession. At this stage, however, simulations using SYMFOR will need to be limited by data from the STREK plots in RKL 1 and RKL 4.

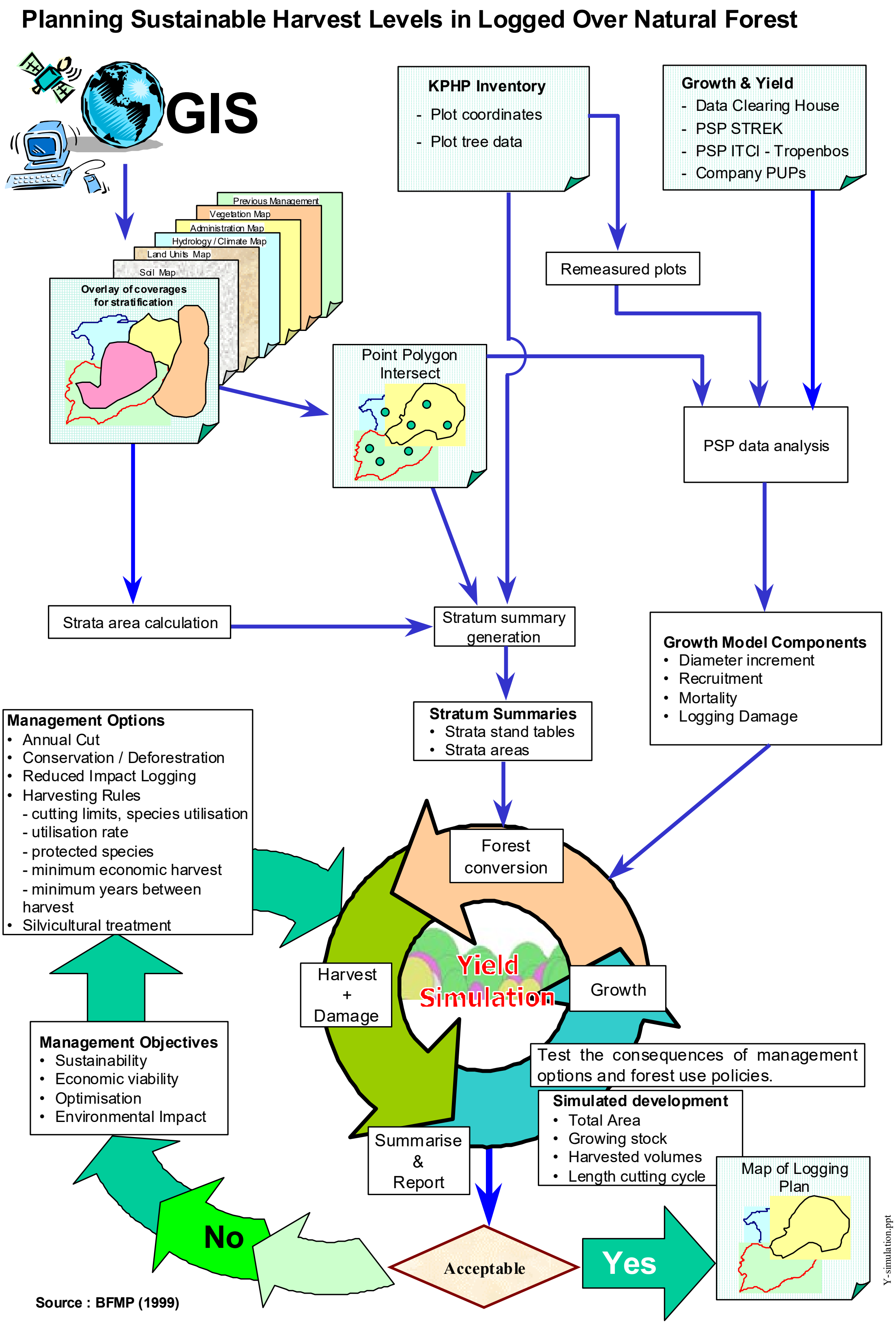


Figure 34. Planning sustainable harvest for logged-over forest. A flow diagram of the information requirements and processes.

Swappable Function	TPTI	RIL
treatment	**TPTI**	**RIL**
logqualify	qualify1	qualify1
logselect	Select1	Select1
felling	**undirectional**	**directional**
dragdamage	dragdamage1	dragdamage1
skidprepdamage	skidprepdamage1	skidprepdamage1
planskidtrails	**straight**	**branched**
calcskidcorners	nocorners	nocorners
skidtrails	skidtrails1	skidtrails1

Table 13. Silvicultural module choices comparing the TPTI and RIL module choices. Differences are highlighted in bold.
(Blank copies of this table are presented in Appendix 3.

Module	Parameter	TPTI 35	RIL 8 stems
calc_treatment1	firstlogging	0	0
calc_treatment1	loggingcycle	35	35
qualify1	dbhcrit	utilgrp 1: 50 cm utilgrp 2: 50 cm utilgrp 3: 50 cm utilgrp 4+ 500 cm	utilgrp 1: 50 cm utilgrp 2: 50 cm utilgrp 3: 50 cm utilgrp 4+ 500 cm
qualify1	qualitylimit	0.3	0.3
select1	nlogmax	**500**	**8**
select1	maxextract	500	500
select1	minextract	0	0
directional	cutdirection	**n/a**	**135**
branched	joinangle	**n/a**	**60**
skidtrails1	skidwidth	5	5[1]
calc_ages1	skidpersist	40	40[2]
skidprepdamage1	skidprepradius	**5**	**3**

Table 14. Silvicultural parameter choices comparing the TPTI 35 and RIL 8 stems parameter sets. Differences are highlighted in bold.
(Blank copies of this table are presented in Appendix 3.

1 The width of a skidtrail could be reduced if tractors were fitted with a smaller blade.
2 The persistence of skidtrails should be increased to exceed the length of the cutting cycle in RIL treatments to ensure that trails are reused.

11.2 Data availability.

The STREK plots.

11.2.1 The STREK project (Silvicultural Techniques for the Regeneration of logged-over forest in East Kalimantan) established 72 hectares of permanent sample plots during 1990 and 1991. These plots were distributed in two types of forest in the concession on Inhutani I. Each sample plot is 4 ha square. Six plots (24 ha) were established in an area of logged-over forest (RKL-1) that had been logged in 1979/80. Another 12 plots (48 ha) were established in an adjacent area of unlogged forest (RKL-4). The plots in RKL4 were harvested by the project from November 1991 through to May 1992.

11.2.2 The plots were utilised to monitor the effects of a range of silvicultural treatments for Dipterocarp forest. The plots in RKL-1 were used in a trial to quantify the benefits of thinning treatments in logged-over forest. Those in RKL-4 were used to compare the effects of conventional and reduced-impact logging techniques on the regeneration of the stand.

11.2.3 Each four hectare plot was surveyed at the start of the experiment, recording details of every tree within the plot with a diameter exceeding 10 cm, a total of over 13,000 records. For each tree, the data recorded included diameter, species and a description of the crown. Tree species were recorded using botanical naming, with the majority of trees now identified to species level. Tree measurements have been repeated at regular intervals of two-years in order to monitor the growth and yield of the forest stand following the logging and silvicultural treatments. The BFMP has continued these measurements and completed the fifth campaign in 1999.

11.2.4 The experimental treatments in RKL-1 compared the growth of untreated logged-over forest with two thinning treatments. A systematic treatment was applied to two plots, where all non-commercial trees above a diameter limit of 20 or 30 cm were removed by poisoning. The second treatment was used to remove competing trees surrounding selected potential crop trees (PCT). In RKL-4 conventional logging techniques were compared with reduce-impact techniques using either a 50 or 60 cm diameter cutting limit. Data from the sample plots were analysed by the STREK project in order to describe the initial effects of the experimental treatments (up to the end of 1995), a period of four years following logging (Bertault & Kadir, 1998).

11.2.5 Data are available from four recording units for each plot over an eight year period (five campaigns). These have been processed into a format suitable for use for SYMFOR resulting in 360 separate data files. This information is available for modelling and statistical analysis. The types of forest data are summarised in Table 15. Treatments were assigned to plots as shown in Table 16. It should be noted that the conventional logging treatment in RKL 4 used a 60 cm cutting limit.

11.2.6 Measurement campaign 5 coincided with an extreme drought over the period of 1997-1999. High levels of mortality were observed and data from this campaign should not be considered to be representative of the trial.

Forest Type	Data availability
Primary Forest	All plots in RKL 4 for campaign 1
	Control plots in RKL 1, campaigns 2-5
Logged-over forest	All plots in RKL 1 for campaign 1
	Control plots in RKL 1, campaigns 2-5
	Treated plots in RKL 4, campaigns 2-5
Thinning treatments	Treated plots in RKL 1, campaigns 2-5
Logging treatments	Treated plots in RKL 4, campaigns 2-5

Table 15. Summary of types of data available from the STREK trial and BFMP database.

RKL	Treatment	Plots
1	Control	4,5
1	Systematic thinning	1,6
1	Potential crop trees	2,3
4	Control	1, 4, 10
4	Conventional dbh > 60 cm	8, 9, 11
4	Reduced impact logging dbh > 50 cm	2, 3, 12
4	Reduced impact logging dbh> 60 cm	5, 6, 7

Table 16. Treatments in the STREK experiment

Plots in other areas and forest types.

11.2.7 The STREK data provides information on primary forest in two ages of logged-over forest (RKL-1 and RKL-4). The BFMP environmental framework shows that all of the plots occur in similar categories of forest. Results from simulations using these data will thus not necessarily be representative of other strata in the concession.

11.2.8 Additional sample plots need to be established in other areas of the concession according to the stratification from the BFMP environmental framework. This work is being undertaken as part of a revision of the inventory for the Labanan concession.

11.3 Defining the optimal silvicultural treatments for primary and logged-over forest.

11.3.1 The management plan for the Labanan concession needs to define optimal silvicultural treatments for the different strata of forest. The majority of current production is coming from areas of primary forest. For this reason it is important to define a silvicultural treatment for primary forest that will ensure long-term sustainable production from these areas.

11.3.2 Under the existing management plans, areas of logged-over forest are expected to be harvested again within the next 15 years. The management plan needs to have a prediction of the likely yields from these areas when logged as well as a silvicultural prescription for further management of logged-over areas.

11.3.3 The next sections consider how these management requirements could be addressed using SYMFOR and the data currently available from the STREK trial.

Primary forest.

11.3.4 The examples presented in section **8** show the effects of the conventional TPTI system using simulated logging of twelve representative plots of primary forest in RKL4. This work could be extended using different silvicultural treatments for comparison to define silvicultural options (**8.3**) for optimal management of primary forest.

11.3.5 It is recognised that the simulated logging may not be an accurate representation of logging and damage to the residual stand in practice. For this reason a second approach to growth and yield simulation may be appropriate for the STREK plots. In this approach, SYMFOR would use post logging data collected by the project to initialise the model. These data would have an accurate representation of damage resulting from logging. The simulation would then be used to predict the growth and potential yield of the logged forest at intervals up to and past the expected length of the cutting cycle. This approach would complement results using simulated logging

Logged-over forest

11.3.6 The STREK data have two types of logged-over forest available for study. The post-logging data from RKL4 will only be useful for discussion of growth and yield of recently logged forest. In practice this aspect will be covered by the discussion of management options for primary forest. The data from RKL1 are of much more interest in that they describe the status of an area of logged-over forest that is scheduled to be logged early in the next cutting cycle of the concession.

11.3.7 One appropriate modelling approach would be to use data from plots in RKL-1 to initialise the model and then to make yield projections up to and beyond the expected date of the next harvest. Data from the control plots can be used from any of the measurement campaigns. Other plots should only be used with data from campaign 1 before the thinning treatments were applied.

11.3.8 SYMFOR can be programmed to work with areas of logged-over forest but it is first necessary to generate a new stand definition file (**2.2**). Further information is contained in the SYMFOR help files.

Thinning treatments

11.3.9 The current version of SYMFOR does not implement thinning treatments. The model can, however, be used to analyse results from the STREK thinning trials. This would be done using data from any of the thinning treatments and making a yield projection for the end of the cutting cycle. Data from campaigns three or four would be most appropriate for this approach. The simulations should be compared between experimental treatments and then could be compared with the same plots without treatment using data from campaign 1. The lengths of the simulations would need to be adjusted to make an allowance for the time difference between the campaigns used to initialise the simulations.

11.3.10 A future version of the software (SYMFOR 2000) will include thinning as one of the supported silvicultural treatments.

Other silvicultural systems and treatments

11.3.11 Treatments such as replanting and clearing have not been implemented within SYMFOR for simulation of the TPTI system.

11.3.12 SYMFOR has been programmed to simulate the TPTJ (Strip clearing and planting) system but as yet has not been calibrated. This option should not be used for management until suitable calibration data become available.

11.4 Future work.

11.4.1 The work suggested here should be considered to be the first phase of defining the silvicultural component of the management plan for the Labanan concession. Results from this analysis should be combined with economic modelling and concession wide growth and yield modelling using the Yield Simulation System. When combined these tools may suggest that management objectives for the concession need to be adjusted. The development of the management plan will thus be an iterative procedure.

11.4.2 New data will become available from both the refined inventory program and new measurements from the STREK plots. The growth and yield simulations should be extended using these data as they become available.

11.4.3 The management plan will evolve as the available tools develop and more data becomes available. Management objectives will change as will market conditions. All of these considerations mean that a good management plan is one that can adapt to changing conditions and the availability of information.

12 Summary.

12.1.1 This training document has provided an introduction to the application of the SYMFOR growth and yield model for management planning in Indonesian forest concessions. The participants in the workshop will have used these tools to contribute to the development of a management plan for the Labanan concession of PT Inhutani I an East Kalimantan.

12.1.2 The model requires data from 1 hectare sample plots. The only suitable data currently available for the Labanan are from the STREK experimental plots. These plots describe the condition of the forest at two stages following logging (RKL-1 and RKL-4) but are recognised as being from the same original forest type. New plots are required to extend the modelling process to other areas of the concession. These will be implemented as part of a revised inventory program being developed by the BFMP project.

12.1.3 SYMFOR is only one component of the integrated approach to yield scheduling for the concession (Figure 34). The results must be linked with those from the environmental framework (GIS), concession scale growth and yield modelling (YSS) and economic modelling.

12.1.4 An iterative approach is required for yield scheduling. The predictions and conclusions from analysis should be regularly updated as models are improved and new data become available. In the medium term, results should be compared against actual yields and the achievement of management objectives.

12.1.5 The iterative approach to yield scheduling leads to a management regime that is able to adapt to changing forest or economic conditions. Such adaptive management will ensure the long-term sustainability of forest resources in Indonesia.

13 Acknowledgement

13.1.1 SYMFOR is an output from a project funded through the Forestry Research Programme of the UK Department For International development (DFID) for the benefit of developing countries. Project R6915 Forestry Research Programme.

http://meranti.ierm.ed.ac.uk/g&y/home.htm

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15 Appendix 1. BFMP Commercial Species Groups

Group
1. Meranti
2. Other dipterocarp. Fast growing
3. Other dipterocarp Slow growing
4. Major non-dipterocarp commercials
5. Minor non-dipterocarp commercials
6. Non commercial species
7 Protected species

16 Appendix 2. SYMFOR ecological species groups.

Group	Name (reference)	Characteristics	Dominant members
1	Fast growing *Shorea*	Large trees, light demanding, very fast growing	*Shorea johorensis*, *S. leprosula*
2	*Dipterocarpus*	Large trees, shade tolerant, slow growing	*Dipterocarpus*, some *Shorea*
3	Other large dipterocarps	Large trees, shade tolerant, fast growing	*Shorea*, *Parashorea*, *Dryobalanops*
4	Small dipterocarps	Default group for Dipterocarpaceae species	*Hopea*, *Vatica*, some *Shorea*, *Dipterocarpus*
5	*Anthocephalus*	Small trees, fast growing, highly disturbed forest	*Anthocephalus chinensis*
6	*Macaranga*	Small trees, light demanding, very fast growing	*Macaranga*
7	Gap small trees	Small trees, recruit in light areas	*Aglaia, Knema, Artocarpus*
8	Other small trees	Small trees, default group for non-Dipterocarpaceae species	*Diospyros, Dacryodes, Polyalthia*
9	Shade small trees	Small trees, recruit in shady areas	*Macaranga lowii, Gonystylus, Madhuca, Kayea*
10	Unknown	"Unknown" species, genus or family identity	Unknown

17 Appendix 3. Silvicultural module and parameter settings

Swappable Function	TPTI
treatment	TPTI
logqualify	qualify1
logselect	Select1
felling	undirectional
dragdamage	dragdamage1
skidprepdamage	skidprepdamage1
planskidtrails	straight
calcskidcorners	nocorners
skidtrails	skidtrails1

Table 17 Silvicultural module choices for the TPTI system

Module	Parameter	TPTI 35
calc_treatment1	firstlogging	0
calc_treatment1	loggingcycle	35
qualify1	dbhcrit	utilgrp 1: 50 cm utilgrp 2: 50 cm utilgrp 3: 50 cm utilgrp 4+ 500 cm
qualify1	qualitylimit	0.3
select1	nlogmax	500
select1	maxextract	500
select1	minextract	0
directional	cutdirection	n/a
branched	joinangle	n/a
skidtrails1	skidwidth	5
calc_ages1	skidpersist	40
skidprepdamage1	skidprepradius	5

Table 18 Silvicultural parameter choices for the TPTI system

Swappable Function	RIL
treatment	RIL
logqualify	qualify1
logselect	Select1
felling	directional
dragdamage	dragdamage1
skidprepdamage	skidprepdamage1
planskidtrails	branched
calcskidcorners	nocorners
skidtrails	skidtrails1

Table 19 Silvicultural module choices for the RIL system

Module	Parameter	RIL 8 stems
calc_treatment1	firstlogging	0
calc_treatment1	loggingcycle	35
qualify1	dbhcrit	utilgrp 1: 50 cm utilgrp 2: 50 cm utilgrp 3: 50 cm utilgrp 4+ 500 cm
qualify1	qualitylimit	0.3
select1	nlogmax	8
select1	maxextract	500
select1	minextract	0
directional	cutdirection	135
branched	joinangle	60
skidtrails1	skidwidth	5
calc_ages1	skidpersist	40
skidprepdamage1	skidprepradius	3

Table 20 Silvicultural parameter choices for the RIL system limited to a harvest of 8 stems per hectare.

18 Appendix 4. Modifications to standard SYMFOR installation for workshop sessions.

18.1 Modified configuration files for SYMFOR

Filename	Directory	Description
mm.ini	symfor	model manager
pars.txt	symfor	parameter settings
mods.txt	symfor	module settings
runsets.ini	symfor	Multiple runsets

Table 21. Modified configuration files for SYMFOR used in the workshop. These files should be copied to the **`symfor`** program directory (Normally **`c:\program files\symfor`**.)

18.2 Stand configuration files

Filename	Directory	Description
nologging.csv	symfor\stands	Unlogged stand file
stand1.csv	symfor\stands	Example of logged stand file
rkl1.scv	symfor\stands	Stand file for C1 data in RKL1

Table 22. Modified configuration files for SYMFOR used in the workshop. These files should be copied to the **`stands`** directory under the SYMFOR program directory.

18.3 Excel spreadsheet used in the training session

Filename	Directory	Description
SYMFOR summary1.xls	symfor\analysis	Analysis of multiple runs

Table 23. Excel spreadsheet used in the workshop. This file should be copied to the **`analysis`** directory under the SYMFOR program directory.

18.4 Post processing outputs used in the workshop

Filename	Directory	Description
tpti-felled.csv	symfor\output	Felled tree data
tpti-live.csv	symfor\output	Live tree data

Table 24. Example output files from the SYMFOR post processor. These files should be copied to the **`output`** directory under the SYMFOR program directory.Data files for SYMFOR

Filename	Directory	Description
R4P01RU2C1.DBF	symfor\strekplots	RKL4 Plot 1
R4P02RU2C1.DBF	symfor\strekplots	RKL4 Plot 2
R4P03RU4C1.DBF	symfor\strekplots	RKL4 Plot 3
R4P04RU1C1.DBF	symfor\strekplots	RKL4 Plot 4
R4P05RU4C1,DBF	symfor\strekplots	RKL4 Plot 5
R4P06RU4C1.DBF	symfor\strekplots	RKL4 Plot 6
R4P07RU3C1.DBF	symfor\strekplots	RKL4 Plot 7
R4P08RU1C1.DBF	symfor\strekplots	RKL4 Plot 8
R4P09RU1C1.DBF	symfor\strekplots	RKL4 Plot 9
R4P10RU1C1.DBF	symfor\strekplots	RKL4 Plot 10
R4P11RU3C1.DBF	symfor\strekplots	RKL4 Plot 11
R4P12RU1C1.DBF	symfor\strekplots	RKL4 Plot 12
R4P12RU1C1.DBF	symfor\strekplots	RKL4 Plot 12

Table 25. Data files from the logging experiment from the STREK trial. All files are from the first measurement campaign. The code **RU*n*** identifies the recording unit in each plot. These files should be copied to the **strekplots** directory under the SYMFOR program directory.