Manual for the European Forest Information Scenario Model (EFISCEN 2.0)

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FOREWORD

Long-term scenario modelling plays an important role in the research strategy of EFI. Without reliable information on the present forest resources – including their area by species, age and volume distribution and their potential development under various forest management policies, the decisions on the directions for future cannot be made on a sound basis.

The model – EFISCEN – has been developed to facilitate various types of analysis where long-term and countrywide or European wide approaches are needed.

Professor Ola Sallnäs from the Swedish University of Agriculture provided the basic version of the model for further development at EFI in 1995. Over the years, the model has evolved to include more elements for simulation, such as full carbon account of forests. This version of the model utilises forest inventory data, which can be described as an age-volume matrix. The simulation of a stem diameter approach (e.g. uneven-aged forests) will be included in the next version of EFISCEN.

For the development of this type of methodology it is essential to have a wide user community to utilise the model and to suggest further improvements to it. We hope that this manual will encourage the user to test the model version 02 and find ways to utilise it in different types of analyses.

I would like to thank those involved in the development process of EFISCEN. Ari Pussinen for his continuous efforts to improve the model and for writing this manual, and Gert-Jan Nabuurs and Mart-Jan Schelhaas for their work with the model.

Joensuu, December 2001

Risto Päivinen

ABSTRACT

The European Forest Information Scenario Model (EFISCEN) is a large-scale matrix model, which compiles information on forest resources in Europe and produces projections of the possible future development of forest resources. It uses forest inventory data as input. So far, EFISCEN has been applied to 30 European countries and some regions in Russia. The current version of EFISCEN also provides a platform to calculate carbon stocks and flows in trees and forest soils based on forest inventory data. This manual explains how the model works, how the data are technically entered into the model and describes the contents of the output files. The manual provides basic information for new users of the model and gives potential users an overview of the potential of the model.

Keywords: forest resources, carbon stocks, models, modelling, scenarios, EFISCEN, forest inventory, Europe

1. INTRODUCTION

Humans plan for the future. In forestry this means that we want to know our production possibilities and consequences of various management policies. The planning happens at the stand scale, at the forest holding scale or at even larger scales. In this manual we present one approach to make scenarios for large areas, e.g. at the country scale. Large-scale forestry scenario models are models that are able to make long-term projections of forest resources of a large geographical area (see e.g. Nabuurs and Päivinen 1996).

The European Forest Information Scenario model (EFISCEN) is a forest resource assessment model, especially suitable for strategic, large scale (>10 000 ha) and long-term (20–50 years) analysis. EFISCEN 2.0 is suitable for assessments of the future state of the forest under assumptions of future felling levels. The model does not use any optimisation, but simulates the state of forest resources under management regimes defined by the user.

The main advantage of this model is that it is not very data intensive. It requires rather basic forest inventory data which most European countries have available. The basic output of the model consists of the state of the forest at five-year intervals, e.g. growing stock, increment, felling and age class distribution.

The core of the growth simulator of the EFISCEN 2.0 model is based on a model developed for even-aged forests by Ola Sallnäs at the Swedish University of Agricultural Sciences (Sallnäs 1990). The original aim was to develop a forest growth model that could be incorporated in a forest sector model. Later in the early 1990s it was modified and used by IIASA (International Institute for Applied Systems Analysis) to study the effect of air pollution on European forests (Nilsson et al. 1992).

Nowadays EFISCEN is in use and under further development at the European Forest Institute (EFI) for new forest resource projections at the European level (Nabuurs et al. 1998; Päivinen and Nabuurs 1997; Nabuurs et al. 2001) and in Russia (Päivinen et al. 1999; Lioubimow et al. 1998). At EFI it has been validated with historical data (Nabuurs et al. 2000).

In the EFISCEN 2.0 version the following adaptations were made to the model compared to earlier version:

- Thinnings were incorporated in a different way in the model, resulting in a more realistic increment after thinning (section 2.4.1.);
- The increment rates at high growing stocks were modified;
- All calculations are now carried out for five-year age classes;
- Transient increment rate changes due to e.g. environmental changes can now be incorporated;
- Full forest biomass balance can be calculated including soil carbon (section 2.7, 2.8 and 2.9).

The EFISCEN model is under constant development and version 3.0 will incorporate natural mortality rates and a stochastic approach for natural disturbances (Schelhaas et al In press). The EFISCEN version 4.0 will incorporate a multi-country module that links the countries through consumption rates and wood products trade flows (Nabuurs et al. 2001).

Some countries in Europe report their forest inventory data by diameter classes, which creates a need for a different modelling approach. This so-called uneven-aged approach is in use for parts of Belgium, France and Italy and the whole of Spain. The development of this element to EFISCEN is underway.

The aim of this manual is to help the users to understand the functioning of the model, to be able to parameterise it and to run it. Furthermore, the manual contains the description of input and output data of the model. However, this version of the model is not as user-friendly as the authors wish, and therefore new users may need some guidance from more experienced users.

2. THE EVEN-AGED MODEL

2.1 INPUT DATA

EFISCEN is a timber assessment model, which means that the user specifies a certain harvest level and the model checks if it is possible to harvest that amount and simulates the development of the forest under that harvest level. The forest area is first divided into forest types. For each country different forest types can be distinguished by region, owner class, site class and tree species depending on the level of detail of the input data. For each forest type the following data should be available for each age class (Example 1):

- area (ha)
- average standing volume over bark (m^3ha^{-1})
- net current annual increment over bark (m^3ha^{-1})

Further, information is needed about the management regime, such as thinning regime, thinning intensity in the past, and final cutting ages. If the carbon budget of the forest area is to be calculated, then biomass distribution parameters, weather data and litter production data are needed as well. The length of the simulation period can be altered by changing the number of five-year time steps. However, the credibility of results decreases in long-term simulations and the results after about 50 years simulation should not be taken as realisation of real situation, while errors accumulate in the model.

Example 1. Inventory data from Finland

The forest inventory data in this example is provided by the Finnish Forest Research Institute, which conducts the inventory in Finnish forests. We will follow this example throughout the manual. The inventory data of Finland consists of two regions (Northern and Southern Finland), one owner class (no need to distinguish different owner classes, such as private, state and companies, because there are no major differences between owner classes, e.g. management does not differ), four types of tree species (*Pinus sylvestris*, *Picea abies*, *Betula* spp., other deciduous) and eight site classes (four fertility classes for both mineral soils and peatlands).

2*1*4*8 = 64 forest types (matrixes) in Finland

The data of one forest type is presented below, showing *Pinus sylvestris* (species 1) on *Myrtillus* type forest on mineral soils (site class 2, medium fertile) in Southern Finland (region 1).The total Finnish input data set of EFISCEN consists of 64 tables like this one. Age classes are 20 years long and the first one includes bare forest land, i.e. forests without trees due to e.g. clear cut.

REGION	1
OWNER CLASS	1
SITECLASS	2
SPECIES	1

AGE years	AREA ha	VOLUME m^3ha^{-1}	INCREMENT $m^3ha^{-1}yr^{-1}$
10	667718	14	1.63
30	410370	89	6.88
50	194522	158	7.33
70	258085	183	6.21
90	100000	200	5.32
110	167714	199	4.35
130	63182	180	3.34
150	20814	181	2.76
160	9015	226	2.55

2.2 MATRIX SET-UP

EFSICEN is a matrix model, where the state of the forests is depicted as an area distribution over age and volume classes. For each forest type that is distinguished, a separate matrix is set up, which consists of 6 to15 age-classes and 10 volume classes and (see Figure 2.1). The amount and width of the age classes is dependent on the input data. The width of the volume classes is set by a parameter, X1, which is the upper limit of the first volume class and can be set separately for all forest types. The area per forest type is divided over the cells using the input data. The area within an age class is distributed over the volume classes in such a way that the mean volume as given in the inventory data is matched.

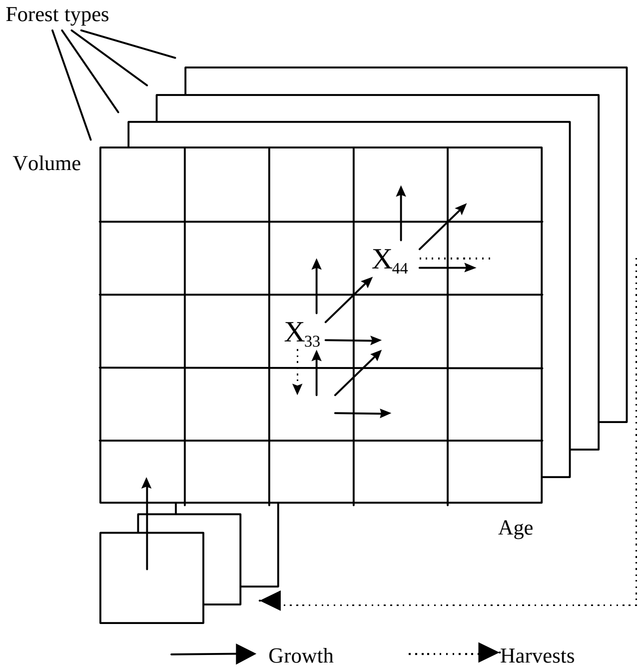


Figure 2.1. The area matrix approach (Nilsson et al. 1992).

To calculate the distribution (area over age and volume classes), three variables are used: (i) the mean volume per hectare; (ii) the coefficient of variation in volume per hectare; and (iii) the correlation between volume per hectare and age or transformations of age. The calculation is performed in four steps:

1. Calculate the variance in volume per hectare, using mean volume per hectare and the coefficient of variation:

$$S^2 = (mv * cv)^2 \quad \text{(Formula 1)}$$

where S^2 = variance in volume per hectare
mv = mean volume per hectare
cv = coefficient of variation

2. Calculate the conditional variance given mean age:

$$S^2_{ma} = (1 - cr^2) * S^2 \quad \text{(Formula 2)}$$

where S^2_{ma} = variance in volume per hectare given mean age
cr = coefficient of correlation between age and volume per hectare
S^2 = variance in volume per hectare

3. Calculate the ratio of variance to age, and use this ratio to calculate the variance in each age class:

$$k = S^2_{ma} / ma \qquad \text{(Formula 3)}$$

where k = ratio of variance to age
S^2_{ma} = variance in volume per hectare given mean age
ma = mean age

4. The variance in age class i is then

$$s_i^2 = k * ma_i \qquad \text{(Formula 4)}$$

where s_i^2 = variance in age class i
k = ratio of variance to age
ma_i = mean age of age class i

The minimum limit for the largest volume class is calculated using the largest volume per hectare for that forest type, plus three times the largest standard deviation. This span is then divided into a sequence of volume classes, using the X1 parameter, which defines the width of the first volume class.

The distribution of area over the volume classes is calculated using the mean deviation and the standard deviation of volume in each age class and a modified normal distribution. Natural logarithm of age is used as a transformation of age in the calculations involving the correlation between age and volume (Example 2).

Example 2. The initialisation of matrixes

In the following table the inventory data of Example 1 is distributed over the age-volume matrix. The numbers in the matrix are thousands of hectares of forest. The upper left cell is the bare-forest-land class.

The used parameters are cv = 0.65, cr = 0.50 and X1 = 50. X1 is the upper limit of the first volume class. Parameters cv and cr describe how the area is distributed around the mean volume (see Formulas 2 and 3, and description of parameters from Chapter 3 Item 6).

The sum of the 81–100 age class (in bold) is 100 (100 000 ha) and the mean volume is 200 m^3ha^{-1} (the inventory data from Example 1).

Age class

Mean volume per class m^3ha^{-1}	0–20	21–40	41–60	61–80	**81 100**	101–121	121–140	141–160	>160
0	293.80	0	0	0	**0**	0	0	0	0
25	373.92	106.71	0	0	**0**	0	0	0	0
75	0	151.18	40.36	23.17	**2.75**	6	9.16	3.06	0
125	0	94.36	61.19	74.46	**26.70**	46.22	17.26	5.64	1.19
175	0	46.94	49.31	71.99	**27.60**	44.22	15.15	4.82	2.85
225	0	11.18	25.65	47.41	**21.08**	33.87	10.45	3.41	2.02
275	0	0	9.53	22.70	**11.78**	19.52	5.64	1.88	1.42
325	0	0	4.35	8.70	**5.03**	8.70	2.47	0.82	0.83
375	0	0	2.82	4.94	**2.24**	3.88	1.29	0.47	0.36
425	0	0	1.06	3.18	**1.57**	2.71	0.94	0.35	0
475	0	0	0.24	1.53	**1.26**	2.59	0.82	0.35	0

2.3 INCREMENT

The growth dynamics are incorporated as five-year net annual increment as a percentage of the growing stock. The real volume increment percent per age class is calculated from the input data on the volume increment and the growing stock (cubic meters per hectare). The growth functions of the model are of the following type:

$$I_{vf} = a_0 + \frac{a_1}{T} + \frac{a_2}{T^2} \qquad \text{(Formula 5)}$$

where I_{vf} = five-year volume increment as a percentage of the growing stock
T = age of the stand in years
a_0, a_1, a_2 = coefficients

The coefficients for growth functions are derived from the relation between inventory data on age and real volume increment percent (see Example 3). The mean volume in an age-volume cell will deviate from the mean volume series as provided in the input data. Accordingly, the volume increment percent also deviates from the value given by the function, which means that some correction must be made. The correction is made according to:

$$I_{va} = I_{vf} * \left(\frac{V_m}{V_a}\right)^{beta} \qquad \text{when } V_a \le V_m \qquad \text{(Formula 6)}$$

$$I_{va} = \frac{I_{vf} * V_m}{V_a} \qquad \text{when } V_a > V_m \qquad \text{(Formula 7)}$$

where I_{va} = five-year percent volume increment for actual standing volume
I_{vf} = five-year percent volume increment given by the function
V_a = actual standing volume (m^3ha^{-1})
V_m = standing volume (m^3ha^{-1}) from the mean volume series
beta = parameter

The relationship between the relative standing volume and the relative volume increment is described by the parameter *beta* (see Nilsson et al. 1992). From studies of this relationship in yield tables and other data, the value of the parameter ranges from 0.25 to 0.45, depending on species, site classification, and the type of data used to construct the yield tables. If the actual standing volume is higher than the standing volume in the mean volume series, the absolute increment does not increase any more, i.e. the stand is regarded as fully stocked and higher standing volume does not increase net annual increment (m^3ha^{-1}).

Example 3. The estimation of growth function

The data used is from the previous examples for Finland. This procedure can be done, for example, using Microsoft Excel. The predicted increment is the increment calculated using the growth function.

REGION 1
OWNER CLASS 1
SITE CLASS 2
SPECIES 1

AGE, years	AREA, ha	VOLUME, m^3ha^{-1}	INCREMENT, $m^3ha^{-1}yr^{-1}$	5 years increment, %	Predicted increment, %
10	667718	14	1.63	58.21	58.24
30	410370	89	6.88	38.65	38.04
50	194522	158	7.33	23.20	24.23
70	258085	183	6.21	16.97	17.31
90	100000	200	5.32	13.30	13.20
110	167714	199	4.35	10.93	10.50
130	63182	180	3.34	9.28	8.58
150	20814	181	2.76	7.62	7.15
160	9015	226	2.55	5.64	6.56

Coefficients	
a_0	–2.61
a_1	1525.2
a_2	–9166.63

Coefficients a_0, a_1 and a_2 are estimated with regression from the original five-year increment data based on inventory (column 5), and the five-year increment is then predicted (column 6) using Formula 5

Figure 2.2 shows increment 'points' from the inventory data and the predicted growth function.

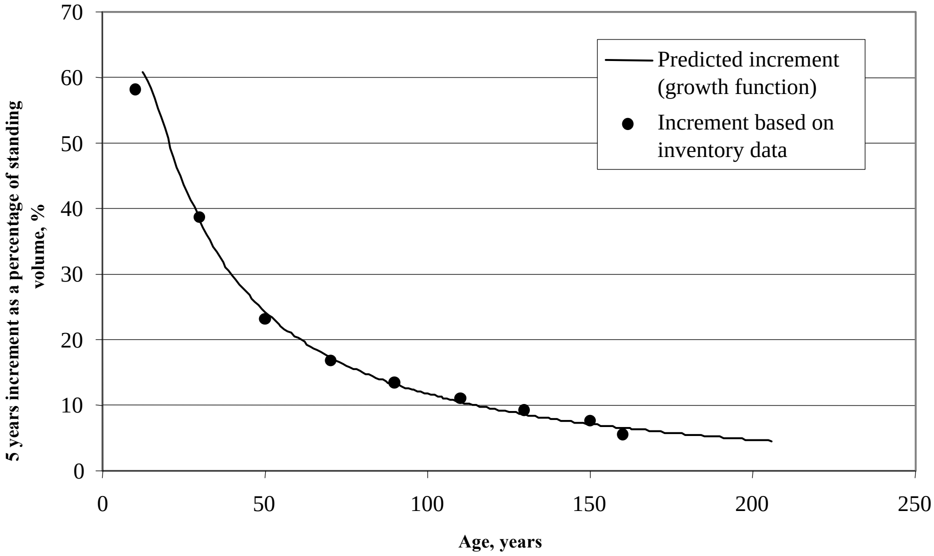


Figure 2.2. The increment based on the inventory data and the derived growth function.

Example 4. The use of growth functions

Let us take the forests at 90 years old with a standing volume of 175 m^3ha^{-1}. In Example 2 we can see that there are 27 600 ha of such forests at the beginning of the simulations.

Five-year increment as a percentage of standing volume by using the function (see Example 3):

$$I_{vf} = a_0 + \frac{a_1}{T} + \frac{a_2}{(T)^2} = -2.61 + 1525.20 / 90 - 9166.63 / 90^2 = 13.2\%$$

The correction according to the mean volume series (obtained from inventory data):

$$I_{va} = I_{vf} * \left(\frac{V_m}{V_a}\right)^{beta} = 13.2 * (200 / 175)^{0.4} = 13.92\%$$

i.e. the increment percentage is greater due to low volume, but the absolute increment (m^3 ha^{-1}) is actually lower than in stands with larger volume. The increment is:

13.92 % * 175 = 24.37 m^3 ha^{-1} (per 5 years)

The difference between two subsequent volume classes is 50 m^3ha^{-1}, and therefore we obtain the calculated increment when 48.78 % of the area moves one volume class up (24.37/50=48.73%). In our example, 13 449 ha (48.73% of 27 600 ha) will move one volume class up (to volume class 225 m^3ha^{-1}) during five years and 14 151 ha stay in the same volume class (volume class 175 m^3ha^{-1}).

In the matrix, increment is expressed as transition fractions between cells. Example 5 shows how the growth functions are translated into transitions in the matrix.

Example 5. Transition fractions between cells

If it is assumed that at t = 0 (at the beginning of simulations), there are 10 000 ha in age class 50–55 and volume class 100 –150 $m^3\ ha^{-1}$. The mean age in this cell is 52.5 years and the mean volume is 125 $m^3\ ha^{-1}$. Age class width is 5 years, so in one time step of 5 years, 100 % of the area moves to the next age class. The 5 years volume increment is calculated using Formula 5:

$$I_{vf} = a_0 + \frac{a_1}{T} + \frac{a_2}{(T)^2} = -2.61 + 1525.20 / 52.5 - 9166.63 / 52.5^2 = 23.12\%$$

And the correction according to mean volume series:

$$I_{va} = I_{vf} * \left(\frac{V_m}{V_a}\right)^{beta} = 23.12 * (125 / 158)^{0.4} = 21.05\%$$

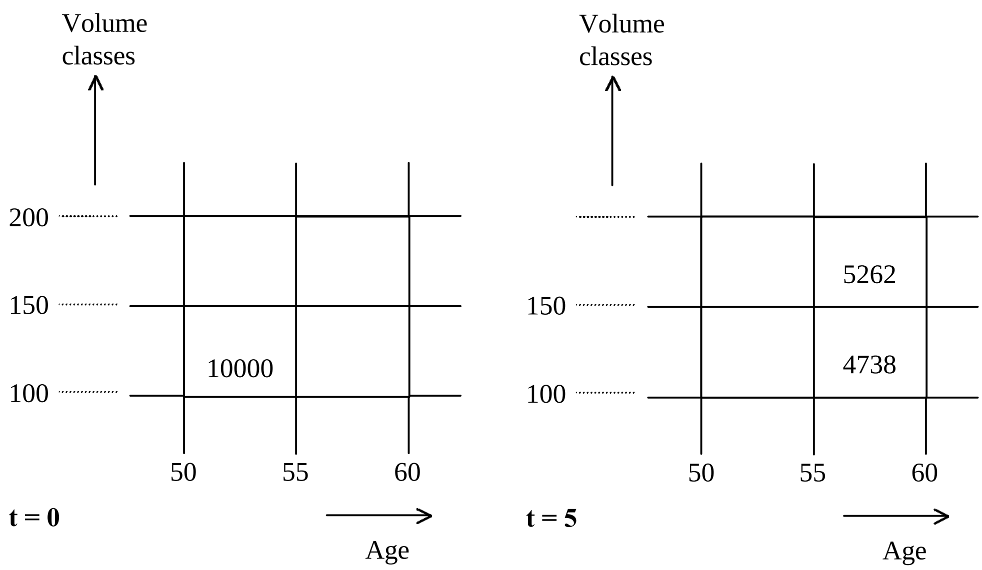
So after 5 years (t=5) the average volume must have risen by 21.05%:

$1.2105 * 125\ m^3\ ha^{-1} = 151.31\ m^3\ ha^{-1}$

The average volume of the second volume class is 175 $m^3 ha^{-1}$. Now we have to calculate the transition fraction from one volume class to the next.

$$\begin{cases} x * 125 + y * 175 = 151.31 \\ x + y = 1 \end{cases} \Rightarrow \begin{cases} x = 0.4738 \\ y = 0.5262 \end{cases}$$

So, 47.38% of the area (10 000 ha) stays in the same volume class (100–150 m^3ha^{-1}) and 52.62% of it moves to the next volume class (150–200 m^3ha^{-1}).



2.4 MANAGEMENT ACTIVITIES

Management is controlled at two levels in the model. First, for each forest type a basic management of thinning and final felling is incorporated. This is the theoretical management regime, which is applied according to handbooks or expert knowledge for forest management in the region or country to be studied. This theoretical regime must be seen as constraint of what might be felled. Second, total required volumes of felling from thinning and final felling are specified for the region or country as a whole for each time period. Based on the theoretical management regimes, the model searches and might find, depending on the state of the forest, the required volumes. Further the success of a reforestation after clear felling can be incorporated per tree species, as well as a possible tree species change after a clear felling, and a forest area expansion (see for further explanation section 2.6).

2.4.1 Thinning

Thinning regimes can be defined for each cell of the matrices, i.e. by each forest type and by volume and age class (see Figure 2.3). The thinning regime implies that it is possible to thin in that cell. The actual thinning is a fraction of the increment, i.e. the maximum thinning volume is the total increment in the cells of the thinning regime. When an area in a cell is thinned it does not move one volume class higher, but actually stays in the same volume class. Thinned volume is the volume class change that did not happened due to thinning.

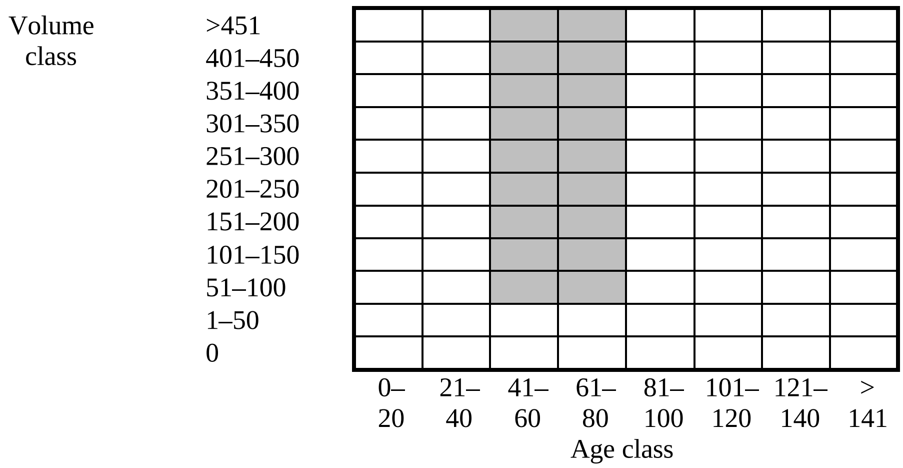
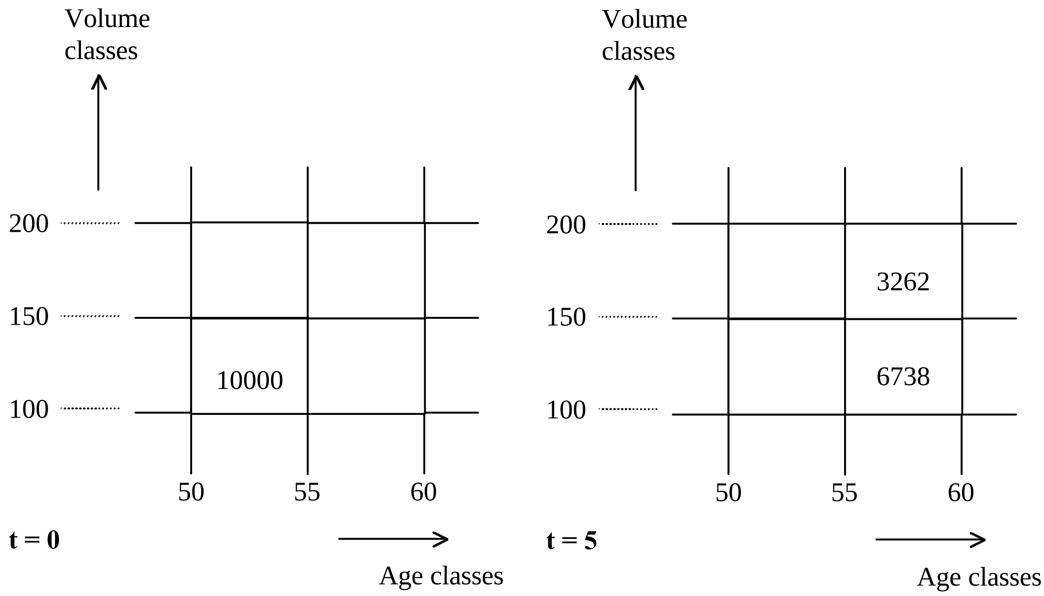


Figure 2.3. Example of the theoretical thinning regimes for pine in southern Finland. The shaded cells can be thinned.

Example 6. Thinning

In Example 5, 5262 hectares grow to the next volume class during a five-year simulation step, so that area can be thinned. The difference in average volume between the volume classes, 175–125 = 50 m^3ha^{-1}, is the increment during the five-year periods. So the absolute increment that can be thinned is 50 m^3ha^{-1} * 5262 ha = 263 100 m^3. If the required volume of thinning is 100 000 m^3 during the five-year simulation step, 2000 ha (=100 000 m^3/50 m^3ha^{-1}) is thinned. That area stays in the lower volume class and the situation is following:



If an area of forest is not thinned it moves to the next volume classes explained in Section 2.3. A thinned area does not grow during the period in which it is thinned, i.e. the increment is thinned away. The difference between the volume, which the area would have had when it would grow normally and the volume it had when it is thinned, is the amount of wood that is obtained from the thinning. In Example 6 this was 50 m^3ha^{-1}. In the next period the thinned area grows normally according to the rules. However, because the growing stock of the thinned area is lower than the growing stock of the forest that was not thinned, the increment of the thinned area is somewhat lower than the increment of the area that was not thinned. Besides the normal increment rate, part of the thinned area will grow one volume class extra during the second period, the so called ‘growth boost’. As soon as the forest has got the extra volume class, it will no longer be counted as thinned area, and it can be thinned again. The areas, which have not got ‘growth boost’ yet, cannot be subjected to thinning.

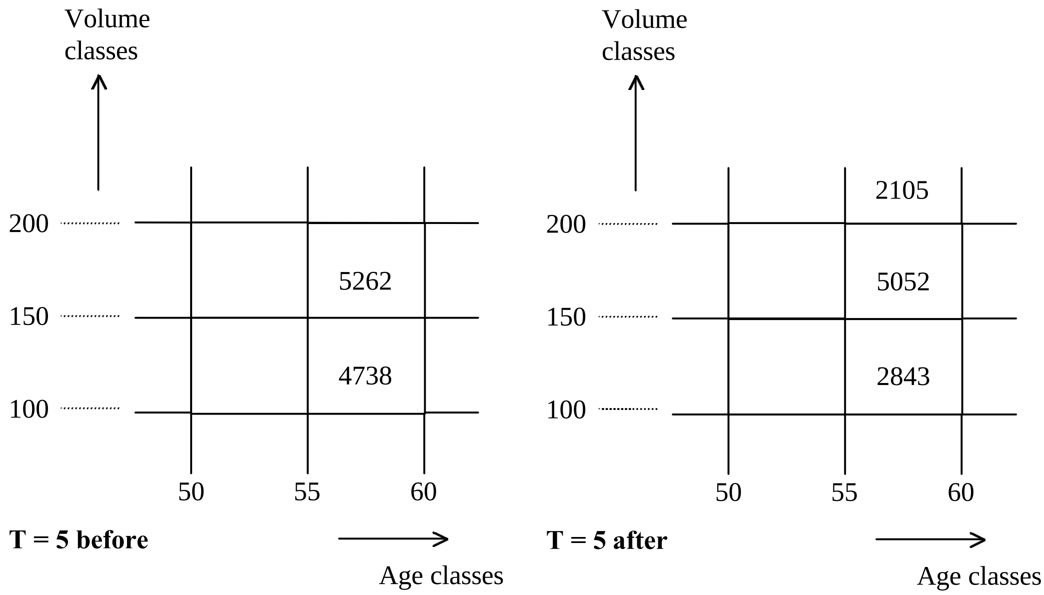
To run the model the fraction of growth boost has to be defined. This fraction is defined as the fraction of thinned area, which grows back to the original volume per time step. According to growth and yield tables (Koivisto 1959), 0.4 was assessed as a growth boost parameter for pine forest in Myrtillus site type in Finland (the volume of thinned and remaining standing stock in the model is then approximately the same as in managed and unmanaged stands). Further the proportion of area, which has at the beginning of the simulation a lower standing volume due to recent thinning must be estimated. If the annually thinned area (A_{thi}) is known in the past, the thinned area in the beginning of simulation (A) is:

$$A = 5 * A_{thi} * (1 + (Re_{thi}/(1+Re_{thi}))) \quad \text{(Formula 8)}$$

where Re_{thi} = growth boost parameter

Example 7. Increment of thinned forests

If it is assumed that all 10 000 hectare has been thinned during previous five-year period and it grows according to the growth functions, i.e. the standing volume is 151.31 m^3ha^{-1} (see below, T=5 before). Because of the growth boost in thinned stands, 40% of the area gains one extra volume class and the net increment is 20 m^3ha^{-1} higher than in unmanaged stands. This growth boost after thinning causes the steeper slope in managed stands than in unmanaged stands. This is shown in Figure 2.4.



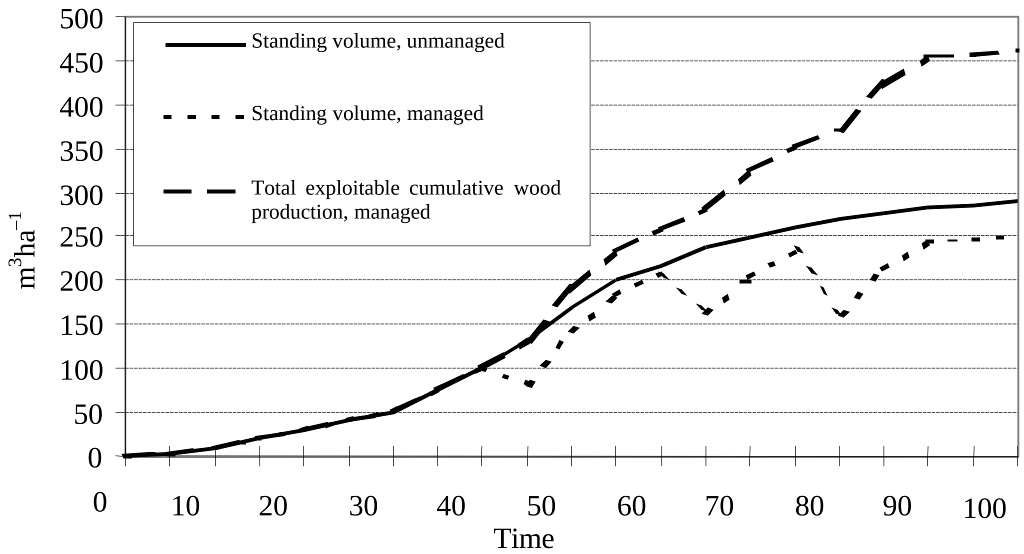


Figure 2.4. The development of standing volume of a stand in managed and unmanaged forests and the total cumulative exploitable wood production (thinned + standing volume) of a managed stand.

2.4.2 Final felling

The final felling regime is expressed as the proportion of each cell that can be felled, depending on the stand age (see Figure 2.5). This can also be dependent on actual standing volume. A felled area is moved outside the matrix to a bare-forest-land class (see Figure 2.1). The final felling regimes can be obtained by handbooks, yield tables or other sources, such as statistical yearbooks.

Volume class	0–20	21–40	41–60	61–80	81–100	101–120	121–140	> 141
>451	0.0	0.0	0.0	0.0	0.9	0.9	0.9	0.0
401–450	0.0	0.0	0.0	0.0	0.9	0.9	0.9	0.0
351–400	0.0	0.0	0.0	0.0	0.9	0.9	0.9	0.0
301–350	0.0	0.0	0.0	0.0	0.9	0.9	0.9	0.0
251–300	0.0	0.0	0.0	0.0	**0.9**	0.9	0.9	0.0
201–250	0.0	0.0	0.0	0.0	**0.7**	0.7	0.7	0.0
151–200	0.0	0.0	0.0	0.0	**0.5**	0.5	0.5	0.0
101–150	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.0
51–100	0.0	0.0	0.0	0.0	0.2	0.2	0.2	0.0
1–50	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Age class

Figure 2.5. Example of the theoretical final felling regimes. The maximum fraction of the area that may be felled is incorporated for each volume and age class in this example.

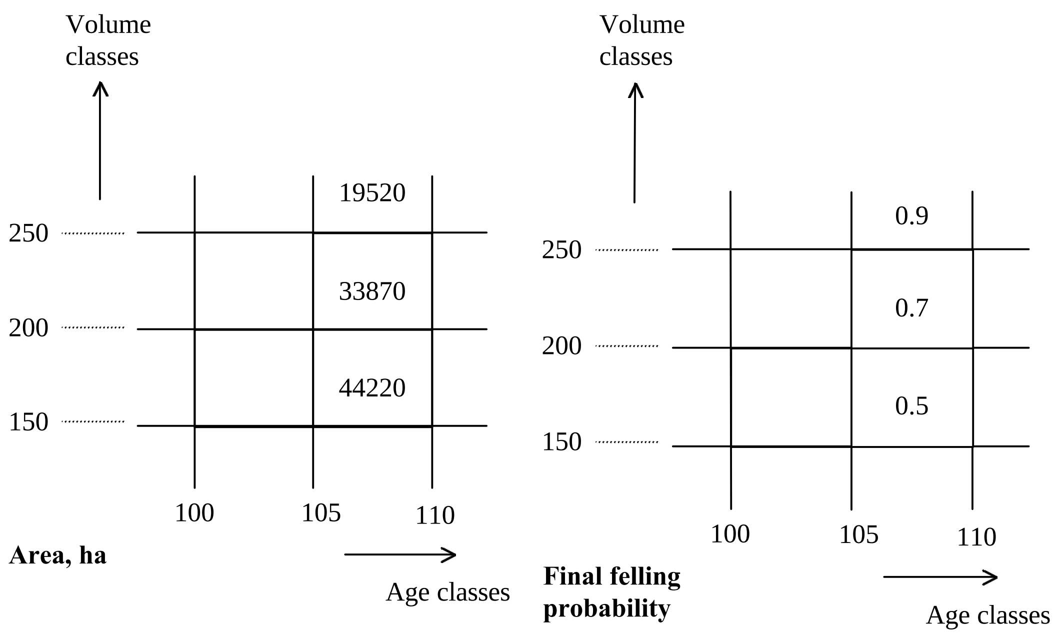
Example 8 shows an example for spruce in Finland. Depending on total demanded harvesting volume a number of final fellings are executed.

Example 8. Final felling

It is assumed, that it is possible to clear fell only at age class 101–105 and volumes 150–300 (see Example 2), i.e. it is possible to cut in following three cells.

Cell A: 44 220 ha, 175 m^3ha^{-1}
Cell B: 33 870 ha, 225 m^3ha^{-1}
Cell C: 19 520 ha, 275 m^3ha^{-1}

The maximum fraction of final felling in these cells is 0.5, 0.7, 0.9, i.e. the final felling is more probable in stands with high growing stock. The following situation arises:



The maximum felled amount is:

Cell A: 44 220 ha * 175 m^3ha^{-1} * 0.5 = 3 869 250 m^3
Cell B: 33 870 ha * 225 m^3ha^{-1} * 0.7 = 5 334 525 m^3
Cell C: 19 520 ha * 275 m^3ha^{-1} * 0.9 = 4 831 200 m^3
Total: 14 035 million m^3

If the required clear felled volume is 5 million m^3, 36.5% of maximum is clear felled:

Cell A: 44220 ha * 0.5 * 0.365 = 8070 ha
Cell B: 33870 ha * 0.7 * 0.365 = 8654 ha
Cell C: 19520 ha * 0.9 * 0.365 = 6412 ha

The total area of clear felled area in this example would be 23 136 ha.

2.5 REGENERATION

Regeneration is regarded as the movement of area from the bare-forest-land class to the first volume and age class. The amount of area that is regenerated is regulated by a parameter that expresses the intensity and success of regeneration, the young forest coefficient. This parameter is the percentage of area in the bare-forest-land class that will move to the first volume and age class during five years. This area will then attain the average volume and age of that class. It is possible to change tree species after clear-cutting. The tree species (change) to be regenerated on clear felled areas can be defined by regions (Section 3.19) (Example 9).

Example 9. Regeneration

In Example 2 there are 293 800 ha in the bare-forest-land class. The young forest coefficient for Scots pine in Finland is 0.75, i.e. (0.75 * 293 800) 220 350 ha grows to the first volume class and 73 450 ha stays in the bare-forest-land class in the first five years.

2.6 AFFORESTATION AND DEFORESTATION

It is also possible to take afforestation and deforestation into account. The user can add or remove area per tree species in each time step of the simulations. The area will then be added to the bare-forest-land class of each forest type of that tree species, or the area is removed from the bare-forest-land class.

2.7 CHANGE OF INCREMENT DUE TO CHANGED ENVIRONMENT

The model can simulate the development of the forest for decades. For various reasons, increment rates may change during long simulation periods. The model can take into account such changes in increment rate. The basis of the increment calculation is always the increment as calculated by the incorporated growth functions, which are based on the inventory data. These growth functions are used to calculate the increment in the matrix, and from that the transition probabilities in the matrix are derived (see Section 2.3 ‘Increment’).

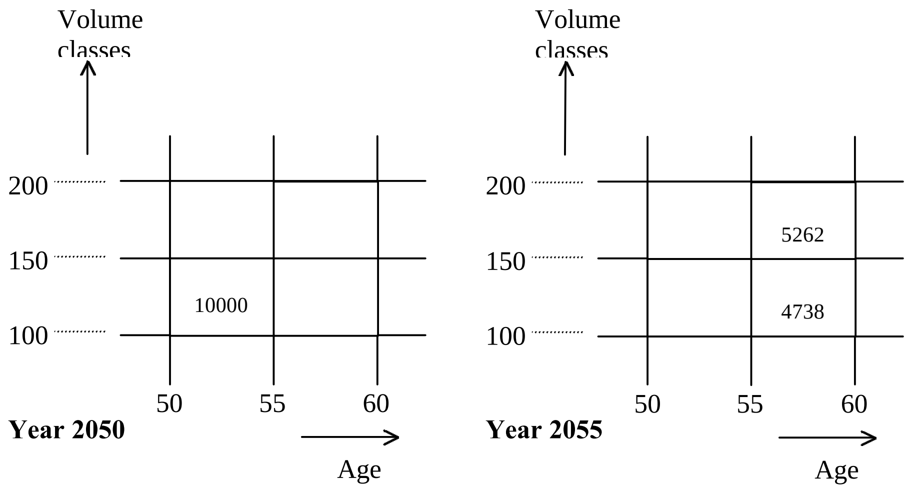
If changes in the growth function will be simulated, the transition possibilities in the matrix are to be adapted. The new increment rates are defined relative to the basic ones (the ones from the inventory data), and can be defined by regions, tree species and age-class (see Section 3.18).

Example 10. Change of increment.

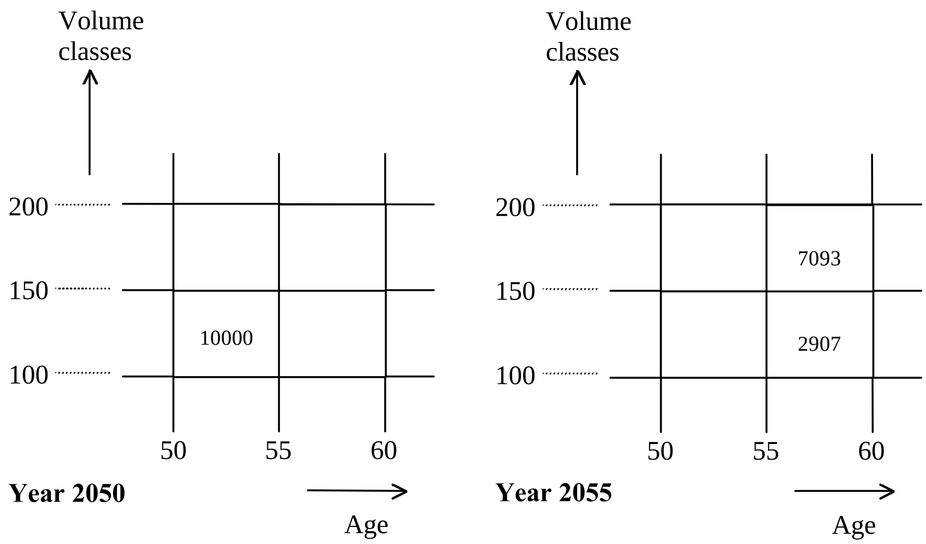
Process based model has simulated growth under current (1990) and changing climate conditions. Process based modellers have provided the following table.

Age Class	1990	2010	Year 2030	2050	2070
	$m^3ha^{-1}yr^{-1}$	Ratio	Ratio	Ratio	Ratio
0–20	4.0	1.618	1.725	1.99	2.145
21–40	7.9	1.205	1.355	1.511	1.622
41–60	8.6	1.171	1.333	**1.348**	1.408
61–80	6.8	1.174	1.249	1.45	1.482
81–100	4.7	1.225	1.339	1.505	1.567
101–150	4.7	1.136	1.273	1.538	1.372

The increment was as follows in Example 5:



In the year 2050, the increment under changed climate conditions would be 34.8% higher (see the number in bold in the table above), i.e. the area would change as follows:



2.8 BIOMASS AND LITTER PRODUCTION

Based on the calculated standing (stem) volumes by EFISCEN, the model calculates the biomass of branches, coarse roots, fine roots and foliage (Example 11). For this calculation the model requires biomass distribution tables by age classes. These tables are results of more detailed models, e.g. process based models, or are based on values taken from the literature. The biomass distribution is defined by regions and tree species. It is also possible to change the biomass distributions over time, for example because of climate change.

Each year a proportion of the stems, branches, roots and leaves of the trees die, resulting in litter production (Example 12). This litter production is calculated, and it is possible to change the proportions of litter production over time. For these calculations a proportion of annual litterfall of the standing biomass is needed. Also, when a thinning or final felling is carried out, all biomass of the other tree components is added to the litter production and thus litter production depends on the harvest level in the region. There is also a possibility to simulate the efficiency of forestry operations through defining a proportion of felled stem wood that is actually taken out from the forest (i.e. the ratio removals/felling) (Section 3.16).

Example 11. Calculation of biomass

It is assumed there are 100 ha of 10-yr-old coniferous forest in which growing stock is 25 m^3ha^{-1}, equal to 2500 m^3 and there are 200 ha of 90-yr-old coniferous forest in which growing stock is 225 m^3ha^{-1}, i.e. total of 45 000 m^3. The applied biomass distribution table is given below. The dry wood density used in this case 0.4 Mg m^{-3} and carbon content is 50%.

Table 2.1. biomass distribution

	Dry weight, total tree biomass	Stem	Branches	Coarse Roots	Fine Roots	Foliage
Age class	Mg ha^{-1}	Share of total	Share of total	Share of total	Share of total	Share of total
0–20	17.92	0.396	0.182	0.0123	0.129	0.170
21–40	139.49	0.538	0.097	0.268	0.043	0.054
41–60	218.81	0.633	0.079	0.227	0.029	0.032
61–80	275.40	0.655	0.076	0.226	0.021	0.022
81–100	342.93	0.719	0.063	0.187	0.015	0.016
101–150	342.93	0.719	0.063	0.187	0.015	0.016
>150	342.93	0.719	0.063	0.187	0.015	0.016

Note: second column is not used at all (total tree biomass), it is just for checking the logic of the table.

The biomass of stem in 10-yr-old forests:
2500 m^3 * 0.4 Mg/m^3 * 0.5 = 500 Mg C
and stem is 39.6% of total biomass. Therefore the total biomass is:
500 Mg C / 0.396 = 1263 Mg C
of which 39.6% in stem, 18.2% in branches, 12.3% in coarse roots, 12.9% in fine roots and 17% in foliage.

The total biomass of trees in 90-yr-old forests:
45 000 m^3 * 0.4 Mg m^{-3} * 0.5 / 0.719 = 12 517 Mg C
of which 71.9% in stem, 6.3% in branches, 18.7% in coarse roots, 1.5% in fine roots and 1.6% in foliage.
Note: the values per hectare can be obtained by dividing the totals by area.

Example 12. Litter production:

Table 3.2. Litter production				Managed stands	
Year 2010					
	Proportion of annual litterfall of the standing biomass in that compartment				
Age class	Stem	Branches	Coarse roots	Fine roots	Foliage
0–20	0.003	0.156	0.006	0.159	0.213
21–40	0.003	0.129	0.005	0.191	0.276
41–60	0.002	0.128	0.004	0.193	0.286
61–80	0.001	0.127	0.004	0.197	0.291
81–100	0.001	0.126	0.003	0.200	0.292
101–150	0.001	0.126	0.003	0.200	0.292
>150	0.001	0.126	0.002	0.200	0.292

10-yr-old forest

Annual foliage litter production: 0.17 * 1263 Mg C * 0.213 = 45.7 Mg C foliage litter per year in 100 ha.
Stem litter: 0.396 * 1263 Mg C * 0.3 = 1.5 Mg C stem litter per year.
The other compartments of litter production (i.e. branches, roots and fine roots) are calculated in the same way.

Logging residues (slash)

If you cut 1000 m^3 of the 90-yr-old forest and you remove 90% of the stem from the forest (removals are 90% of fellings) then:
Stem: 1000 m^3 * 0.4 Mg C m^{-3} * 0.5 * (1–0.9) = 20 Mg C of stem wood stays in the forest as litter
Foliage: 0.016 * (1000 m^3 * 0.4 Mg m^{-3} * 0.5 / 0.719) = 4.45 Mg C of foliage stays in the forest as litter

2.9 SOIL

The EFISCEN model contains a dynamic soil carbon sub-module that calculates the amount of carbon in soil. Carbon input into the soil module is litter production of trees calculated in the tree module. The sub-module consists of three litter compartments describing physical fractionation of litter (one for stem litter, one for branch and coarse root litter, and one for foliage and fine root litter) and five compartments describing microbiological decomposition in soil (one for the soluble compounds of litter, one for holocellulose, one for lignin-like compounds and the other two for humus compounds) (Figure 2.6). Each of the litter compartments has a specific fractionation rate (ai) and each of the soil compartments a specific decomposition rate (ki). These rates determine fractions that are removed from the contents of the compartments each year. Carbon removed from the litter compartments is divided into the soluble, holocellulose and lignin-like soil compartments according to the chemical composition of the litter (ci). A part of carbon removed from the soil compartments (pi) is tranferred to the subsequent compartment and the rest out of the system; from the second humus compartment, carbon is only transferred out of the system.

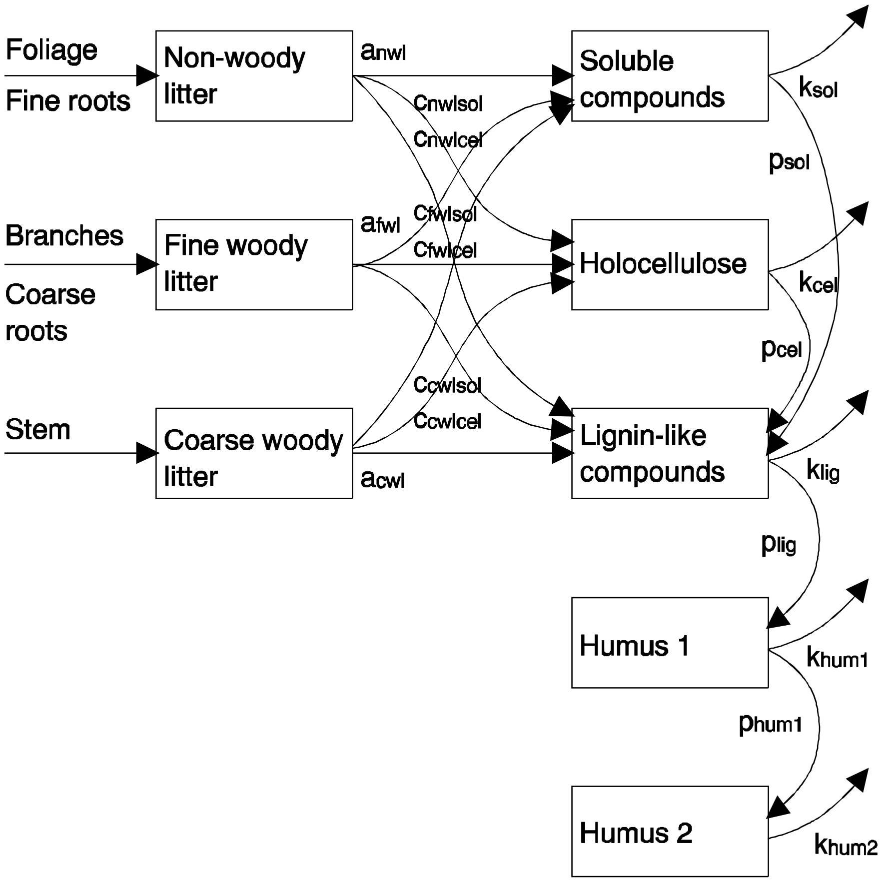


Figure 2.6. Flow chart of the soil carbon submodule in EFISCEN. The boxes represent carbon compartments, the arrows carbon fluxes, and the text by the arrows represent parameters controlling the fluxes (see Table 2.1).

The fractionation rates (ai) and the decomposition rates (ki) depend on annual mean temperature (T) and the difference between precipitation and potential evaporation from May to June (P–E):

$$ai(T, P-E) = 1 + (0.0937 * (T - 4)) + 0.00229((P - E) - (-50)) * a0 \qquad \text{(Formula 9)}$$
$$ki(T, P-E) = 1 + s * (0.0937 * (T - 4)) + 0.00229((P - E) - (-50)) * k0. \qquad \text{(Formula 10)}$$

These dependencies were established by reanalysing data on the decomposition of Scots pine needles across Europe (Berg et al. 1993). The reference rates, a0 and k0, were determined for conditions where T = 4°C and P–E = –50 mm by adjusting model-calculated mass loss rates to litter bag experiments (Berg et al. 1982; Berg et al. 1984) and model-calculated steady state amounts and accumulation rates of soil carbon to measured values (Liski and Westman 1995; Liski et al. 1998). Parameters decreases the temperature dependence of humus decompostion (Liski et al. 1999; Giardina and Ryan 2000). It was set at 0.6 for the first humus compartment and 0.36 for the second one; it was set at 1 for the other compartments.

The soil sub-module operates on an annual time step. It is initialized by setting the compartments to steady state with the input of the first studied year 1990. At the start of the simulations an initial soil carbon content should be known. The model calculates this initial content from the first year litter input. It assumes that this level of input occurred for years in the past, and calculates the steady state from first simulation period input. The model was developed for Finnish conditions (mean annual temperature +4°C), and therefore weather data of the country to be simulated should be added to the weather file before starting a simulation.

Table 2.1. Parameters of the soil carbon sub-module for the reference conditions (annual mean temperature 4°C, the difference between precipitation and potential evaporation 50 mm between May–September). The fractionation and decomposition rates were dependent on climate according to Formulas 9 and 10. The other parameters were similar for all conditions.

Parameter	Value
Fractionation rates (per year)	
a_{nwl}	1
a_{fwl}	0.5
a_{cwl}	0.05
Litter composition	
c_{nwlsol} for conifers	0.27
c_{nwlcel} for conifers	0.51
c_{fwlsol} for conifers	0.03
c_{fwlcel} for conifers	0.65
c_{cwlsol} for conifers	0.03
c_{cwlcel} for conifers	0.69
c_{nwlsol} for deciduous trees	0.38
c_{nwlcel} for deciduous trees	0.36
c_{fwlsol} for deciduous trees	0.03
c_{fwlcel} for deciduous trees	0.65
c_{cwlsol} for deciduous trees	0.03
c_{cwlcel} for deciduous trees	0.75
Decomposition rates (per year)	
k_{sol} for conifers	0.5
k_{sol} for deciduous trees	0.8
k_{cel}	0.3
k_{lig}	0.15
k_{hum1}	0.013
k_{hum2}	0.0012
Transfer proportions	
p_{sol}	0.15
p_{cel}	0.15
p_{lig}	0.18
p_{hum1}	0.18

2.10 OUTPUTS OF EFISCEN

The output of the EFISCEN consists of a series of files (see Figure 2.7). In these files the development of growing stock, increment, age class distribution, amount of wood harvested by final felling and by thinning, area affected by final cuttings and thinning, and biomass data of stem, roots, needles/leaves, branches, litter production, slash and soil are presented. Some parameters are given for the total area and some also per tree species and/or region.

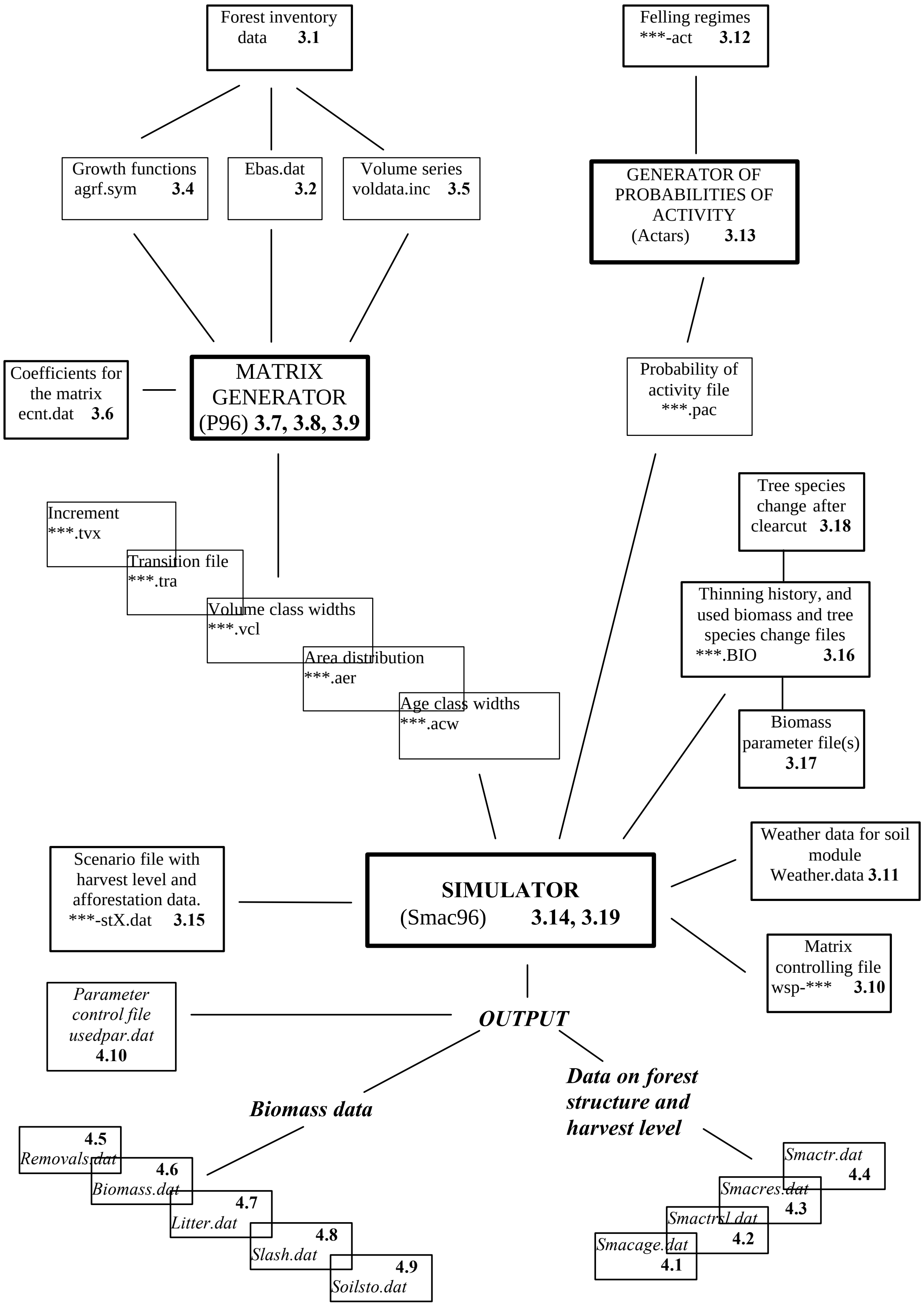


Figure 2.7. Overview of the modules and files in the EFISCEN model. Numbers refer to section numbers in the chapters 3 and 4 of this manual: *** is used to represent the country codes.

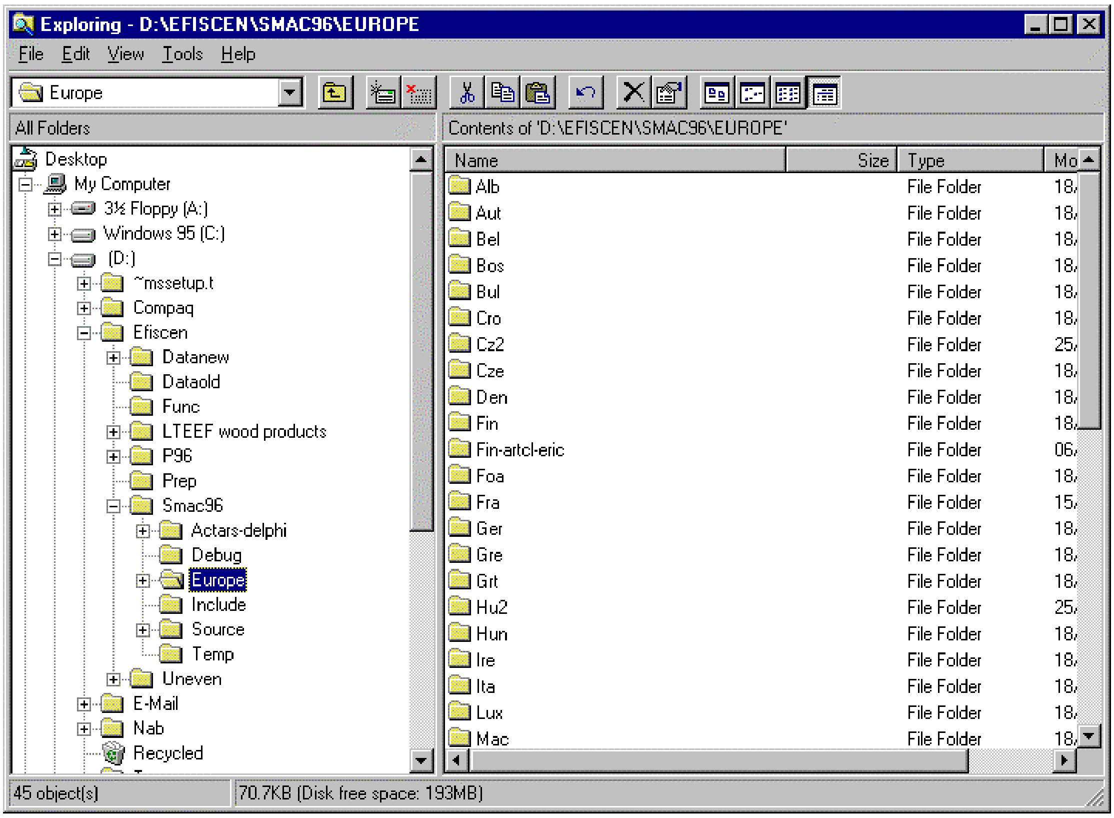


Figure 2.8. Directory structure in EFISCEN 2.0.

The directory structure of the EFISCEN model is shown in Figure 2.8. Examples of the most important output files are in Chapter 3.

3. PROCEDURE FOR A NEW COUNTRY

In this section a brief introduction to the use of EFISCEN model is presented. EFISCEN has a long history and that is why it is not very user-friendly model. The model is mainly intended for researchers and there is no user-friendly interface available. If new inventory data is available, the user has to create a "a new country" and this process is presented in this section. However, after someone has created a new country, i.e. input files for the simulator 'Smac96' it is quite easy to produce different scenarios, and the user does not need much computer expertise.

3.1 INPUT DATA

The input data can be found mainly from institutes that are conducting national forest inventories. Values for area, mean volume and mean net annual increment per age class are needed. The forest can be divided into different forest types, according to region, owner, tree species and site class, depending on the available input data. If increment is not available, growth and yield tables can be used, but real inventory data are preferred.

The input file can be made in Excel and should have this format:

region	owner	site class	tree species	number of age classes
1	1	1	1	X
1	1	1	2	X
1	1	2	1	X
1	1	2	2	X
1	1	3	1	X
etc.				

Example of input file with 3 tree species:

```
REGION=1
OWNER=1
Site class=1
SPECIES=1 (PINE)
         1         1         1                 1
       AGE      AREA    VOLUME         INCREMENT
        10      1271        10               1.5
        30      5008        42               4.8
        50      2901       169               6.5
        70       947       207               3.2
        90       153       306               1.8

REGION=1
OWNER=1
Site class=1
SPECIES=2 (SPRUCE)
         1         1         1                 2
       AGE      AREA    VOLUME         INCREMENT
        10       881        25               1.5
        30      3592       103               5.5
        50      2081       172               5.3
        70       679       215               5.4
        90       110       238               4.8

REGION=1
OWNER=1
Site class=1
SPECIES=3 (BIRCH)
         1         1         1                 3
       AGE      AREA    VOLUME         INCREMENT
        10      7246        17               2.6
        30     23606        59                 4
        50     13674        95               4.8
        70      4462       116                 4
        90       720       154               3.5
```

```
REGION=1
OWNER=1
Site class=2
SPECIES=1 (PINE)
         1         1         2                   1
       AGE      AREA    VOLUME           INCREMENT
        10      9488        15                 2.1
        30     65910        67                 4.8
        50     58743       138                 5.1
        70     18230       201                 4.3
        90      4986       257                 3.7
```
etc.

The first age class (in this case 0–19) should include the bare-forest-land class (no trees due to recent clear cut etc.)

The raw input files can be stored in the directory EFISCEN\Datanew***, where *** is the new country code, three character long.

The input file must also be stored as a ***-data.prn file in the directory EFISCEN\Prep.

3.2 INPUT DATA: CREATING EBAS -FILE

Ebas file is an intermediate file between programmes. Open an existing ***-pre.for file in EFISCEN\Prep and save it in the same format but change the country code into the new country code. Adapt this file to the data structure of the new country.

NREG = number of regions
NKAT = number of ownership categories
NBON = number of site classes
NTRB = number of tree species
NALD = number of age classes

Change all old ***-country codes into the new country code. Change the number of lines to skip, according to your input file. Change the age-class structure, according to your data. Compile ***-pre.for and build the executable (with Fortran PowerStation). Then run ***-pre.exe. This creates an ***-ebas.dat -file in the Prep -directory. Move this file to the EFISCEN\P96\Ebas.

3.3 GROWTH FUNCTIONS

Growth functions can be prepared in a file in EFISCEN\Func***-func.xls. Increment is incorporated as the five-year increment as a percentage of standing volume. So compute the increment as a percentage of the growing stock in five years (see also Section 2.3 and Example 3). The growth functions used are of the following type:

$$I_{\mathrm{vf}} = a_0 + \frac{a1}{T} + \frac{a2}{T^2} \quad \text{(Formula 5)}$$

where I_{vf} = five-year volume increment in percent of the standing volume
T = age of the stand in years
a_0, a_1, a_2 = coefficients

Fit a growth function on the percentage increment data. This can be done in Excel with the ‘Regression’ option of ‘Data analysis’ under ‘Tools’. Select as y input range the five-year increment as a percentage of standing volume and as x input range 1/A and $1/A^2$.

Data can be aggregated for each tree species over different regions or site classes. The same growth function can later be combined with different volume series. This will save a lot of computing time, since you do not have to fit a growth function for every site class. See Figure 2.2 for an example of a growth function fitted to increment data.

3.4 ADDING GROWTH FUNCTIONS TO THE CODE

The growth functions are listed in the file EFISCEN\P96\Include\agrf.sym. Open this file and add your growth functions. Continue the numbering and add the new growth function numbers also at the top of the file where all the numbers are listed.

3.5 VOLUME SERIES

In the file EFISCEN\P96\Include\voldata.inc the volume series are listed. If the data have been aggregated (see above ‘3’), more volume series can be listed under one growth function. E.g. growth function 327 can be connected to five volume series: 3270–3274.

There should always be 15 numbers per volume series, even if the actual number of age classes is less. The volume series should be smoothed, i.e. extra fluctuations are taken away.

3.6 COEFFICIENTS FOR THE MATRIX

The matrix needs some coefficients to be built up. These are listed in the file EFISCEN\P96\Ecnt***-ecnt.dat. So copy a file from another country and save it under the new country code. Then edit the file according to the new country. Each line represents a forest type. The order is the same as in the input file (ebas.dat). For each line the following five coefficients have to be given:

cv = coefficient of variation
cr = correlation (between age and volume per hectare)
X1 = upper limit of lowest volume class (m^3ha^{-1})
tvxf = number of growth function to be used
beta = parameter

cv is usually set at 0.65. When the cv is higher, the areas are spread out further over the volume classes.

cr: is set according to the following scheme:

	group			
	1	2	3	4
spruce, beech	0.55	0.6	0.65	0.7
pine, oak	0.45	0.5	0.55	0.6
Others	0.5	0.55	0.6	0.65

group 1: all forests
group 2: when site classes are distinguished.
group 3: when forest is well stocked.
group 4: when forest is well stocked and site classes are distinguished.

These values are a guideline and can be changed according to the insight of the user.

X1: is set so that forest areas in the inventory data (ebas.dat) are distributed over the age classes. X1 should also be set so that the highest volume class includes between 0.1% and 1% of the area of the forest type. At this stage it is impossible to determine if it is, but there is an opportunity to change it later. For those forest types where the areas are not evenly distributed over the age-classes (for instance where only very young plantations exists), the X1 values found for the evenly distributed forest types can be copied, if the development of the stands resembles each other over time.

tvxf: indicates which the growth function, combined with a volume series is used. When the data have been aggregated, the same growth function will be referred to several times, but connected to another volume series.

beta: is a correction factor for the relative increment. When the real volume is lower than the mean volume, the relative increment is increased and when the real volume is higher the increment percentage is decreased (see also Section 2.3).
Example of ecnt file:

```
PARAMETER NREG=2,NKAT=1,NBON=10,NTRSL=3,NAGE=13,NVOL=10,LAND='FIN'
   .65   .50   60   7900   .4000
   .65   .60   75   7910   .4000
   .65   .55   38   7920   .4000
   .65   .50   65   7901   .4000
   .65   .60   65   7911   .4000
   .65   .55   40   7921   .4000
   .65   .50   75   7902   .4000
```

(The columns in the table represent the following coefficients. Respectively:
`cv    cr   X1   tvxf    β )`

NREG = number of regions
NKAT = number of ownership categories
NBON = number of site classes
NTRSL = number of tree species
NAGE = number of age classes
NVOL = number of volume classes
LAND = country code

Example of results of varying coefficients:

Difference in area distribution at the beginning of simulation, as generated with program P96, for a forest type in Leningrad region. Volume classes are represented by columns and age classes by rows.

Coefficient of variation (cv) is 0.55

```
stp : ST   1  REG   2,  KAT   1,  BON   1,  TRSL   2
.1     .0     .0     .0     .0     .0     .0     .0     .0     .0     .0     .0
.9     .5     .1     .0     .0     .0     .0     .0     .0     .0     .0     .0
.0     .7    1.0    1.3     .6     .1     .0     .0     .0     .0     .0     .0
.0     .5    1.3    5.0    5.6     .6     .3     .0     .0     .0     .0     .0
.0     .3    1.1    5.6    6.3     .7     .3     .0     .0     .0     .0     .0
.0     .0     .7    4.3    5.4     .6     .3     .0     .0     .0     .0     .0
.0     .0     .3    2.4    3.3     .4     .2     .0     .0     .0     .0     .0
.0     .0     .1    1.0    1.5     .2     .1     .0     .0     .0     .0     .0
.0     .0     .1     .5     .6     .1     .0     .0     .0     .0     .0     .0
.0     .0     .0     .3     .4     .0     .0     .0     .0     .0     .0     .0
.0     .0     .0     .1     .2     .0     .0     .0     .0     .0     .0     .0
```

Coefficient of variation is set in example below at 0.65, i.e. the area is more widely distributed to different volume classes (rows) within age classes (columns).

```
stp : ST   1  REG   2,  KAT   1,  BON   1,  TRSL   2
.1     .0     .0     .0     .0     .0     .0     .0     .0     .0     .0     .0
.9     .5     .4     .0     .0     .0     .0     .0     .0     .0     .0     .0
.0     .6     .9    3.0    2.3     .2     .1     .0     .0     .0     .0     .0
.0     .6    1.2    4.5    5.5     .6     .3     .0     .0     .0     .0     .0
.0     .3    1.0    5.0    5.7     .6     .3     .0     .0     .0     .0     .0
.0     .0     .6    3.8    4.7     .5     .2     .0     .0     .0     .0     .0
.0     .0     .3    2.2    3.1     .3     .2     .0     .0     .0     .0     .0
.0     .0     .1    1.0    1.5     .2     .1     .0     .0     .0     .0     .0
.0     .0     .1     .5     .6     .1     .0     .0     .0     .0     .0     .0
.0     .0     .0     .3     .4     .0     .0     .0     .0     .0     .0     .0
.0     .0     .0     .1     .3     .0     .0     .0     .0     .0     .0     .0
```

3.7 EDITING THE MATRIX GENERATOR P96 FILE

Go to EFISCEN\P96\p96.for. In the top of this file, the new country with its data structure has to be added. The other country must be 'commented away' (put a C in front of the line). Make sure the three-character country code is included after 'country?'

3.8 COMPILING P96

Save the file EFISCEN\P96\p96.for and choose the option build from the 'Fortran Powerstation' or from 'Digital Visual Fortran'. P96 will now be compiled and the executable p96.exe will be built.

3.9 RUNNING P96

Running p96.exe will set up the initial matrix. The executable should be run from the EFISCEN\P96 -directory.

From the MS-DOS prompt, go to EFISCEN\P96. Type p96. (It is also possible to run the program directly via e.g. the Windows Explorer).

It asks:

- Which country? Enter three digit code
- Are you going to change x1? 1 (= yes)
- treat structure? 1
- mage = nage ? 1

After every forest type the program asks: change X1? If you want to change X1, type the new X1, if not, type 1. At the top of the screen you can see what the volume classes are that have been calculated for this forest type and the area that is in those volume classes. If area in the last volume class is not between 0.1% and 1%, you can change the X1 value. Also the widths of the volume classes can be regarded as a good check; they should ideally have about the same width. This will not actually change the ecnt file, so when you want to change it permanently, you have to go back to the ecnt file and edit it. By raising the X1 value, you will raise the width of the lowest volume class. This determines the width of the rest of the volume classes and less volume will enter the last volume class. Lowering X1 has the opposite effect. The run can be stopped if you press CTRL+C.

After running the program for a forest type, you will see a screen similar to the one below:

```
GP = 4.187939071005917E-002 XIN(J,3)=     190.000000000000000
VS = 301.000000000000000 TVX=       7590 XIN=      190.000000000000000 J=8
arg = 1.584210526315790
GP = 4.807775976342205E-002 C1(iread)  3.000000000000000E-001 iread=1
FTVX(j),j,gp,xin(j,3),arg
1.826954871010038         8   4.807775976342205E-002
190.000000000000000       1.584210526315790
TILLV[XTKVOT,FTVX=  9.645258589081823E-001       1.826954871010038
      X0      X1      X2      X3      X4      X5      X6      X7      X8      X9     X10
      .0    65.0   130.0   195.0   260.0   325.0   390.0   455.0   520.0   586.0   625.0
      .0    57.4     9.5     9.9    10.6     6.9     3.4     1.3      .6      .3      .1
TVXJMF
 ING TIL     4.8     6.0     4.4     2.9     2.6     2.4     2.6     2.1
 FUN TIL     4.9     5.6     4.6     4.2     3.5     2.5     2.3     1.8
 BER TIL     4.8     5.5     4.6     4.2     3.5     2.5     2.3     1.8
IETT           0       0       0       0       0       0       0       0

VOLJMF
 ING VOL    37.0   156.0   220.0   282.0   294.0   245.0   259.0   190.0
 BER VOL    37.0   156.0   220.0   282.0   294.0   245.0   259.0   190.0
NEW X1? - ELSE 1
```

The first two highlighted lines show the borders of the volume classes (first line) and the share of area in the volume classes (second line). So in this case, there is no area in the bare-forest-land class (X0) and 57.4% in the first volume class (X1), which ranges from 0 to 65 m^3ha^{-1}. The highest volume class ranges from 586 to 652 m^3ha^{-1} and contains 0.1% of the forest area.

The second highlighted area contains information about the increment. The first line of this area shows the increment for each age class as given in the input file. The second line shows the increment for each age class as calculated with the growth function and volume function. The third line shows the increment for each age class as calculated by the model with the current matrix set-up.

The last highlighted area shows the average volume per hectare. The first line shows the mean volume for each age class as given in the input file and the second line shows the mean volume for each age class as calculated from the matrix in the model with the current X1.

After running p96, in the directory 'EFISCEN\P96\Output' the following files are created:
***.vol: containing the widths of the volume classes;
***.aer: containing the area distribution over the age and volume classes;
***.acw: containing the widths of the age classes;
***.tra: containing the transition fractions;
***.tvx: containing data about the increment.

If the first age class of a forest type contains a high volume of wood and X1 is low, p96 sometimes models a negative area in order to divide this high volume over the first two volume classes of the matrix. It can be checked in the ***.aer file if there are negative areas for certain forest types. If there is a negative area, the X1 value of the concerning forest type should be increased (in the EFISCEN\P96\ecnt.file) until there are no negative areas modelled by p96.

Make the following directories:

EFISCEN\Smac96\Europe***
EFISCEN\Smac96\Europe***\In
EFISCEN\Smac96\Europe***\Out

Move files to the directory: EFISCEN\Smac96\Europe***\In.

3.10 PREPARING WSP FILE

Copy a wsp-***.f from the EFSICEN\Smac96\Europe*** -directory and copy it to your country main directory (EFISCEN\Smac96\Europe***) and save it with the new country code. Edit it according to the data structure. The wsp file is a file that includes country parameters into the code when compiling Smac96. Therefore, before compiling, wsp-***.f must be copied to a file named wsp96.f to the folder EFISCEN\Smac96\Include. Smac96 uses the latter file every time, so the right country version of wsp-***.f must be copied to wsp96.f.

3.11 ADDING WEATHER DATA

For the soil module of EFISCEN weather data should be added to the WEATHER.DAT file in the directory EFISCEN\Smac96\Europe. The data should be added by country and by regions. First the three digit country code should be added, then for each region three lines with the following data should be defined (see example for Finland below):

Line 1: years of observation
Line 2: region, mean annual temperature, °C
Line 3: Difference between precipitation and potential evaporation during May–September, mm.

```
Weather file for EFISCEN's soil module, country:
by countries and regions
ARI P. AND JARI L. 3/1999
The FIRST LINE IS the YEAR OF OBSERVATION

fin
1    1   21   41    61    81
1  4.0  4.8  5.6   6.4   7.2
1  –50. –60. –70.  –80.  –90.
2    1   21   41    61    81
2  2.0  2.8  3.6   4.4   5.2
2  –50. –70. –90. –110. –130.
```

Even if the carbon balance option is not analysed in the output, the weather data still have to be added. In that cast, simply copy another country and edit it into the right format. The climate data will only affect decomposition of the soil!

3.12 ACTARS , DEFINING MANAGEMENT REGIMES

Go to EFISCEN\Smac96\Source and save ***-act.for -file with the new country code. Edit the file according to the data structure and replace *** by the new country code. In this file the final felling and thinning regimes are defined, so they can be changed for your country. These felling regimes represent theoretical regimes, acting as constraints when later running the country scenario (see also Section 2.4.2). The final felling regimes specify the fraction of area that may be felled in a certain cell during the five-year simulation period. The fraction varies usually by age and/or by volume class but it can be defined for every cell of the matrix of each forest type. Thinning regime defines the cells in matrix where you can thin. Usually this is defined by age.

3.13 COMPILING/RUNNING ACTARS

Use Fortran PowerStation to compile and build the executable from the ***-act.for. The executable file is called ***-act.exe and is also in the Source -directory. Copy this executable file to the country's home directory (EFISCEN\Smac96\Europe***). Then run this file, this can be done via Windows Explorer. This produces a file called ***.pac in the EFISCEN\Smac96Europe***\In -directory. This file includes the management regimes.

3.14. COMPILING SIMULATOR SMAC

Open file EFISCEN\Smac96\Source\smac96.for (wsp-***.f from EFISCEN\Smac96 \Europe*** -directory has been copied earlier to EFISCEN\Smac96\Include\wsp96.f). Compile smac96.for and build smac96.exe. This produces the smac96.exe executable file in the Source -directory. Copy this file to the country home directory (EFISCEN\Smac96\Europe***).

3.15 SCENARIO INPUT FILES

The scenario files are placed in the directory EFISCEN\Smac96\Europe***\In. They are called ***-st-X.txt, where X is a character. Copy one of these files from another country and rename it with the new country code. For each scenario you can have a separate scenario file. The structure of the scenario files is as following:

'Antal perioder': Number of simulation periods. Each period is five years, i.e. 10 means 50 year simulation run.
KATL is the number of the lowest category of owners that is taken into account to simulations and KATH is the highest.
BONL is the number of the lowest site class, BONH is the highest class to be taken into account in the simulation. By changing these numbers you can run the model for some specific owner and/or site classes. If you do not remember to modify these numbers according to the country, you may simulate only part of the area, i.e. if you miss some area in results compared to inventory data, check these numbers.

Then you have to specify for each tree species if it is coniferous (1), deciduous (2) or coppice (3). So when you have pine, spruce, oak and birch, the code here is 1 1 2 2.

Total 1 is the total felling level for coniferous species (total felling in million m^3 over 5 years). Include thinning in this volume. Gall 1 is the amount of wood that is thinned from coniferous species. Total 2 and gall 2 are the equivalent figures for deciduous species and total 3 and gall 3 are for coppice. When there is no forest in one of those groups, –1 should be given. For all those groups you can give only five felling levels. The first five numbers are the felling levels. The following four numbers indicate the five-year periods in which these harvest levels should be obtained. In the example shown below, the total harvest level of coniferous species is 250 in period 1. In periods 2 and 3 the harvest level of conifers is 270, in periods 4 and 5 the harvest level of conifers is 280. The harvest level rises to 290 at the start of period 6, and after period 8 the harvest level stays at 300.

Then the ratios between removals and felling should be included. The felling and thinning, defined 1n rows 11–16, are the amounts of wood felled in the forest, the removals are the amounts of wood taken out of the forest. The difference between felling and removals stays in the forest as stem wood slash.

The following numbers represent the young forest coefficients. These coefficients are a measure of the effectiveness of regeneration (see Section 2.5 and Example 8). From the area which is in the bare-forest-land class, this share is entering the lowest age- and volume class and will thus be considered as planted or naturally regenerated and has reached the average volume of the lowest volume class.

Further the area of afforestation can be added for each period and for each tree species. When you add 1 in a certain period for pine, all forest types of pine will get 1000 ha extra in the clear area. So when you have 9 site classes and 2 owner classes, 18 000 ha is added.

Example of scenario file (***-st-X.TXT):

```
               ANTAL PERIODER     20

               KATL,KATH          01 01
               BONL,BONH          01 08

  Specify species group for every species (1=conif.2=decid.3=copp.)
1 1 2 2
UNGK * AND * AVV1  AVV2  AVV3  BR1  BR2 * GAL1  GAL2  GAL3  BRYT1 BRYT2 * GAREA
     *     *                            *                               *
250.0 270.0 280.0 290.0 300.0 02 04 06 08          total 1
100.0 110.0 110.0 130.0 140.0 02 04 06 08          gall  1
 55.0  55.0  55.0  55.0  55.0 02 04 06 08          total 2
 10.0  10.0  10.0  10.0  10.0 02 04 06 08          gall  2
 –1.0 –1.0 –1.0 –1.0 –1.0 02 04 06 08              total 3
 –1.0 –1.0 –1.0 –1.0 –1.0 02 04 06 08              gall  3
The fraction of stem TAKEN OUT FROM the forest by tree species group (and clear/thinn)
.95 .95 .95           clearcut
.9  .9  .9            thinning

 0.75 0.75 0.40 0.40 0.40 0.40 0.40 1.00 0.90 0.90 0.90 0.90
 0.75 0.75 0.75 0.75 0.75 0.40
     ENTER NEW AREAS AFFORESTATED BY PERIOD AND SPECIES
1   0.0   00.0  0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
1   0.0   00.0  0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
```

3.16 ***.BIO FILE

This input file is placed in the directory EFISCEN\Smac96\Europe***\In. Copy a file from another country and place it in the correct directory. Change the name according to the new country code and define the following parameters:

- Thinning history, by region and tree species: to what extent are the forests in inventory data thinned (% of area, not fully stocked because of thinning);
- Growth boost parameter after thinning: the fraction of the thinned area which grows back to the original volume (the volume it would have without thinning) during a five-year simulation period;
- The name of the biomass parameter file by each region and tree species, and the year of observed change of parameters in the file. In the biomass parameter file change of increment, biomass distribution and litter production parameters should be defined by period and by climate scenario. The litter production parameters are used for the soil module. For explanation of the file, see section below;
- The name of the file in which the tree species change after clearcut is described, by region and site class.

An example of a ***.bio file is given below:

```
Parameter file for EFISCEN, country:
fin
number of regions:2 tree species:4

Thinning history by region and tree species
 1 1  .3
 1 2  .3
 1 3  .3
 1 4  .3
 2 1  .3
 2 2  .3
 2 3  .3
 2 4  .3
growth boost parameter after thinning by region and tree species:
 1 1  0.4
 1 2  0.4
 1 3  0.4
 1 4  0.4
 2 1  0.4
 2 2  0.4
 2 3  0.4
 2 4  0.4
Biomass parameter file by each region and tree species
   second row: the year of observation in biomass parameter file after start (year 1), if in
wsp96.f: IYEAR=5, five different observation years

 1 1 f07sc019.csv
      1.  21. 41. 61. 81.

 1 2 f07sc019.csv
      1.  21. 41. 61. 81.

 1 3 f07sc019.csv
      1.  21. 41. 61. 81.

 1 4 f07sc019.csv
      1.  21. 41. 61. 81.

 2 1 f07sc019.csv
      1.  21. 41. 61. 81.

 2 2 f07sc019.csv
      1.  21. 41. 61. 81.

 2 3 f07sc019.csv
      1.  21. 41. 61. 81.

 2 4 f07sc019.csv
      1.  21. 41. 61. 81.

Tree species change after clearcut
region,site class
1 1 nochange.txt
1 2 nochange.txt
1 3 nochange.txt
1 4 nochange.txt
1 5 nochange.txt
1 6 nochange.txt
1 7 nochange.txt
1 8 nochange.txt
2 1 nochange.txt
2 2 nochange.txt
2 3 nochange.txt
2 4 nochange.txt
2 5 nochange.txt
2 6 nochange.txt
2 7 nochange.txt
2 8 nochange.txt
```

3.17 BIOMASS PARAMETER FILE

First of all changes of increment can be defined in this file. See table below. For each period and age-class the new increment rates should be defined as fractions of the initial ones. If increment rate stays constant a rate of 1.0 should be used. The periods defined in this file must correspond to the periods defined in the ***.bio -file.

Age Class	1990	2010	2030	2050	2070
	$m^3ha^{-1}yr^{-1}$	ratio	Ratio	Ratio	ratio
0–20	4.0	1.618	1.725	1.990	2.145
21–40	7.9	1.205	1.355	1.511	1.622
41–60	8.6	1.171	1.333	1.348	1.408
61–80	6.8	1.174	1.249	1.450	1.482
81–100	4.7	1.225	1.339	1.505	1.567
101–150	4.7	1.136	1.273	1.538	1.372
>150	4.7	1.136	1.206	1.508	1.372

(year)

Distribution of biomass is also defined in this file. For each period and age-class the share of the total tree biomass in stem, branches, coarse roots, fine roots and foliage should be given. The sum of these shares should be 1.0. Data about biomass distribution can be found in literature or can be obtained from more detailed models, e.g. ‘process based models’.

Table 2.1. Biomass distribution					current climate	
Year 1990						
Age Class	dry weight, total tree biomass	stem	branches	coarse roots	fine roots	foliage
	Mg /ha	share of total	share of total	share of total	share of total	share of total
0–20	17.92	0.496	0.182	0.022	0.129	0.170
21–40	139.49	0.798	0.097	0.008	0.043	0.054
41–60	218.81	0.863	0.069	0.007	0.029	0.032
61–80	275.40	0.897	0.053	0.007	0.021	0.022
81–100	342.93	0.919	0.043	0.007	0.015	0.016
101–150	342.93	0.919	0.043	0.007	0.015	0.016
>150	342.93	0.919	0.043	0.007	0.015	0.016

Further, litter production should be defined for each period and each age-class. The litter production of a compartment (e.g. foliage) should be given as percentage of the standing biomass of that compartment (e.g. as percentage of the total standing volume of the foliage). Litter production data should be provided for managed and unmanaged stands, but if the data is not available for managed and unmanaged, the other is enough to run the model.

Table 3.2. Litter production				scenario 1 managed stands	
Year 2010					
	proportion of annual litterfall of the standing biomass in that compartment				
Age Class	stem	branches	Coarse Roots	Fine Roots	foliage
	%	%	%	%	%
0–20	0	0.156	0	0.159	0.213
21–40	0	0.129	0	0.191	0.276
41–60	0	0.128	0	0.193	0.286
61–80	0	0.127	0	0.197	0.291
81–100	0	0.126	0	0.200	0.292
101–150	0	0.126	0	0.200	0.292
>150	0	0.126	0	0.200	0.292

3.18 TREE SPECIES CHANGE FILES

For each region and site class a tree species change file is constructed. In these files, the tree species change after clearcut (regeneration) should be defined. The tree species change files should be placed in the ***\In directory, and listed in the ***.bio file (see Section 3.16).

```
 1  0.2  0.0  0.8  0.0
 2  0.0  0.2  0.8  0.0
 3  0.0  0.0  1.0  0.0
 4  0.0  0.0  0.0  1.0
```

Each row and column represents a species so the number of tree species determines the size of the table. If tree species do not change numbers on the diagonal (top-left corner to bottom-right corner) should be 1.0 and the other numbers zero. In the above example, the first species (row 1) will replaced by 80% by species number 3 and on 20% of the area will be regenerated by species 1. Species 4 will be regenerated totally by itself.

3.19 RUNNING SMAC

In order to run the EFISCEN model, you need to run the smac96.exe in the country home directory. It asks:

- Which country?	Enter the country code (three characters)
- Type of run	Enter number of scenario you want to run (it implies which ***-st-X.txt you want to run, i.e. you enter one character. This is not case sensitive).
- Give text to be placed in the headers	Enter a title, for instance scenario X and who made the run, etc.
- Regions?	Enter the regions you want to run the model for. When you enter for example “2, 4”, you will run the model for the regions 2, 3 and 4.
- Current climate or climate scenario?	Enter “0” if you want to run the model for the current climate, and “1” if you want to run the model with modified increment, biomass distribution and litter production parameters (defined in the biomass parameter file).
- Managed or unmanaged?	With the option managed/unmanaged you can choose if you run the soil module for managed or unmanaged forest. This choice only affects litter production and soil carbon stock and therefore it has no effect on increment. Litter production for managed or unmanaged forest is defined in the biomass parameter file.

4. DESCRIPTION OF OUTPUT

After the model run is finished, the country main directory shows the following files: smacres.dat, smactr.dat, smactrsl.dat, smacage.dat, smacplot.dat, removals.dat, biomass.dat, litter.dat, slash.dat, soilsto.dat, thin.dat and usedpar.out. These files should be moved to EFISCEN\Smac96\Europe***\Out\ScenarioX. For each scenario you can make a separate directory. The output files can be processed with e.g. Microsoft Excel. The content of the most important output files is described next. (note: M = Mega $=10^6$, G= Giga $=10^9$ and T= Tera $=10^{12}$)

4.1 SMACAGE.DAT

Below the upper-left part of the output file ‘smacage.dat’ of scenario 1 of Hungary is shown. In ‘smacage.dat’ the age class distribution is given for each period and tree species. The first column represents the time step (0=initial situation, 1=after 5 year, 2=after 10 year …), the second column the tree species (in this example there are six tree species). The third column is the total area in thousands of hectares occupied by the species in this period. The fourth until the last column give the division over age classes of the species, the width of the age classes is ten years. So, in the beginning 9.48 % of tree species one is 0- to 10-yr-old (9.48% of 383 000 ha = 36 308 ha), 3.61% is 10- to 20-yr-old (3.61% of 383 000 ha = 13 826 ha).

```
Hungary, scenario 1
REG     1   7 TR[SL    1   6
 AREAL        252.     1490.        0.
 0 1   383.   9.48   3.61   4.84   4.84   4.10   4.10   4.39   4.39   5.24
 0 2   363.  14.94  14.13  13.78  13.78   8.45   8.45   8.92   8.92   3.41
 0 3   471.   5.19   2.24   3.91   3.91   3.96   3.96   3.77   3.77   4.61
 0 4   127.  22.72  21.63  12.46  12.46  10.00  10.00   4.59   4.59    .71
 0 5   147.   9.20   9.19  11.68  11.68   9.33   9.33   8.73   8.73   5.36
 0 6   252.   5.84   4.93  10.35  10.35  14.17  14.17   9.11   9.11   5.57
 1 1   383.  13.67   3.61   3.61   4.84   4.84   4.10   4.10   4.39   4.39
 1 2   363.   6.42  14.13  14.13  13.78  13.78   8.45   8.45   7.32   7.32
 1 3   471.  12.86   2.24   2.24   3.91   3.91   3.96   3.96   3.77   3.77
 1 4   127.   1.20  21.63  21.63  12.46  12.46  10.00  10.00   4.59   4.59
 1 5   147.   8.90   9.19   9.19  11.68  11.68   9.33   9.33   7.56   7.56
 1 6   252.   5.44   4.93   4.93  10.35  10.35  14.17  14.17   9.11   9.11
 2 1   383.  15.42   5.47   3.61   3.61   4.84   4.84   4.10   4.10   4.39
 2 2   363.  10.60   2.57  14.13  14.13  13.78  13.78   8.45   6.93   6.00
 2 3   471.  16.93   5.14   2.24   2.24   3.91   3.91   3.96   3.96   3.77
 2 4   127.   1.19    .48  21.63  21.63  12.46  12.46  10.00  10.00   4.59
 2 5   147.  14.44   3.56   9.19   9.19  11.68  11.68   9.33   8.07   6.53
 3 1   383.  15.86   6.17   5.47   3.61   3.61   4.84   4.84   4.10   4.10
 3 2   363.  13.71   4.24   2.57  14.13  14.13  13.78  13.78   6.91   5.66
```

4.2 SMACTRSL.DAT

Below there is an example of the output file ‘smactrsl.dat’ for the business as usual scenario, i.e. the felling level during the simulation period is the same as was observed in the past.

The first row contains the title of the run and the lowest and highest region. The second line contains the simulated tree species. The first block of lines below gives output on all species for the total forest area. The first row represents the initial situation. Each of the next rows represents a simulated period, the second row presents felling and increment during period 1 and growing stock after the first period. In this example for Finland there are 12 periods (1–12). The columns represent; column 1, volume thinned (1000 m^3 /5 years); column 2, volume of final felling (1000 m^3/ 5 years); column 3, growing stock (m^3ha^{-1}); column 4, area (1000 ha); column 5, felling ($m^3ha^{-1}yr^{-1}$); column 6, increment ($m^3ha^{-1}yr^{-1}$).

```
Finland, scenario 5, business as usual                          REG     1   2 TR[SL    1   4
      0.      0.  93. 19622.6     .00     .00
 107900. 162000.  97. 19622.6    2.75    3.70
 107900. 162000. 102. 19622.6    2.75    3.64
 107900. 162000. 106. 19622.6    2.75    3.57
 107900. 162000. 110. 19622.6    2.75    3.51
 107900. 162000. 113. 19622.6    2.75    3.46
 107900. 162000. 117. 19622.6    2.75    3.42
 107900. 162000. 120. 19622.6    2.75    3.38
 107900. 162000. 123. 19622.6    2.75    3.36
 107900. 162000. 126. 19622.6    2.75    3.35
 107900. 162000. 129. 19622.6    2.75    3.34
 107900. 162000. 132. 19622.5    2.75    3.34
 107899. 162000. 135. 19622.5    2.75    3.34
```

In the second block, the same data are given, but only for the first tree species.

```
      0.      0.  74. 11022.7     .00     .00
  47654.  74378.  79. 11022.7    2.21    3.08
  47624.  72192.  83. 11022.7    2.17    3.03
  47886.  70434.  87. 11022.7    2.15    2.99
  48645.  69068.  91. 11022.7    2.14    2.99
  49831.  68071.  96. 11022.7    2.14    3.00
  51216.  67483. 100. 11022.7    2.15    3.02
  52605.  67362. 104. 11022.7    2.18    3.03
  53862.  67703. 108. 11022.7    2.21    3.04
  54902.  68446. 113. 11022.7    2.24    3.05
  55689.  69502. 116. 11022.7    2.27    3.06
  56220.  70770. 120. 11022.7    2.30    3.06
  56517.  72144. 124. 11022.7    2.33    3.07
```

In the third block, the same data are given, but only for the second tree species.

```
    0.      0.   143.  4712.1     .00     .00
  37147.  52922. 149.  4712.1    3.82    5.12
  37176.  55108. 155.  4712.1    3.92    5.07
  36914.  56866. 160.  4712.1    3.98    4.93
  36155.  58232. 164.  4712.1    4.01    4.80
  34969.  59229. 167.  4712.1    4.00    4.66
  33584.  59817. 170.  4712.1    3.96    4.52
  32195.  59938. 172.  4712.1    3.91    4.40
  30939.  59598. 175.  4712.1    3.84    4.31
  29898.  58854. 177.  4712.1    3.77    4.24
  29111.  57798. 180.  4712.1    3.69    4.21
  28580.  56530. 182.  4712.1    3.61    4.19
  28283.  55156. 186.  4712.1    3.54    4.20
```

In the fourth block, the same data are given, but only for the third tree species.

```
      0.      0.  81.  3537.8     .00     .00
  21664.  30677.  84.  3537.8    2.96    3.68
  21608.  30288.  88.  3537.8    2.93    3.60
  21570.  30050.  91.  3537.8    2.92    3.47
  21555.  29925.  93.  3537.8    2.91    3.35
  21554.  29878.  94.  3537.8    2.91    3.24
  21558.  29882.  96.  3537.8    2.91    3.17
  21562.  29918.  97.  3537.8    2.91    3.11
  21564.  29969.  98.  3537.8    2.91    3.08
  21564.  30022.  98.  3537.8    2.92    3.05
  21562.  30071.  99.  3537.8    2.92    3.04
  21560.  30111.  99.  3537.8    2.92    3.04
  21558.  30141. 100.  3537.8    2.92    3.04
```

In the fifth block, the same data are given, but only for the fourth tree species.

```
    0.      0. 110.   350.0     .00     .00
 1436.   4023. 116.   350.0    3.12    4.30
 1492.   4412. 121.   350.0    3.37    4.29
 1530.   4650. 124.   350.0    3.53    4.20
 1545.   4775. 126.   350.0    3.61    4.04
 1546.   4822. 128.   350.0    3.64    3.88
 1542.   4818. 128.   350.0    3.63    3.76
 1537.   4782. 129.   350.0    3.61    3.67
 1535.   4731. 129.   350.0    3.58    3.61
 1536.   4678. 129.   350.0    3.55    3.58
 1537.   4629. 129.   350.0    3.52    3.57
 1540.   4589. 129.   350.0    3.50    3.57
 1542.   4559. 130.   350.0    3.49    3.57
```

4.3 SMACRES.DAT

A part of the output file smacres.dat for Finland is presented below. Only period 1 is given.

```
           PERIOD    1

DISTRIBUTION OF AREA ON VOLUME/AGE (1000 HA)
```

The (10-year) age classes are presented horizontal (in rows)→, the volume classes vertical (in columns)↓. This is a sum up over all matrixes in the model, note that volume classes are not the same in different matrixes. The first row is volume class 0, and represents the bare-forest-land class, i.e. 1 106 000 ha bare-forest-land in this case.

```
 1106.    0.    0.    0.    0.    0.    0.    0.    0.
 2506. 1532. 1058.  544.  240.  104.   56.   31.  127.
  192.  989. 1041.  857.  590.  333.  202.  121.  364.
    2.  597.  806.  792.  631.  377.  229.  133.  329.
    0.  187.  407.  513.  447.  265.  152.   83.  172.
    0.   19.  143.  239.  225.  133.   72.   37.   68.
    0.    3.   48.   90.   90.   54.   29.   14.   28.
    0.    0.   22.   38.   36.   22.   12.    6.   11.
    0.    0.    3.   16.   19.   10.    5.    2.    3.
    0.    0.    0.    2.    3.    3.    1.    1.    1.
    0.    0.    0.    0.    0.    0.    0.    0.    0.

 DISTRIBUTION OF AREA ON SPECIES/AGE (1000 HA)
```

The first line represents the first species, etc. 10-year age classes.

```
 2445. 1746. 1839. 1665. 1223.  738.  456.  261.  649.
  724.  435.  672.  850.  760.  448.  249.  137.  438.
  580.  989.  925.  548.  290.  113.   51.   29.   12.
   56.  157.   93.   28.    8.    3.    1.    1.    3.

 DISTRIBUTION OF AREA ON REGION/AGE (1000 HA)

 2380. 2200. 1974. 1760. 1470.  839.  364.  125.   72.
 1426. 1128. 1555. 1330.  811.  462.  393.  303. 1030.

  MEANVOLUME (M3/HA)     TOT AREA (KHA)
              97.35             19 623.

 MEANVOLUME (M3/HA) AND MEANAGE ON REGION/SPECIES
```

In the first two rows the data of the first region for each of the four tree species are given, in the second two rows the data of the second region by tree species are given. In the last two rows the data of the total country are given.

	spp1	spp2	spp3	spp4	average region 1
vol	96.4	172.3	106.8	120.8	122.5
age	53.1	65.1	43.9	37.0	54.9
	60.6	82.8	61.1	87.4	64.0
	70.3	104.2	53.3	53.1	71.6
	78.7	149.3	84.4	116.4	
	61.6	75.1	48.5	39.1	

The first of two rows below show the total volume of fellings by final cut and thinning in the whole area. The second shows the mean volume of fellings in final cut and thinning per hectare.

```
------------------------------------------------------------
CUTTINGS (FINAL, THIN O SUM; KM3.):   162000.   107900.   269900.
MEANVOLUME IN CUTTINGS (FINAL O THIN; M3/HA):    137.     54.
```

Fellings and mean volume of fellings are given as totals for 5 years in thinning and final felling.

```
TOT AREA (1000 HA) AND TOT VOLUME (1000 M3)
OF FINAL CUTTINGS ON REGION/SPECIES
```

	spp1	spp2	spp3	spp4	total
Area reg1	364.	190.	153.	22.	729.
Vol. reg 1	53162.	39929.	23196.	3672.	119959.
Area reg2	222.	130.	101.	2.	455.
Vol. reg 2	21216.	12992.	7481.	352.	42041.
Total country	586.	320.	254.	24.	
	74378.	52922.	30677.	4023.	

```
TOT AREA (1000 HA) AND TOT VOLUME (1000 M3)
OF THINNING ON REGION/SPECIES

    583.     469.     262.      16.    1330.
  33439.   34150.   14819.    1293.   83702.

    401.      66.     196.       3.     667.
  14214.    2997.    6845.     143.   24198.

    984.     535.     458.      19.
  47654.   37147.   21664.    1436.
```

4.4 SMACTR.DAT

The first line contains the title of the run and the lowest and highest region as well as simulated tree species (lowest and highest). The first block of lines below represents results for the total of all tree species by region. The first row of numbers represents the initial situation. Each of the next 12 rows represents a simulated period. The second row of numbers represents period 1 etc. For each region there are four columns: Column 1,volume of thinning (1000 m^3/5 years), column 2 volume of final felling (1000 m^3/5 years), column 3, growing stock (m^3ha^{-1}) and column 4, area (1000 ha), i.e. the number of columns depend on number of regions. After 12 rows the same data is presented by tree species.

```
Finland, scenario 5, business as usual
REG     1    2 TR[SL    1    4
      0.       0. 117. 11199.9       0.       0.  62.  8718.9
  83984.   96063. 126. 11199.8  23928.  65937.  63.  8719.0
  83161. 103650. 135. 11199.8  24783.  58351.  64.  8718.9
  82880. 110339. 144. 11199.8  25105.  51661.  66.  8718.9
  82976. 115799. 152. 11199.8  25063.  46201.  68.  8718.9
  83267. 120331. 160. 11199.7  24807.  41670.  70.  8718.9
  82633. 123039. 168. 11199.8  25418.  38961.  73.  8718.9
  81782. 125069. 175. 11199.8  26215.  36931.  76.  8718.9
  67562. 140428. 183. 11199.8  22449.  39472.  80.  8718.9
  67351. 141445. 189. 11199.7  22651.  38455.  83.  8718.9
  66674. 141102. 195. 11199.8  23326.  38798.  86.  8718.9
  66136. 140723. 201. 11199.7  23864.  39177.  89.  8718.9
  65812. 140313. 206. 11199.7  24188.  39588.  92.  8718.9
      0.       0.  92.  5581.9       0.       0.  58.  5612.5
  33620.   52271.  97.  5581.9  14338.  40056.  59.  5612.5
```

4.5 REMOVALS.DAT

Annual removals (over bark) per year from final cut and thinning by tree species groups (1 = coniferous; 2. = non-coniferous; 3=coppice)
* 1. column: Simulation period
* 2. column: annual removals of coniferous species from final cuttings, thousand m^3
* 3. column: annual removals of non-coniferous species from final cuttings, thousand m^3
* 4. column: annual removals of coppice species from final cuttings, thousand m^3
* 5. column: annual removals of coniferous species from thinning, thousand m^3
*6. column: annual removals of non-coniferous species from thinning, thousand m^3
* 7. column: annual removals of coppice species from final thinning, thousand m^3

```
   1  28435.60   8486.58       .00  17515.55   1728.37       .00
   2  28466.72   8517.86       .00  17739.02   1742.67       .00
   3  28483.22   8535.88       .00  17950.08   1769.90       .00
   4  28497.22   8543.72       .00  17173.27   1790.70       .00
```

4.6 BIOMASS.DAT

Biomass of trees, expressed as carbon in coniferous and non-coniferous species by compartment (stem, branches, coarse roots, fine roots and foliage). Note: coppice is not included as a separate category in this file and is included in the non-coniferous category.

* 1. column: Simulation period (0=initial situation, 1=situation after 5 years)
* 2. column: Biomass of stem, coniferous tree species, Tg C
* 3. column: Biomass of branches, coniferous tree species, Tg C
* 4. column: Biomass of coarse roots, coniferous tree species, Tg C
* 5. column: Biomass of fine roots, coniferous tree species, Tg C
* 6. column: Biomass of foliage, coniferous tree species, Tg C
* 7. column: Biomass of stem, non-coniferous tree species, Tg C
* 8. column: Biomass of branches, non-coniferous tree species, Tg C
* 9. column: Biomass of coarse roots, non-coniferous tree species, Tg C
* 10.column: Biomass of fine roots, non-coniferous tree species, Tg C
* 11. column: Biomass of foliage, non-coniferous tree species, Tg C
* 12 column: total Biomass of trees, Tg C

0	297.92	63.82	51.39	52.13	48.66	64.95	18.90	12.74	16.26	14.58	641.36
1	306.49	68.53	53.65	55.36	52.51	68.98	20.05	13.55	17.44	15.45	672.02
2	315.08	71.72	55.54	57.76	55.32	71.88	20.41	14.01	18.09	15.73	695.50
3	323.41	73.48	57.04	59.27	57.19	73.90	20.05	14.19	18.25	15.47	712.19
4	332.51	75.00	58.52	60.78	58.42	75.31	20.45	14.45	18.31	16.02	729.74
5	342.39	76.87	60.15	62.13	59.99	76.45	20.43	14.59	18.01	16.38	747.34

4.7 LITTER.DAT

Annual litter production of trees, expressed as carbon in coniferous and non-coniferous species by compartment (stem, branches, coarse roots, fine roots and foliage).

* 1. column: Simulation period (0=initial situation, 1=situation after 5 years)
* 2. column: Annual litter production of stem, coniferous species, Gg C
* 3. column: Annual litter production of branches, coniferous species, Gg C
* 4. column: Annual litter production of coarse roots, coniferous species, Gg C
* 5. column: Annual litter production of fine roots, coniferous species, Gg C
* 6. column: Annual litter production of foliage, coniferous species, Gg C
* 7. column: Annual litter production of stem, non-coniferous species, Gg C
* 8. column: Annual litter production of branches, non-coniferous species, Gg C
* 9. column: Annual litter production of coarse roots, non-coniferous species, Gg C
* 10. column: Annual litter production of fine roots, non-coniferous species, Gg C
* 11. column: Annual litter production of foliage, non-coniferous species, Gg C
* 12. column: Annual total litter production of trees, Gg C

1	3378.99	5656.05	4492.50	24161.24	17658.33	708.92	1599.04	1138.45	7543.91	5148.70	71486.13
2	3459.57	5878.45	4617.43	25170.27	18558.26	744.78	1633.04	1171.28	7826.48	5246.06	74305.62
3	3537.53	6035.58	4719.89	25838.90	19188.63	774.33	1625.75	1187.02	7917.38	5179.12	76004.13
4	3565.50	6074.39	4764.34	26430.86	19537.82	793.49	1655.62	1202.59	7958.57	5361.38	77344.56

4.8 SLASH.DAT

Felling residues produced per year in harvested forests. This file can be used to assess bioenergy potentials of felling residues or study the importance of felling residues in litter production.

* 1. column: Simulation period (1=slash production during years 1–5)
* 2. column: Felling residues of stem in final cut areas, Gg C yr^{-1}
* 3. column: Felling residues of branches in final cut areas, Gg C yr^{-1}
* 4. column: Felling residues of coarse roots in final cut areas, Gg C yr^{-1}
* 5. column: Felling residues of fine roots in final cut areas, Gg C yr^{-1}
* 6. column: Felling residues of foliage in final cut areas, Gg C yr^{-1}
* 7. column: Felling residues of stem in thinned areas, Gg C yr^{-1}
* 8. column: Felling residues of branches in thinned areas, Gg C yr^{-1}
* 9. column: Felling residues of coarse roots in thinned areas, Gg C yr^{-1}
* 10. column: Felling residues of fine roots in thinned areas, Gg C yr^{-1}
* 11. column: Felling residues of foliage in thinned areas, Gg C yr^{-1}

1	388.65	1206.37	1182.59	843.83	820.05	427.64	1048.00	787.81	938.00	827.90
2	389.31	1217.75	1188.65	861.51	832.41	432.93	1054.23	795.25	946.26	827.53
3	389.68	1231.99	1195.82	886.52	850.35	438.22	1089.01	810.61	975.30	848.98
4	389.91	1247.70	1203.65	915.54	871.49	421.42	1066.92	784.38	952.58	825.75

4.9 SOILSTO.DAT

This file contains carbon stocks on forest floor originated from trees within a country or simulated regions (see section soil for more detailed information).

* 1. column: Simulation period (0=initial situation, 1=situation after 5 years)
* 2. column: Non-woody litter (NWL), i.e. foliage and fine root litter, Tg C
* 3. column: Fine woody litter (FWL),i.e. branches and coarse roots, Tg C
* 4. column: Coarse woody litter (CWL), i.e. stem litter, Tg C
* 5. column: Soluble (SOL), Tg C
* 6. column: Cellulose (CEL), Tg C
* 7. column: Lignin (LIG), Tg C
* 8. column: Soil Organic Matter, fast pool (SOM1), Tg C
* 9. column: Soil Organic Matter, slow pool (SOM2), Tg C
*10. column: Total Carbon stock of litter and soil), Tg C

```
0  54.56  25.77  81.75  36.69  123.61  162.45  337.41  657.95  1480.19
1  54.56  25.77  81.75  36.69  123.61  162.45  337.41  657.95  1480.19
2  56.85  26.57  82.28  38.02  127.05  164.76  337.50  657.95  1490.98
3  58.18  27.11  83.17  38.92  130.12  168.14  337.97  657.96  1501.57
4  59.34  27.38  84.08  39.64  132.62  171.50  338.87  657.97  1511.40
```

4.10 USEDPAR.DAT

This file contains the used biomass distribution and litter production parameters by region (IREG), tree species (ITRB) and observation year (IYEAR) in the simulation. This fil e is mainly for checking parameters.

*Used scenario
*Biomass distribution parameters by region, tree species, observation year and age class
*Litter production parameters by region, tree species, observation year and age class

```
USED SCENARIO:
          1

 ALLOCATION, IREG,ITRB,IYEAR          1           1           1
  .500  .200  .100  .100  .100
  .500  .200  .100  .100  .100
  .500  .200  .100  .100  .100
  .500  .200  .100  .100  .100
  .500  .200  .100  .100  .100
  .500  .200  .100  .100  .100
  .500  .200  .100  .100  .100
 LITTER PROD, IREG,ITRB,IYEAR          1           1           1
  .020  .100  .050  .050  .500
  .030  .100  .050  .050  .500
  .040  .100  .050  .050  .500
  .020  .100  .050  .050  .500
  .020  .100  .050  .050  .500
  .020  .100  .050  .050  .500
  .030  .100  .050  .050  .500

 ALLOCATION, IREG,ITRB,IYEAR          1           1           2
  .250  .250  .100  .150  .250
  .350  .200  .100  .150  .200
  .450  .150  .100  .150  .150
  .500  .100  .100  .150  .150
  .550  .100  .100  .150  .100
  .550  .100  .100  .150  .100
  .550  .100  .100  .150  .100
```

4.11 OTHER OUTPUT FILES

For special purposes, e.g. carbon budget, it is possible to produce also other output files. The content of those files can be asked from the authors, as well as further information about above files. Furthermore, if some specific output is needed, some variables are easy to produce for regions, owner class, site class, tree species or for combinations of forest types.

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