Manual for the European Forest Information Scenario model (EFISCEN 4.1)

P.J. Verkerk, M.J. Schelhaas, V. Immonen, G. Hengeveld, J. Kiljunen, M. Lindner,

G.J. Nabuurs, T. Suominen, S. Zudin

EFI Technical Report 99, 2016

Manual for the European Forest Information Scenario model (EFISCEN 4.1)

P.J. Verkerk, M.J. Schelhaas, V. Immonen, G. Hengeveld, J. Kiljunen, M. Lindner, G.J. Nabuurs, T. Suominen, S. Zudin

Publisher: European Forest Institute
Yliopistokatu 6, FI-80100 Joensuu Finland
Tel. + 358 13 252 020
Fax. + 358 13 124 393
Email: publications@efi.int
http://www.efi.int

Disclaimer: This report has been written with support from the EU 7th framework project Trees4Future (project number 284181). The views expressed are those of the authors and do not necessarily represent those of the European Forest Institute or the funding agent.

Table of contents

Summary

The European Forest Information SCENario Model (EFISCEN) is a large-scale forest model that projects forest resource development on regional to European scale. The model uses national forest inventory data as a main source of input to describe the current structure and composition of European forest resources. Based on this information, the model can project the development of forest resources, based on different scenarios. These scenarios are mainly determined by management actions, but the model can also take into account changes in forest area, as well as changes in growth e.g. due to climate change.

EFISCEN provides output on basic forest inventory data (species, area, stemwood volume, increment, mortality, age-structure), and the model includes multiple indicators related to important forest ecosystem services (carbon sequestration, biodiversity, recreation, wind and fire risk), enabling the assessment of impacts of different policy and management strategies at the national and European level.

Through its underlying detailed forest inventory database, the projections can provide these insights at varying scales, thus serving forest managers and policy makers at the national and international levels.

To improve transparency and to ensure the tool could be used by the entire research community, EFISCEN was re-implemented into Java, the current version is called EFISCEN 4.1. The model and its source code are now freely available under the GNU General Public License conditions. This manual describes how to conduct simulations with EFISCEN 4.1.

1. Introduction

European forests are a crucial resource to supply a growing bio-economy, they provide multiple ecosystem services and they can and mitigate the effects of climate change. To assess how European forest can accommodate these multiple demands, simulation models are useful tools. The European Forest Information SCENario model (EFISCEN) has been validated (Nabuurs et al. 2000; Thürig and Schelhaas 2006) and used in many studies to provide insight in European forest resource development, woody biomass availability and ecosystem service provisioning. (e.g. Böttcher et al. 2012; Eggers et al. 2008; Hanewinkel et al. 2013; Karjalainen et al. 2003; Nabuurs et al. 2000, 2001, 2007; Schelhaas et al. 2010, 2015; Verkerk et al. 2011a,b, 2014). A complete publication overview is available at: http://efiscen.efi.int.

EFISCEN is a large-scale forest model that projects forest resource development on regional to European scale. The model uses national forest inventory data as a main source of input to describe the current structure and composition of European forest resources. The model can project the development of forest resources, based on different scenarios. These scenarios are mainly determined by management actions, but the model can also consider changes in forest area and growth rates. EFISCEN provides ouput on basic forest inventory data (species, area, stemwood volume, increment, mortality, age-structure), but the model includes multiple indicators related to important forest ecosystem services (carbon sequestration, biodiversity, recreation, wind and fire risk), enabling the assessment of impacts of different policy and management strategies at the national and European level, thus serving forest managers and policy makers at the national and international levels.

The core of the EFISCEN model was developed in the late 1980s for Sweden by Prof. Ola Sallnäs at the Swedish Agricultural University (Sallnäs 1990). The first European application of this model was carried out by the International Institute for Applied Systems Analysis (IIASA) in the early 1990s (Nilsson et al. 1992). With help from the original developers, the model was transferred to EFI in 1996, and given the name EFISCEN. The model was developed further both by EFI and Alterra, resulting in EFISCEN 2.0 (Pussinen et al. 2001). Development of the model continued and the model was then re-programmed into C++ code and a user interface was added. This version was called EFISCEN 3.0. The EFISCEN model has been described in detail by Schelhaas et al. (2007) for EFISCEN version 3.1.3.

To improve transparency and to ensure the tool could be used by the entire research community, EFISCEN was re-implemented from C++ to Java and the source code of the model is now freely available under the GNU General Public License conditions. This version is called EFISCEN 4.1. The process to re-implement and improve EFISCEN was started by EFI in 2011 with participation by the University of Eastern Finland and Alterra. Besides re-implementation, model functionality has been extended as well. Functionality was added to improve the graphical user interface, as well as to make the model more flexible for use in various scenarios. In addition, the whole code was verified and checked, including documentation on model structure and testing.

This manual describes how to conduct simulations with EFISCEN 4.1. For a detailed description of the model, its history and steps needed to prepare input files, we refer to Schelhaas et al. (2007) as these did not change between EFISCEN 3.1.3 and EFISCEN 4.1.

2. Model overview

2.1 Documentation and availability

Information on availability and documentation of EFISCEN can be found at http://efiscen.efi.int. The model and its source code are freely available and are distributed under the GNU General Public License conditions (www.gnu.org/licenses/gpl-3.0.html). For more information, please contact:

- Dr. Hans Verkerk (EFI): hans.verkerk(at)efi.int
- Prof Dr. Gert-Jan Nabuurs (Alterra): gert-jan.nabuurs(at)wur.nl
- General email address: efiscen(at)efi.int

2.2 History and development

The core of the EFISCEN model was developed in the late 1980s for Sweden by Prof. Ola Sallnäs at the Swedish Agricultural University. The first European application of this model was carried out by the International Institute for Applied Systems Analysis in the early 1990s. With help from the original developers, the model was transferred to EFI in 1996, and given the name EFISCEN. The model has been further developed since both by EFI and Alterra. The current version is EFISCEN 4.1. Key improvements in EFISCEN 4.1 as compared to EFISCEN 3.1.3:

- A Graphical User Interface (GUI) has been redesigned with additional functionality. Total and selected data is now divided to two tabs to make the interface less crowded;
- In the GUI, the user can now select multiple regions, owners, sites or species in the selection tree and data are shown in the selected-tab accordingly;
- All simulation values that are shown in the panels can also be shown in the graphs with their history. Variables to show as graphs can now be easily toggled by clicking corresponding buttons;
- Error messages have been made more descriptive, three sets of log files are provided describing events, errors are written to log files, and fault tolerance of the program has been improved;
- Time step specification in scenario files has been changed so the last parameter values are used when last step in scenario file is reached, rather than re-running the whole scenario;
- Area scaling factors can now be applied to individual matrices through a newly added scenario file;
- Management parameters that were previously fixed through the simulation can now change. They are defined in two new scenario files. This feature allows the user to modify management regimes along the course of the simulation;
- Scenario file format has been extended to include individual matrix scaling and thinning and felling change files;
- All output files are now written in .csv format;
- It is possible for the user to specify a list of output files that need to be created;
- Outputs can directly be saved to an external database. Databases that are currently supported are MySQL, PostgreSQL and Microsoft Access.

2.3 Architecture and modules

The main EFISCEN model performs the simulations. Within the EFISCEN model we can distinguish 1) the matrix simulator, 2) a carbon module to convert outputs to carbon stocks and 3) a soil module based on the YASSO soil model (Liski et al. 2005). EFISCEN 4.1 is implemented in Java. To prepare required input files, a separate program (P-2009) can be used to initialise the matrices based on the forest inventory input data.

2.4 Minimum requirements

The minimum requirements to run EFISCEN are Java version 8 update 40.

2.5 Concept

EFISCEN is a large-scale forest model that projects forest resource development on regional to European scale. The model uses national forest inventory data as a main source of input to describe the current structure and composition of European forest resources. The model can project the development of forest resources, based on scenarios for policy, management strategies and climate change impacts. EFISCEN provides insights in large-scale forest resource development, wood and biomass production, biodiversity and ecosystem services, thereby serving forest managers and policy makers at the national and international levels. A detailed model description is given by Schelhaas et al. (2007) and a schematic overview is shown in Figure 2.1.

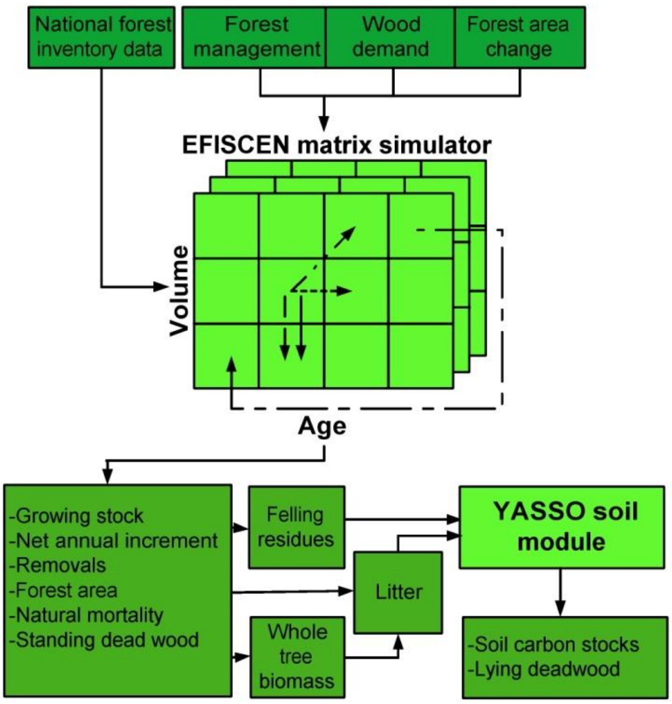

Figure 2.1: Schematic presentation of the EFISCEN model (Sallnäs 1990; Schelhaas et al. 2007).

EFISCEN is a matrix model in which the state of the forest is described as an area distribution over age and volume classes, based on data on area, growing stock and increment by age class and forest type collected from national forest inventories. For each forest type that is distinguished in the input data (which might be according to species, region, site class and owner), a separate matrix is set up. During simulations, forest area moves between matrix cells, describing different natural processes (e.g. growth and mortality) and human actions (e.g. forest management). Aging of the forest is simulated by moving area to a higher age class, while growth is simulated by moving the area to a higher volume class. Transitions can be changed over time to simulate changes in growing conditions (e.g., due to climate change).

Management scenarios are specified at two levels in the model. A basic management regime defines the period during which thinnings can take place and a minimum age for final fellings for each forest type separately. These regimes can be regarded as constraints on the total harvest level. The demand for wood is specified externally and EFISCEN may fell the demanded wood volume if available. Wood demand is the main determinant of forest resource use. Thinning in the model is simulated by moving area one volume class down. Only area that was moving to a higher volume class (increment) can be subjected to thinning. The user can pre-specify an age range where thinnings can be carried out. If a thinning will be carried out or not depends on the actual demand for thinnings. A user-defined fraction of the area that has been subjected to a thinning will be moved up one volume class extra to simulate the growth response after a thinning. Final fellings are simulated by taking the area out of a certain cell. Final felling chances can be pre-set by the user as a function of age and volume class. The fraction that is actually harvested depends on the actual demand for wood from final fellings. Area that is taken out of the matrix is put in a separate class, the non-stocked area. Regeneration is simulated as the movement from the non-stocked area into the lowest age and volume class of the matrix. Natural mortality is simulated by moving a fraction of the area in a certain cell one volume class down. This fraction can be set by the user as a percentage of the growing stock, varying by age class. The actual fraction of the area that is moved down will then depend on the average volume before, and the difference between the volume classes. Only area that has not recently been thinned can be subjected to natural mortality.

Based on the information mentioned above, EFISCEN projects stem wood volume, increment, age-class distribution, removals, forest area, natural mortality and deadwood for every five-year time-step. With the help of biomass expansion factors, stem wood volume is converted into whole-tree biomass and subsequently to whole tree carbon stocks. Information on litterfall rates, felling residues and natural mortality is used as input into the soil module YASSO (Liski et al. 2005), which is dynamically linked to EFISCEN and delivers information on forest soil carbon stocks.

2.6 Model inputs

The forest area under study is usually separated into forest types, which can be separated based on administrative unit, ownership, tree species and site class. To initialise the model, EFISCEN needs the area, average growing stock volume and net annual increment per age class of each forest type. If the user applies gross annual increment, data about natural mortality per age class is required. Furthermore, information needs to be available on the thinning and final felling regime. To convert growing stock volume into estimates of carbon in total tree biomass, the user needs to provide the model with biomass distribution functions. Additionally, the model can simulate carbon dynamics in the soil via its soil model YASSO. This requires data on turnover rates of different biomass components, litter quality, and climate parameters. The separate input files are described in chapter 3.

2.7 Model outputs

EFISCEN provides estimates of forest area, growing stock, increment, standing dead wood, harvest level and age class distribution over time. These are provided on different aggregation levels (e.g. per species, regions, total). Furthermore, the model can provide information on carbon stocks in biomass and soil, deadwood (an indicator for biodiversity), risk indicators and ecosystem services. The separate output files are described in chapter 5.

2.8 Validation

The model has been validated by (i) comparing its growth functions against growth functions of other models (Sterba 2003), (ii) comparing its projections against other projections carried out for the same forests (e.g. Nilsson et al 1992; Böttcher et al. 2012), and (iii) running the model on historic data and comparing the output to present day forest state. Separate validation studies have been conducted for Finland with EFISCEN 1.0 (Nabuurs et al. 2000) and for Switzerland with EFISCEN 2.2 (Thürig and Schelhaas 2006). A sensitivity analysis has been carried out with EFISCEN 3.1.3 (Schelhaas et al. 2007).

2.9 Strengths and limitations of the model

EFISCEN is designed for large forest areas (e.g. provinces or countries). Application to smaller areas is possible, but there have been no studies yet to determine the minimum size and effects of scale on uncertainty of the projections. Generally, several thousand hectares is considered a safe minimum.

EFISCEN has been developed for even-aged, managed forests. Deviations from this situation (e.g. uneven-aged or unmanaged forests and shelterwood systems) make the application of EFISCEN less suitable. Furthermore, the model is currently not suited to simulate fast growing tree species with very short rotations, due to the 5-year time step. The model can handle small decreases in forest area, but is not suited to deal with large-scale deforestation issues.

One outcome of the Finnish validation study (Nabuurs et al., 2000) was a decrease in increment levels after 30-40 years in EFISCEN 1.0. In later versions a mechanism has been introduced to counteract this. Increment levels seem to be more realistic for longer timeframes now. However, a new validation would be needed to determine appropriate time horizons for reliable projections. Despite this, the current practice of 50-60 years projection horizons seems to be well defendable.

EFISCEN distributes harvest over forest types based on availability of wood. As a result, harvests for some forest types may be overestimated as compared to what happens in reality, and harvest for other forest types may be underestimated, which may compensate for each other at a more aggregated level (Thürig and Schelhaas 2006). To obtain reliable results for individual forest types (e.g. results at regional and/or at species level), harvest practices should be carefully parameterised at the level of forest types.

As with all models, uncertainties in EFISCEN depend largely on the quality of the input data. Especially a correct estimation of the increment functions is important for the model outcomes. Initial uncertainties propagate through the model with every simulated time step, and thus the overall uncertainty increases. For 10-12 time steps (50-60 years) the model is considered to give reasonable projections. With increasing projection length, observed patterns become more important than absolute values.

3. Model inputs

3.1 Conventions

In this description, the symbol *** is used to denote the country name. The naming of the files is flexible, since files are either selected by the user, or the file names to be used are listed in other files. This gives the user the opportunity to distinguish different versions of certain files by using different names (for example with scenario files).

The hash symbol (#) can be used for inserting comments in the forest resource input files (not in the scenario input files). The program will not read lines that start with #. To separate items in a line, spaces should be used (or in many scenario files commas), but not tabs.

When several items of the same kind are listed in an input file, a number indicating how many items there are must precede the item list. This is both valid for matrices/forest types (for example the number of input matrices in an input file) as well as within lines (for example how many parameters are listed to define the final felling regime).

Forest types are always identified by four digits, representing respectively the region, owner class, site class and tree species. Many parameter values can be set separately for a forest type, or for a class of forest types. Here the same identification system is used. A zero can be used to include all forest types of a certain class. For example, 2 1 0 3 selects the matrix of the second region, first owner class, all site classes and the third tree species, as they are defined in the ***.efs file. Similarly, all matrices can be selected by listing 0 0 0 0. However, be aware that for the definition of the matrices (***.aer and ***.vcl files) every matrix should be defined separately, so here no zeros as index are allowed.

Scenario files contain lines starting with a time step number. As a convention, the values in this line are valid until (and including) the specified time step. In case simulations are continued beyond the latest time-step specified EFISCEN 3.1.3 started the loop from the beginning when no more parameters were defined. In EFISCEN 4.1 this has been changed so the last parameter values are used when no more values are defined. It is recommended to explicitly define all scenario inputs for the full length of the simulation.

Various input files contain information on volumes. The model does not require whether volumes are reported with or without bark, but it is important for the quality of the simulation results to be consistent. It is recommended to define all volumes with bark.

Figure 3.1 gives an overview of the file structure of EFISCEN 4.1. The files in the upper half of the figure are parameter files, while the files in the lower half of the figure are scenario files. EFISCEN 4.1 expects that all input files are located within the same folder.

An input dataset for testing purposes is available at:
http://www.efi.int/portal/virtual_library/databases/efiscen/model_documentation

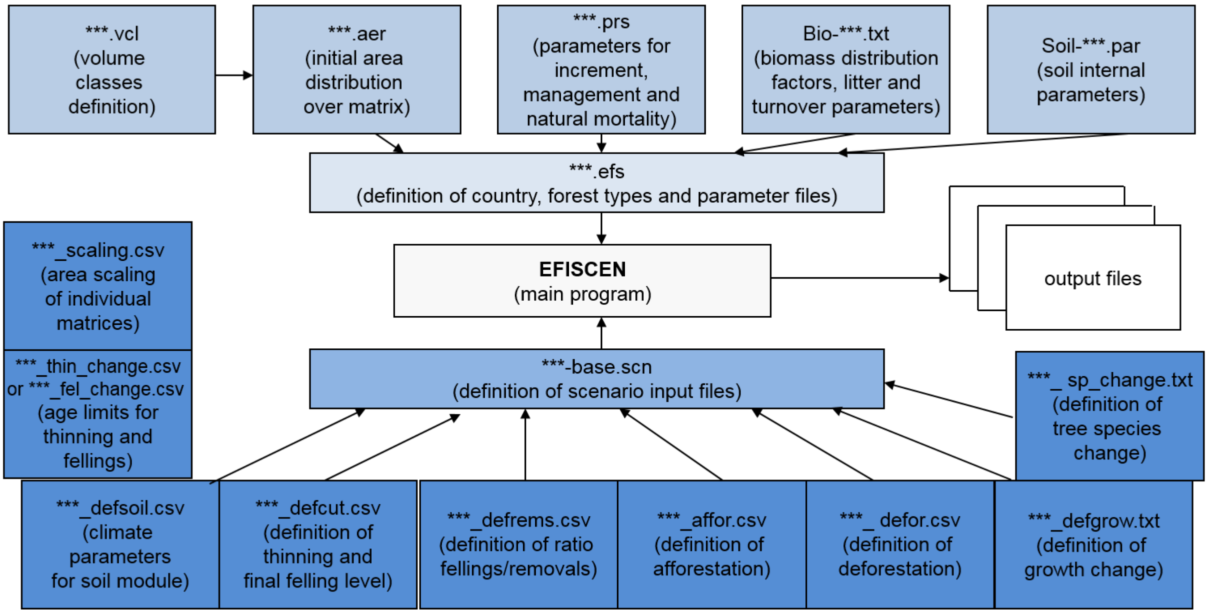

Figure 3.1: Overview of file structure for as input to EFISCEN 4.1. Files in the top half of the figure are input and parameter files. Without these files the model cannot run. Files in the lower half of the figure are scenario files. All these files are needed when a certain scenario is to be evaluated.

3.2 Forest resource input files

3.2.1 Initialisation file

The initialisation file (***.efs) defines the base year for the start of the simulation, i.e. the (mean) year of the forest inventory. Furthermore, the forest types are defined in accordance with the matrix setup. For each category (region, owner class, etc.), first the number of classes that is distinguished is defined, followed by the definition of those classes (region names, owner names, etc.). For mapping purposes, a regional identification number can be defined, but this is not obligatory. The ID number is the ISO country code times 1000 plus the number of the region. ISO country codes can be for example found at http://unstats.un.org/unsd/methods/m49/m49alpha.htm. Furthermore, the names and locations of the parameters file, the biomass allocation file, the matrix file and the soil parameters file are defined. The initialisation file should have the ending '*.efs*'. Finally, values need to be separated using spaces, not tabs or commas. All parameters are specified in Table 3.1 and an example for Czech Republic is given in Box 3.1.

Table 3.1: Description of input variables in the initialisation file (***.efs)

Parameter	Explanation	Unit
Country name	Name of country for which parameters are provided	-
Base year	Year for which forest inventory input data are provided	-
Regions	Geographical regions for which forest inventory input data are provided	-
Owners	Owner classes for which forest inventory input data are provided	-
Sites	Site-classes for which forest inventory input data are provided	-
Species	Tree species (groups) for which forest inventory input data are provided	-
File_name_parameters	Name of file in which tree-related parameters are provided	-
File_name_bioparameters	Name of file in which bioparameters are provided	-
File_name_matrices	Name of file in which matrices are provided	-
File_name_soils	Name of file in which soil parameters are provided	-

```
EFISCEN experiment file
#Experiment's initialisation file
#EFISCEN - Czech Republic
Czech Republic
#Base year (starting simulation)
2000
#Regions should be listed first, started from how many
14
1  203001 BRENENSKY
2  203002 BUDEJOVICKY
3  203003 JIHLAVSKY
4  203004 KARLOVARSKY
5  203005 KRALOVEHRADECKY
6  203006 LIBERECKY
7  203007 OLOMOUCKY
8  203008 OSTRAVSKY
9  203009 PARDUBICKY
10  203010 PLZENSKY
11  203011 PRAHA
12  203012 STREDOCESKY
13  203013 USTECKY
14  203014 ZLINSKY
#Owners
1
1 ALL
#2 Private
#Sites
1
1 ALL
#Species
10
1 Spruce
2 Fir
3 Pine
4 Larch
5 Other_Conifers
6 Oak
7 Beech
8 Maple
9 Ash
10 Other_broadleaves
#File name for parameters
Czech.prs
#
#File name for bioparameters
biocomp.txt
#File name for matrixes
cze.aer
#
#File name for soils
soilcze.par
#END
```

Box 3.1: Example of a country initialisation file for the Czech Republic (czech.efs).

3.2.2 Parameters file

The parameters file (***.prs) defines all tree-related parameters needed for the simulation, including age class size and number, coefficients for the growth functions, age classes for thinnings and final fellings as well as the optimal volume per age class. The time step for simulation defines the 5-year time step that is usually applied. Other time steps could be applied in different forest types (like fast growing plantations), but that has not been tested in this version yet.

The number of age classes can be taken from the input data, and should correspond with the number of age classes in the ***.aer file. The lines that define the size of the age and volume classes are not in use.

The growth function is defined by the three parameters a_0, a_1 and a_2 (see Equation 5 in Schelhaas et al. 2007). Optionally, confidence intervals can be added, defining age limits for the application of the growth function. In that case, the minimum and maximum age must be given in addition to the growth function coefficients.

To define the final felling regime, the user can choose one out of two options: (1) giving the minimum age for final fellings; after reaching that age, all forest will be available for final felling or (2) to define the minimum age and the corresponding felling probability, the age at which the felling probability will reach 100%, and the felling probability for forest younger than the minimum age.

For the thinning regime, the minimum and maximum age for thinnings is defined. In case the age range of thinnings and final fellings overlap, part of the final fellings will not be found even when there is enough removal volume available. The reason is that the model first calculates on which fraction of the available area thinnings and final fellings should be carried out, without taking into account the overlap. An area cannot be subjected to thinning and final felling in the same time step. Since thinnings are carried out first, less area is available for final fellings. However, the fraction to be subjected to final felling is not adapted to this change in available area. It is recommended not to have overlap between the thinning and felling range.

The volume series define the optimal volume per age class. This is difficult to determine, usually the values from the input data are copied. Here, first the age class limits are defined for which the volume series are valid (AgeLims). These age class limits also define the age classes for the initial matrices, so they should also match the input data. Note that the maximum age defined here is used to define the upper limit of the age dimension in the matrix.

Mortality can be defined by forest type and age class. Mortality is specified as a proportion of the growing stock that dies due to natural mortality each time step. This proportion is converted into area transitions, depending on the average growing stock volume per volume class. Currently it is only possible to move the area one volume class down. Therefore, the highest possible mortality rate in the upper volume class is 10%, assuming equal volume classes. Even though it is possible to enter higher values, the actual mortality rate will be limited by the volume class width.

The volume subject to natural mortality will move to a standing deadwood pool; it is assumed that the trees remain standing for a while. The deadwood volume fall rate defines the proportion of the standing deadwood pool that moves to the coarse woody litter pool of the soil sub-module each time step. This rate reflects not only whole trees falling down, but also stem pieces falling off.

The thinning history parameter (Thhistory) defines the proportion of the area within the possible thinning range that is not available for thinnings, because of a recent thinning. After this area has received the growth boost, it will be available for thinnings again.

Values need to be separated using spaces, not tabs or commas. All parameters are specified in Table 3.2.

Table 3.2: Description of input variables in the parameters file (***.prs)

Parameter	Explanation	Unit
step	Number of years included in one simulation step	year
AgeClassNum	Number of age-classes on the x-axis of a matrix	-
X1	Width of age-classes (not used by model)	year
VolClassNum	Number of volume-classes on the y-axis of a matrix	-
Y1	Width of volume-classes (not used by model)	m^3 over bark ha^{-1}
a0	Growth function coefficient	-
a1	Growth function coefficient	-
a2	Growth function coefficient	-
growth_min_age	Minimum age where growth function is valid	year
growth_max_age	Maximum age where growth function is valid	year
YForest	Young forest coefficient	-
Gamma	Growth boost coefficient defining the proportion of thinned area that is moved up one extra volume-class	-
min_age	Minimum age at which final fellings can start	year
max_age	Age at which final felling probability reaches maximum value	year
min_tresh	Felling probability at minimum age at which final fellings can start	-
max_tresh	Felling probability at minimum age at which final fellings can start	-
level_below	Felling probability for forests younger than the minimum age	-
starting_age_below	Proportion of minimum age at which final fellings can start	-
ThinRange_lower	Minimum age at which thinnings can be executed	year
ThinRange_upper	Maximum age at which thinnings can be executed	year
Beta	Coefficient to avoid matrix diversion	-
AgeLims	Age classes of volume series	year
VolSers	Optimal growing stock per age class	m^3 over bark ha^{-1}
MortAgeLims	Age classes for mortality rates	year
MortRate	Proportion of growing stock that dies each time-step through ageing, suppression and/or disturbances	time $step^{-1}$
Decay	Proportion of standing deadwood that falls down each time step	time $step^{-1}$
Thhistory	Proportion of the area within the defined thinning range that is not available for thinnings, because of a recent thinning	-

An example is given in Box 3.2 for Czech Republic.

```
#Experiment's parameters file
#Czech Republic
#Step of simulation (how many years are in one tick)
5
#For all parameters which can be depend on Reg:Own:Site:Spec
#combination - corresponding IDs could be given (0 - means for all)
#Then size of array then array itself
#For all next name_of_parameter and n_howmany
#
#Number of age classes (X axis)
AgeClassNum 1
0 0 0 0
1 16
#size of age class (X axis)
X1 1
0 0 0 0
1 10
#Number of volume classes (Y axis)
VolClassNum 1
0 0 0 0
1 10
#size of volume class (Y axis)
Y1 1
```

```
0 0 0 0
1 50.
#
#Growing function's coeff.
GrFunction 10
0 0 0 1
5 -12.87316907 2113.657035 -7729.068793 10 150
0 0 0 2
5 -10.91577278 1930.812189 -7084.449633 10 150
0 0 0 3
5 -7.540788132 1677.718089 -5760.735426 10 150
(...)
#Young forest coeff
YForest 10
0 0 0 1
1 0.7
0 0 0 2
1 0.7
0 0 0 3
1 0.7
(...)
#Regrow after thinnings
Gamma 1
0 0 0 0
1 0.4
#Age of Harvest
#for simplest regimes we provide only one number - age of cutting
#in other case we provide 6 values
#min_age max_age min_tresh max_tresh level_below starting_age_below
Harvest 10
0 0 0 1
6 81 120 0.1 1 0.015 0.2
0 0 0 2
6 96 150 0.1 1 0.015 0.2
0 0 0 3
6 96 120 0.1 1 0.015 0.2
(...)
#Thinnings range
Thinrange 10
0 0 0 1
2 20 80
0 0 0 2
2 20 95
0 0 0 3
2 20 95
(...)
#Beta coeff
Beta 1
0 0 0 0
1 0.4
#Volume series: pair - first age classes limits; second volumes
#again IDs should be first
AgeLims 1
0 0 0 0
16 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170
Volsers 140
#CZE
1 1 1 1
16 7.4 132.0 232.0 338.0 410.0 458.0 497.0 534.0 558.0 557.0 552.0 554.0
518.0 560.0 397.0 403.0
1 1 1 2
```

```
16 7.4 119.0 260.0 339.0 381.0 431.0 467.0 471.0 481.0 467.0 457.0 476.0
441.0 455.0 339.0 365.0
1 1 1 3
16 11.6 101.0 186.0 253.0 310.0 343.0 363.0 366.0 365.0 377.0 385.0 388.0
374.0 318.0 325.0 324.0
(...)
#Natural mortality stuff
#Age limits
MortAgeLims 1
0 0 0 0
4 80 100 120 200
#now rates
MortRates 1
0 0 0 0
4 0.02 0.04 0.1 0.25
#Deadwood volume fall rate
Decay 1
0 0 0 0
1 0.04
#Thinnings history
Thhistory 1
0 0 0 0
1 0.2
#to be continued...
#END
```

Box 3.2: Example of the parameter input file for Czech Republic (Czech.prs). Note that only 3 forest types are shown for management regimes, young forest coefficient and optimal volume series. Data left out is indicated by (…).

3.2.3 Bioparameters file

The bioparameters file (biocomp-***.txt) defines the parameters for carbon content, dry wood density, biomass allocation, and litter production. Each of these can be defined by region, species, owner and site class. Biomass allocation and litter production are age-specific and have to be defined for five tree compartments: stem, branches, coarse roots, fine roots and foliage. Biomass allocation values are shares of the total tree biomass and should add up to one. Litter production fractions define the proportion of the living biomass in a specific compartment that is added to the litter pool each year. Please note here that these amounts are not taken away from that compartment, since this is not a flow model. The stem litter fall rate for example does not influence the simulated standing volume. All parameters are specified in Table 3.3.

Table 3.3: Description of input variables in the bioparameters file (biocomp-***.txt)

Parameter	Explanation	Unit
Carbon	Proportion of carbon in total biomass dry matter	-
WoodDens	Basic wood density	Mg dry matter m^{-3}
BioAgeLims	Age classes for biomass distribution functions	year
BioAllocations	Proportion of total biomass in stem, branches, coarse roots, fine roots and foliage, by age-class	-
LitterAgeLims	Age classes for litter production functions	year
LitterProduction	Proportion of the living biomass in stem, branches, coarse roots, fine roots and foliage that is added to the litter pool each year, by age-class	-
WLCoarseRootsShare	Proportion of litter from coarse roots going to the coarse woody litter class in YASSO	-

The user should be aware of the potential overlap with mortality as defined in the parameters file. The mortality as defined there really decreases the volume in the simulation. When mortality is defined in the parameter file, already most of the stem litterfall rate will be covered. Additional stem turnover as defined in the biocomp-***.txt would therefore only cover parts of the stem that die, for example bark. However, a stem litterfall rate of zero seems appropriate in such cases.

An example for Czech Republic is given in Box 3.3. In this example, in all spruce forest types (indicated by 0 0 0 1) the share of the stem in the total biomass is 38.52% in forests up to 30 years old. Branches account for 34.87%, coarse roots for 4.96%, fine roots for 5% and foliage for 16.65%. With regards to litter production, 0.43% of the stem biomass in spruce forests up to 30 years old is added to the soil as litter, 2.7% of the coarse root biomass, etcetera.

```
#Allocation of Biomass by compartments and litter production (Czech Republic)
#Almost same as in parameters file
#first Carbon content
Carbon 1
#All All All All
0 0 0 0
1 0.5
#Then wood density Mg/m3
WoodDens 10
#All All All Spruce
0 0 0 1
1 0.4
#All All All Fir
0 0 0 2
1 0.4
#All All All Pine
0 0 0 3
1 0.42
(...)
#Then age classes
BioAgeLims 10
#All All All Spruce
0 0 0 1
11 20 30 40 50 60 70 80 90 100 110 1000
#All All All Fir
0 0 0 2
11 20 30 40 50 60 70 80 90 100 110 1000
#All All All Pine
0 0 0 3
8 30 40 50 60 80 100 120 1000
(...)
#Then allocations itself, number after name shows how many combinations are there
#
BioAllocations 10
#All All All spruce
0 0 0 1
#stem share
11 0.3852 0.4743 0.5622 0.6165 0.6424 0.6497 0.6443 0.6388 0.6339 0.6280 0.6188
#branches share
11 0.3487 0.2561 0.1725 0.1295 0.1105 0.1043 0.1056 0.1082 0.1112 0.1153 0.1211
#coarse roots share
```

```
11 0.0496 0.0905 0.1366 0.1545 0.1630 0.1701 0.1787 0.1853 0.1901 0.1943
0.1994
#fine roots share
11 0.0500 0.0413 0.0297 0.0230 0.0194 0.0175 0.0165 0.0156 0.0150 0.0144
0.0140
#foliage share
11 0.1665 0.1378 0.0990 0.0765 0.0647 0.0584 0.0549 0.0521 0.04980 0.0480
0.0467
#All All All Fir
0 0 0 2
(...)
#
#Now litter production parameters
#
#Age classes
LitterAgeLims 1
#All All All All
0 0 0 0
7 20 40 60 80 100 120 1000
#
#Then litter production itself, number after name shows how many
combinations are there
#
LitterProduction 10
#All All All spruce
0 0 0 1
#stem
7 0.0043 0.0043 0.0043 0.0043 0.0043 0.0043 0.0043
#branches
7 0.0270 0.0270 0.0270 0.0270 0.0270 0.0270 0.0270
#coarse roots
7 0.0270 0.0270 0.0270 0.0270 0.0270 0.0270 0.0270
#fine roots
7 0.641 0.641 0.641 0.641 0.641 0.641 0.641
#foliage
7 0.25 0.25 0.25 0.25 0.25 0.25 0.25
#All All All Fir
0 0 0 2
(...)
#Share of coarse roots going to coarse woody litter
WLCoarseRootsShare 1
#All All All All
0 0 0 0
1 0
#
#The end
```

Box 3.3: Extract from the file biocomp.txt for Czech Republic. Part of the data has been left out for clarity, indicated by (…).

3.2.4 Matrix file

In the matrix file (***.aer), the initial area distribution over age and volume classes is defined per forest type. The area is given in units of 1000 ha. The columns represent age classes, the rows volume classes. The first row is reserved for the bare forest land class. The second row shows the area in the first volume class per age class. This file is usually generated with help of the P-2009 tool (see Schelhaas et al. 2007 for details).

An example for Czech Republic is given in Box 3.4.

```
#EFISCEN input file
#volume classes are in the file:
cze.vcl
#First how many
140
# REG OWNER SITE SPECIES
# cze : ST   1  REG   1,  KAT   1,  BON   1,  TRSL   1
1 1 1 1
9.318 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
0.000 0.000 0.000 0.000
2.064 2.051 0.748 0.299 0.084 0.000 0.000 0.000 0.000 0.000 0.000 0.000
0.000 0.000 0.002 0.001
0.000 2.181 0.943 0.837 1.228 0.844 0.428 0.097 0.000 0.000 0.000 0.000
0.006 0.000 0.004 0.002
0.000 0.000 0.625 0.855 1.606 1.644 1.588 1.712 1.054 0.586 0.293 0.126
0.035 0.009 0.005 0.003
0.000 0.000 0.461 0.536 1.294 1.495 1.527 1.695 1.312 0.693 0.305 0.133
0.029 0.010 0.004 0.002
0.000 0.000 0.000 0.238 0.724 0.963 1.100 1.360 1.047 0.550 0.245 0.105
0.023 0.008 0.002 0.001
0.000 0.000 0.000 0.088 0.295 0.459 0.589 0.802 0.657 0.349 0.156 0.068
0.014 0.005 0.001 0.001
0.000 0.000 0.000 0.055 0.128 0.180 0.244 0.366 0.323 0.175 0.079 0.035
0.007 0.003 0.001 0.000
0.000 0.000 0.000 0.030 0.089 0.108 0.119 0.158 0.137 0.075 0.034 0.016
0.003 0.001 0.000 0.000
0.000 0.000 0.000 0.008 0.044 0.071 0.086 0.106 0.083 0.044 0.020 0.009
0.002 0.001 0.000 0.000
0.000 0.000 0.000 0.001 0.013 0.034 0.061 0.103 0.097 0.056 0.026 0.012
0.003 0.001 0.000 0.000
# cze : ST   1  REG   1,  KAT   1,  BON   1,  TRSL   2
1 1 1 2
0.089 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
0.000 0.000 0.000 0.000
0.022 0.053 0.011 0.008 0.009 0.000 0.000 0.000 0.000 0.000 0.000 0.000
0.000 0.000 0.002 0.001
0.000 0.044 0.016 0.018 0.035 0.035 0.020 0.020 0.015 0.019 0.017 0.009
0.009 0.005 0.002 0.001
0.000 0.000 0.013 0.019 0.040 0.042 0.046 0.048 0.042 0.036 0.025 0.021
0.009 0.006 0.002 0.001
0.000 0.000 0.007 0.013 0.032 0.039 0.040 0.041 0.035 0.030 0.021 0.016
0.008 0.005 0.002 0.001
0.000 0.000 0.004 0.007 0.018 0.025 0.029 0.030 0.026 0.022 0.015 0.012
0.006 0.004 0.001 0.001
0.000 0.000 0.000 0.003 0.008 0.013 0.016 0.017 0.016 0.013 0.009 0.008
0.004 0.002 0.001 0.000
0.000 0.000 0.000 0.001 0.004 0.005 0.007 0.008 0.008 0.007 0.005 0.004
0.002 0.001 0.000 0.000
0.000 0.000 0.000 0.001 0.002 0.003 0.004 0.004 0.004 0.003 0.002 0.002
0.001 0.001 0.000 0.000
0.000 0.000 0.000 0.000 0.001 0.002 0.003 0.003 0.002 0.002 0.001 0.001
0.001 0.000 0.000 0.000
0.000 0.000 0.000 0.000 0.001 0.002 0.002 0.003 0.003 0.003 0.002 0.002
0.001 0.001 0.000 0.000
# cze : ST   1  REG   1,  KAT   1,  BON   1,  TRSL   3
1 1 1 3
(...)
```

Figure 3.4: First part of the file containing the initial matrices for Czech Republic (cze.aer).

3.2.5 Volume class file

The volume class file (***.vcl) defines the limits of the volume classes for each forest type. The unit in which volumes are provided is m^3 over bark ha^{-1}. This file is usually generated with help of the P-2009 tool (see Schelhaas et al. 2007 for details).

An example for Czech Republic is given in Box 3.5. In the example, the maximum volume of the first volume class in the matrix 1 1 1 1 is 130 m^3ha^{-1}, the volume in the second volume class in the same matrix ranges from 131 to 260 m^3ha^{-1}.

```
#EFISCEN input file
#First how many
140
# REG OWNER SITE SPECIES
# cze : ST   1  REG   1,  KAT   1,  BON   1,  TRSL   1
1 1 1 1
      130.
      260.
      391.
      522.
      654.
      786.
      918.
     1051.
     1184.
     1317.
# cze : ST   1  REG   1,  KAT   1,  BON   1,  TRSL   2
1 1 1 2
      125.
      251.
      377.
      504.
      631.
      759.
      888.
     1017.
     1147.
     1278.
# cze : ST   1  REG   1,  KAT   1,  BON   1,  TRSL   3
1 1 1 3
(...)
```

Box 3.5: First part of the file containing the limits of the volume classes for Czech Republic (cze.vcl).

3.2.6 Soil file

The soil file (***-soil.par) contains all parameters needed by the soil carbon sub-module YASSO. EFISCEN requires soils to be defined for every region and species; soils for owner-classes and site-classes may be aggregated in one pool for all owner-classes and one pool for all site-classes.

There are two ways of initialising soil carbon stocks in EFISCEN. One way is to define the stocks for all litter compartments (as total carbon in the forest type, Gg C); the other way is to run a spin-up. In the spin-up, the litter input of the first time step will be used as input to YASSO, and then YASSO is run repeatedly until the stocks are in balance. The spin-up will run automatically if the initial stocks are set to 0. Values need to be separated using spaces, not tabs or commas. All parameters are specified in Table 3.4.

Table 3.4: Description of input variables in the soil file (***-soil.par)

Parameter	Explanation	Unit
coarse wl	Initial carbon stock in coarse woody litter compartment	Gg C
fine wl	Initial carbon stock in fine woody litter compartment	Gg C
non wl	Initial carbon stock in non-woody litter compartment	Gg C
soluble	Initial carbon stock in soluble compunds compartment	Gg C
cellulose	Initial carbon stock in cellulose compartment	Gg C
lignin	Initial carbon stock in lignin-like compartment	Gg C
humus1	Initial carbon stock in faster humus compartment	Gg C
humus2	Initial carbon stock in slower humus compartment	Gg C
acwl	Exposure rates of coarse woody litter to microbial decomposition	$year^{-1}$
afwl	Exposure rates of fine woody litter to microbial decomposition	$year^{-1}$
anwl	Exposure rates of non-woody litter to microbial decomposition	$year^{-1}$
ksol	Decomposition rate of soluble compounds	$year^{-1}$
kcel	Decomposition rate of cellulose compounds	$year^{-1}$
klig	Decomposition rate of lignin-like compounds	$year^{-1}$
khum1	Decomposition rate of faster humus	$year^{-1}$
khum2	Decomposition rate of slower humus	$year^{-1}$
psol	Proportion of mass in extractives transferred to lignin-like compounds	-
pcel	Proportion of mass in celluloses transferred to lignin-like compounds	-
plig	Proportion of mass in lignin-like compounds transferred to faster humus	-
phum	Proportion of mass in faster humus transferred to slower humus	-
cw2cel	Proportion of mass in coarse woody litter transferred to cellulose compartment	-
cw2sol	Proportion of mass in coarse woody litter transferred to soluble compartment	-
fw2cel	Proportion of mass in fine woody litter transferred to cellulose compartment	-
fw2sol	Proportion of mass in fine woody litter transferred to soluble compartment	-
nw2cel	Proportion of mass in none woody litter transferred to cellulose compartment	
nw2sol	Proportion of mass in none woody litter transferred to soluble compartment	
chum1	Temperature-moisture dependence parameter for faster humus decomposition	
chum2	Temperature-moisture dependence parameter for slow humus decomposition	

An example for Czech Republic is given in Box 3.6.

```
#Parameter file for EFISCEN (soil), country Czech Republic
#we assume to have soils different by regions and species (14 region 10
species in the Czech)
#so 140 soils should be defined here
soils 140
#Brenensky spruce
1 0 0 1
#initial storages, just in case
#coarse wl, fine wl, non wl, soluble, cellulose, lignin, humus1, humus2
0 0 0 0 0 0 0 0
#decomposition rates
#acwl afwl anwl ksol kcel klig khum1 khum2
0.053 0.54 1.0 0.48 0.3 0.22 0.012 0.0012
#transfer proportions
#psol pcel plig phum
0.2 0.2 0.2 0.2
#Litter composition (NOTE we'll not use toLignin rate)
#cw2cel cw2sol fw2cel fw2sol nw2cel nw2sol
0.69 0.03 0.65 0.03 0.51 0.27
#Climate dependence parameters
#chum1 chum2
0.6 0.36
```

```
#Brenensky Fir
1 0 0 2
#initial storages, just in case
#coarse wl, fine wl, non wl, soluble, cellulose, lignin, humus1, humus2
11.858496  3.251946  4.305259  1.909438  10.570659  10.199889  43.054897
94.701881
#decomposition rates
#acwl afwl anwl ksol kcel klig khum1 khum2
0.053 0.54 1.0 0.48 0.3 0.22 0.012 0.0012
#transfer proportions
#psol pcel plig phum
0.2 0.2 0.2 0.2
#Litter composition (NOTE we'll not use toLignin rate)
#cw2cel cw2sol fw2cel fw2sol nw2cel nw2sol
0.69 0.03 0.65 0.03 0.51 0.27
#Climate dependence parameters
#chum1 chum2 (really in efiscen chum1=0.6 and chum2=0.36, i.e chum1**2)
0.6 0.36
#Brenensky pine
1 0 0 3
(…)
```

Box 3.6: First part of the soil parameter file for Czech Republic.

3.3 Scenario input files

3.3.1 Scenario definition file

In the scenario definition file (***.scn) the file names of the forest growth change file (in case of environmental change scenarios), soil climate, removal demand, removal ratio, afforestation, deforestation, tree species change, matrix scaling, thinning change and final felling change scenarios are given. In case a user does not include tree species change, matrix scaling, thinning change and final felling change as scenario options, it is sufficient to provide only the statement 'nofile' instead of the file name. All parameters are specified in Table 3.5.

Table 3.5: Description of input variables in scenario definition file (***.scn)

Parameter	Explanation	Unit
Scenario_name	Name of scenario	-
Forest growth scenario file	Name of forest growth scenario	-
Soil climate scenario file	Name of soil climate scenario	-
Removal demand scenario file	Name of removal demand scenario file	-
Removal ratio definition scenario	Name of removal ratio definition file	-
Afforestation scenario file	Name of afforestation scenario file	-
Deforestation scenario file	Name of deforestation scenario file	-
Tree species change file	Name of tree species change file	-
Matrix scaling file	Name of matrix scaling file	-
Thinning change	Name of thinning change file	-
Felling change	Name of felling change file	-

Box 3.7 gives an outline of the scenario definition file.

```
#Efiscen_scenario file
#name
Current climate baseline harvest
#Forest growth scenario file
Name of forest growth scenario
```

```
#Soil climate scenario file
Name of soil climate scenario
#removal demand scenario file
Name of removal demand scenario file
#removal ratio definition scenario
Name of removal ratio definition file
#afforestation scenario file
Name of afforestation scenario file
#deforestation scenario file
Name of deforestation scenario file
#tree species change file
name of tree species change file
#matrix scaling file
name of matrix scaling file
#thinning change
name of thinning change file
#felling change
name of felling change file
#END
```

Box 3.7: Outline of the scenario definition file.

3.3.2 Forest growth scenario file

In the forest growth scenario file (***_defgrow.csv), the impact of environmental changes on tree growth can be defined. For each region, tree species, owner class, site class and time step, a ratio can be defined by age classes which will then be used to scale the increment. For example, 1.1 means an increment increase of 10%. If no changes are to be implemented, all ratios should be set to 1. All parameters are specified in Table 3.6.

Table 3.6: Description of input variables in the forest growth scenario file (***_defgrow.csv)

Parameter	Explanation	Unit
growth_ratio_age	Age classes for growth ratio	year
growth_ratio	Ratio defining changes in growth rates due to environmental change	-

Box 3.8 provides an example of the outline of the forest growth scenario file. The name of the applied scenario is “Fast Climate Change”. The number 1 in the next line defines the number of groups (i.e. combinations of regions, site classes etc.) for which separate age limits are given. The next block defines the age class limits for the growth change impacts. Then, 3 blocks of parameters are provided. The first block applies up to time step 2 (first line of block). The growth change is defined for each of the two species separately, but there is no growth change in this period. For time steps 3-6, the two species react differently. For example, in age class 41-60, species 1 has a 20% increment increase and species 2 only a 10% increase. The last block applies to time steps 7-10 and shows even more pronounced increment changes, up to 50% of the baseline increment in old forests of species 2. Input is provided as comma separated text files (.csv).

```
Forest grow scenario file
here we provide Name of scenario and then number of parameters i.e. for how
many groups scenarios are given
Fast Climate Change
1
Comments line 0 0 0 0 means for all: Age limits
0,0,0,0
7,20,40,60,80,100,160,300
num_Step,Gr_0000
```

```
2
2
0,0,0,1
7,1,1,1,1,1,1,1
0,0,0,2
7,1,1,1,1,1,1,1
6
2
0,0,0,1
7,1.1,1.1,1.2,1.2,1.2,1.2,1.2
0,0,0,2
7,1.1,1.1,1.1,1.2,1.3,1.3,1.3
10
2
0,0,0,1
7,1.2,1.3,1.3,1.3,1.3,1.3,1.3
0,0,0,2
7,1.3,1.4,1.5,1.5,1.5,1.5,1.5
```

Box 3.8: Example of the growth change file.

3.3.3 Soil climate scenario file

In the soil climate scenario file (***_defsoil.csv), the climate dependency parameters are defined and the assumed climate during the simulation. The user should note that the parameters in this file are not used when the model is executed without specifying a scenario. In that case, default values are used (α_1 = 0.0937, α_2 = 0.00229, T = T_{ref} = 4, D = D_{ref} = -50). The climate dependency parameters α_1 and α_2 depend on the method how to express the climate dependency: dependent on average annual temperature or on cumulative degree days (see Table 3.3 in Schelhaas et al. 2007). Also the reference conditions need to be listed. The required climate data are either average annual temperature or cumulative degree days (DD, with a threshold of 0°C) and the summer drought index (DI). They can be defined for each region and time step. The summer drought index is defined as precipitation (in the growing season) minus potential evaporation (in the growing season). If the drought index is positive (e.g. precipitation exceeds potential evaporation), it is set to zero assuming that drought does not limit decomposition processes. Input is provided as comma separated text files (.csv). All parameters are specified in Table 3.7.

Table 3.7: Description of input variables in the soil climate scenario file (***_defsoil.csv)

Parameter	Explanation	Unit
α1	Temperature sensitivity	°C days^{-1}
α2	Drouht sensitivity	mm^{-1}
Tref	Reference effective temperature sum in the growing season (0 °C threshold)	°C days
Dref	Reference drought index (precipitation minus potential evapotranspiration from May to September)	mm
DD	Effective temperature sum in the growing season (0 °C threshold)	°C days
DI	Drought index (precipitation minus potential evapotranspiration from May to September)	mm

Box 3.9 shows part of the soil climate scenario file for the Czech Republic, with climate defined per region, assuming a constant climate over the simulation.

```
Soil climate scenario file
here we provide number of parameters i.e. for how many groups scenarios are
given
0.000387,0.00325,1903,-32
```

```
with degree days (threshold 0 degrees)
14
Comments line 0 0 0 0 means for all
1,0,0,0,2,0,0,0,(...)
num_Step,DD_Brenensky,DI_Brenensky,DD_Budejovicky,DI_Budejovicky,DD_Jihla
vsky,DI_Jihlavsky,(...)
100,3070.272,-55.409,2820.764,-18.1063,3070.272,-55.409,(...)
```

Box 3.9: Part of the soil climate scenario file for Czech Republic.

3.3.4 Wood removal demand scenario file

In the wood removal demand scenario file (***_defcut.csv), the amount of roundwood to be removed from the forest is specified. Removal amounts can be defined for the total country, or by region, owner and site class as well as tree species for each time step, separately for thinnings and final fellings. Units are 1000 m^3 overbark per time step. All parameters are specified in Table 3.8.

Table 3.8: Description of input variables in the wood removal demand scenario file (***_defcut.csv)

Parameter	Explanation	Unit
Felling	Amount of roundwood to be removed from forest during final fellings	1000 m3 over bark time $step^{-1}$
Thinning	Amount of roundwood to be removed from forest during thinnings	1000 m3 over bark time $step^{-1}$

In the example in Box 3.10, 9 million m^3 of roundwood removals are requested from final fellings in each of the first two time steps, and 3 million m^3 removals from thinnings. Note that the actual felled volume in the forest will be higher, depending on the ratio removals/fellings that is specified in the removal ratio file. Input is provided as comma separated text files (.csv).

```
Forest harvest scenario file
Comments
baseline
number of combinations
1
Comments line 0 0 0 0 means for all
0,0,0,0
num_Step,Felling,Thinning
2,9000,3000
4,9100,3050
```

Box 3.10: Example of a harvest demand scenario file.

3.3.5 Removal ratio scenario file

The removal ratio scenario file (***_defrems.csv) defines the proportion of the stems, topwood, standing deadwood, branches and foliage that is removed from the forest, separately for thinnings and final fellings. It is possible to define those proportions for each forest type. Residues that are not extracted are left on site to decompose, as estimated by the soil module YASSO. If standing deadwood is not removed and will fall down following the deadwood fall rate specified in section 3.2.2. Input is provided as comma separated text files (.csv). All parameters are specified in Table 3.9.

Table 3.9: Description of input variables in the removal ratio scenario file (***_defrems.csv)

Parameter	Explanation	Unit
fel_stem	Proportion of roundwood removed from the forest from the amount that is felled during final fellings	-
fel_tops	Proportion of stem tops to be extracted as logging residues during final fellings	-
fel_branches	Proportion of branches to be extracted as logging residues during final fellings	-
fel_leaves	Proportion of foliage to be extracted as logging residues during final fellings	-
fel_dwood	Proportion of standing deadwood to be removed during final fellings	-
thin_stem	Proportion of roundwood removed from the forest from the amount that is felled during thinnings	-
thin_tops	Proportion of stem tops to be extracted as logging residues during thinnings	-
thin_branches	Proportion of branches to be extracted as logging residues during thinnings	-
thin_leaves	Proportion of foliage to be extracted as logging residues during thinnings	-
thin_dwood	Proportion of standing deadwood to be removed during thinnings	-

The user should note that the parameters in this file are not used when the model is executed without specifying a scenario. In that case default values are used: removal rate for final fellings 0.95, removal rate for thinnings 0.9 and no removal of topwood, deadwood branches or foliage.

In the example in Box 3.11, 90% of the stem is removed in the case of final fellings, and 94% in the case of thinnings. The remaining 10% for final fellings and 6% for thinnings is considered topwood, of which an additional 50% is extracted as thinning or felling residue. The remaining 50% is assumed to be left on site to decompose, as estimated by the soil module YASSO. Furthermore, 36% of branches and foliage is removed and the remaining branches and foliage are left on site to decompose, as estimated by the soil module YASSO.

```
Removals scenario file
here we Name of scenario, then provide number of parameters, i.e. for how
many groups scenarios are given
based on TBFRA
1
Comments line 0 0 0 0 means for all
0,0,0,0
num_Step,Fel_stem,fel_tops,Fel_branches,Fel_leaves,Fel_dwood,Thin_stem,Th
in_tops,Thin_branches,Thin_leaves,Thin_dwood
100,0.9,0.5,0.36,0.36,0,0.94,0.5,0.36,0.36,0
```

Box 3.11: Example of the definition of removal ratios file

3.3.6 Afforestation scenario

The afforestation scenario file (***_affor.csv) contains the area, and the associated soil carbon stock, to be added during each time step. Units are 1000 ha and Gg C per time step. The area for afforestation will be added to the bare forest land class of the respective forest type matrix or matrices. The area is distributed according to the area already present per forest type. Input is provided as comma separated text files (.csv). All parameters are specified in Table 3.10.

Table 3.10: Description of input variables in the afforestation scenario file (***_affor.csv)

Parameter	Explanation	Unit
affor_area	Area to be added to the bare forest land class	1000 ha time step^{-1}
affor_carbon	Carbon in soil of area to be added to the bare forest land class	Gg C

In the example of Box 3.12, total afforestation will be 18,200 ha, of which 12,900 ha distributed over the forest types in the first region, and 5,300 ha distributed over all forest types in the second region.

```
Forest afforestation scenario file
Comments (do not remove first two lines)
Afforestion scenario
2
Comments
1,0,0,0,2,0,0,0
Afforestation
2,0,0
4,12.9,5.3
5,4.1,0
```

Box 3.12: Example of the afforestation scenario file

3.3.7 Deforestation scenario file

The deforestation scenario file (***_defor.csv) contains the area to be subtracted from the class bare forest land. Areas for deforestation can be defined by region, owner class, site class and tree species. Units are 1000 ha per step. The area for deforestation will be removed from the bare forest land class(es) of the concerned matrices. Thus, deforestation can only take place after a regular final harvest has occurred. If there is not enough area in the bare land class, actual deforestation will simply be equal to the area in the bare land class. Further, all forest types should be covered, even when no deforestation occurs in those types. Soil carbon pools are not directly affected by deforestation, so in principle soil carbon of deforested areas is still included. Input is provided as comma separated text files (.csv). All parameters are specified in Table 3.11.

Table 3.11: Description of input variables in the wood removal demand scenario file (***_defcut.csv)

Parameter	Explanation	Unit
defor_area	Area to be subtracted from the class bare forest land	1000 ha time step^{-1}

In the example of Box 3.13, no deforestation takes place during the first five time steps, and in total 29,800 ha is removed from the bare forest land class of all forest types in time step 6. This total per five years is divided over the matrices according to their ratio in the final felled area.

```
Forest deforestation scenario file
Comments (do not remove first two lines)
Czech deforestation scenario
1
Comments
0,0,0,0
Deforestation
5,0
6,29.8
```

Box 3.13: Example of the deforestation scenario file

3.3.8 Species change file

With the tree species change file (***_sp_change.csv) it is possible to specify the proportion of the area of a tree species (or matrix), which after final felling should be regenerated by another species. If nothing is specified (‘nofile’ in the ***.scn file) then it is always assumed that the same species regenerates as there was before the final harvesting. Input is provided as comma separated text files (.csv). All parameters are specified in Table 3.12.

Table 3.12: Description of input variables in the tree species change file (***_sp_change.csv)

Parameter	Explanation	Unit
species_change	Proportion of the area of a tree species (or matrix), which after final felling should be regenerated by another species	-

The example in Box 3.14 shows that that for the next 100 time steps, species nr 3 will be regenerated to one other species. That species number is nr 8, and this will happen to 60% of all clearcuts of species nr 3.

```
First 4 lines for explanations
Species change scenario sample file
first we set for how many steps scenario
total number of steps in the scenario:
1
number of matrices(species) - who lost the area (source)
1
then step of simulation until the following changes are valid (as in any
scenario file)
100

region, owner, site, species of "source" and how many different tree species
are the "destination" species. On the next line: the number of the
destination species, and what fraction of regenerated area will change to
this new destination species.
1,1,1,3,1
8,0.6
```

Box 3.14: Example of the species change file

3.3.9 Matrix scaling file

The matrix scaling file (***_matrix_scaling.csv) allows scaling the EFISCEN input data of individual matrices to match another area, for example the area reported in international statistics. The scaling of individual matrices is combined with the overall scaling factor which is to be defined in the graphical user interface (section 4.1) or the command line (section 4.2). All parameters are specified in Table 3.13.

Table 3.13: Description of input variables in the matrix scaling file (***_matrix_scaling.csv)

Parameter	Explanation	Unit
matrix_scaling	Factor with which area in all cells of a specified matrix cells is multiplied when loading the initial input data to modify the forest area	-

If nothing is specified (‘nofile’ in the ***.scn file) then it is always assumed that matrices are not scaled individually (i.e. a scaling factor of 1 is assumed). If input is specified, the file is formatted so that the first two lines are always reserved for comments and are not processed by the input loader. The third line has the total number of entries in the file, and after that are the entries consisting of matrix id and a scaling value. The matrix id consists of four numbers identifying region, owner, site and species. The numbers are comma separated. Any of these numbers can be zero meaning all for that category. Setting the matrix id to 0,0,0,0 means scaling is applied to all matrices. Note that scaling is applied only once, before first step of simulation applied, which is different from other scenario files. Input is provided as comma separated values files (.csv). An example is shown in Box 3.14.

```
Matrix scaling file
Country name and scenario
49
1,0,0,1
0.113
1,0,0,2
0.121
```

Box 3.14: Example of the matrix scaling file

3.3.10 Thinning change file

The thinning change file (***_thin_change.csv) allows to define the minimum and maximum age for thinnings, which can change during the simulation. If nothing is specified ('nofile' in the ***.scn file) then the management parameters from the parameters file are used. If an input file is provided, EFISCEN will use information from that file. Input is provided as comma separated values files (.csv). All parameters are specified in Table 3.14.

Table 3.14: Description of input variables in the thinning change file (***_thin_change.csv)

Parameter	Explanation	Unit
thin_change_lower	Minimum age at which thinnings can be executed	-
thin_change_upper	Maximum age at which thinnings can be executed	-

In the example on Box 3.15, thinnings are carried out on forests between 20 and 75 years old until step 2, in steps 3 to 4 thinnings are carried out on forests between 20 and 50 years old and in steps 4-100 thinnings are carried out on forests between 20 and 70 years old.

```
Thinning parameter file
Here we provide number of parameters for how many groups scenarios are
given
Thinning range
1
Comments line 0 0 0 0 means for all
0,0,0,0
num_Step,thinning_l,thinning_h
2,20,75
4,20,50
100,20,70
```

Box 3.14: Example of thinning change file

3.3.11 Final felling change file

The final felling change file (***_fel_change.csv) allows to define the minimum age for final fellings, which can change during the simulation. If nothing is specified ('nofile' in the ***.scn file) then the management parameters from the parameters file are used. If an input file is provided, EFISCEN will use information form that file. Input is provided as comma separated values files (.csv). All parameters are specified in Table 3.15.

Table 3.15: Description of input variables in the final felling change file (***_fel_change.csv)

Parameter	Explanation	Unit
fell_change_age	Minimum age at which final fellings can start	-

In the example on Box 3.16, final fellings are carried out on forests older than 75 years old until step 2, in steps 3 to 4 final fellings are carried out in forests of at least 80 years old and in steps 4-100 final fellings are carried out in forests older than 75 years.

```
Final felling parameter file
Here we provide number of parameters, i.e. for how many groups scenarios
are given
felling range
1
Comments line 0 0 0 0 means for all
0,0,0,0
num_Step,ffelling
2,75
4,80
100,75
```

Box 3.15: Example of final felling change file

4. Model simulations

EFISCEN can be operated from a graphical user interface and using a command line.

4.1 Graphical user interface

To open the graphical user interface (GUI) of EFISCEN the user can go to the EFISCEN folder and create and use a shortcut (under Microsoft Windows). Alternatively, the GUI can be opened from the command line by typing in the command prompt:

```
java –jar Efiscen_guifx.jar
```

EFISCEN performs by design all outputs into comma separated value files (.csv) with comma (,) as list delimiter and dot (.) as decimal symbol. In some computer settings the comma is a decimal symbol. To avoid problems with outputs, two additional parameters must be added in the command line call. Those parameters will prevent EFISCEN4 from using the wrong local settings. It does not affect other applications or operating system itself.
The parameters are:

- Duser.language=US
- Duser.region=US

Then the command will look like this:

```
java -Duser.language=US -Duser.region=US –jar Efiscen_guifx.jar
```

When the GUI is opened and no data is loaded, many of the buttons are disabled. At the top of the window at the menu bar **File, Settings** and **About** are available. When no data is loaded **Open logs** is disabled. By choosing settings, filepaths and usernames for database can be saved. Settings are saved in a text file “settings.txt”, located in the same folder as Efiscen.jar. When the output-window is opened, these settings are loaded to the respective fields by default. The option to save settings is only available in GUI. An example of a settings file is shown in Box 4.1.

```
inputpath=C:\foldername
outputpath=C:\foldername
```

Box 4.1: Example of settings file

Data can be loaded under the **File**-menu by choosing **Load files** (Figure 4.1). EFISCEN only accepts filenames ending with .efs or .scn. It is possible to select the experiment and scenario file to be loaded simultaneously by pressing the Ctrl-button when selecting the files. Experiments can be loaded without a scenario file.

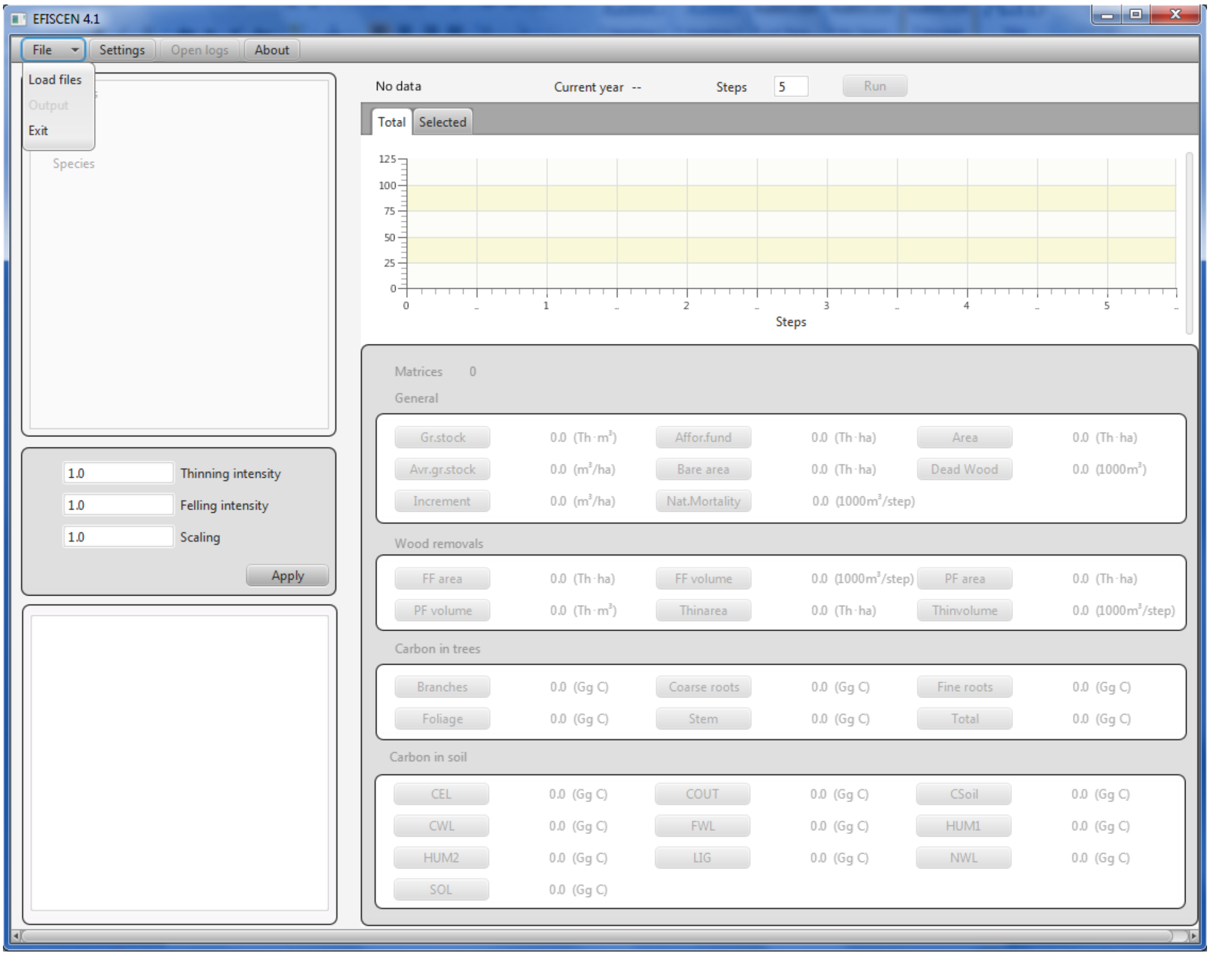

Figure 4.1: The interface at the program start. Before data is loaded many options are locked. Data can be loaded from File-menu.

After loading the experiment file some data is already shown. If EFISCEN runs into problems, it reports about them in the **console** (Figure 4.2, number 2). More info about these errors can be found in the log files, which can be found by pressing **Open logs** (Figure 4.2, number 3).

If the experiment file is loaded without any scenario**, thinning intensity** and **felling intensity** can be entered (Figure 4.2, number 4). This must be done before running the simulation or the changes will not take effect. When a scenario is loaded, thinning and felling intensity boxes are disabled. **Scaling** can be entered at any time and after clicking **Apply** scaling will be calculated immediately (Table 4.1).

Table 4.1: Description of input variables in the graphical user interface

Parameter	Explanation	Unit
Thinning intensity	Proportion of available felling potential that is actually felled	-
Felling intensity	Proportion of available thinning potential that is actually thinned	-
Scaling	Factor with which all area in all matrix cells is multiplied when-loading the initial input data to modify the forest area	

Simulations can be run by entering the number of **steps** (5 by default) and pressing **run** (Figure 4.2, number 5). The user can display graphs indicating various variables during the simulation by clicking **data buttons** under the graph (Figure 4.2, number 6). You can get more info about the buttons by placing the cursor on top of the button for a moment.

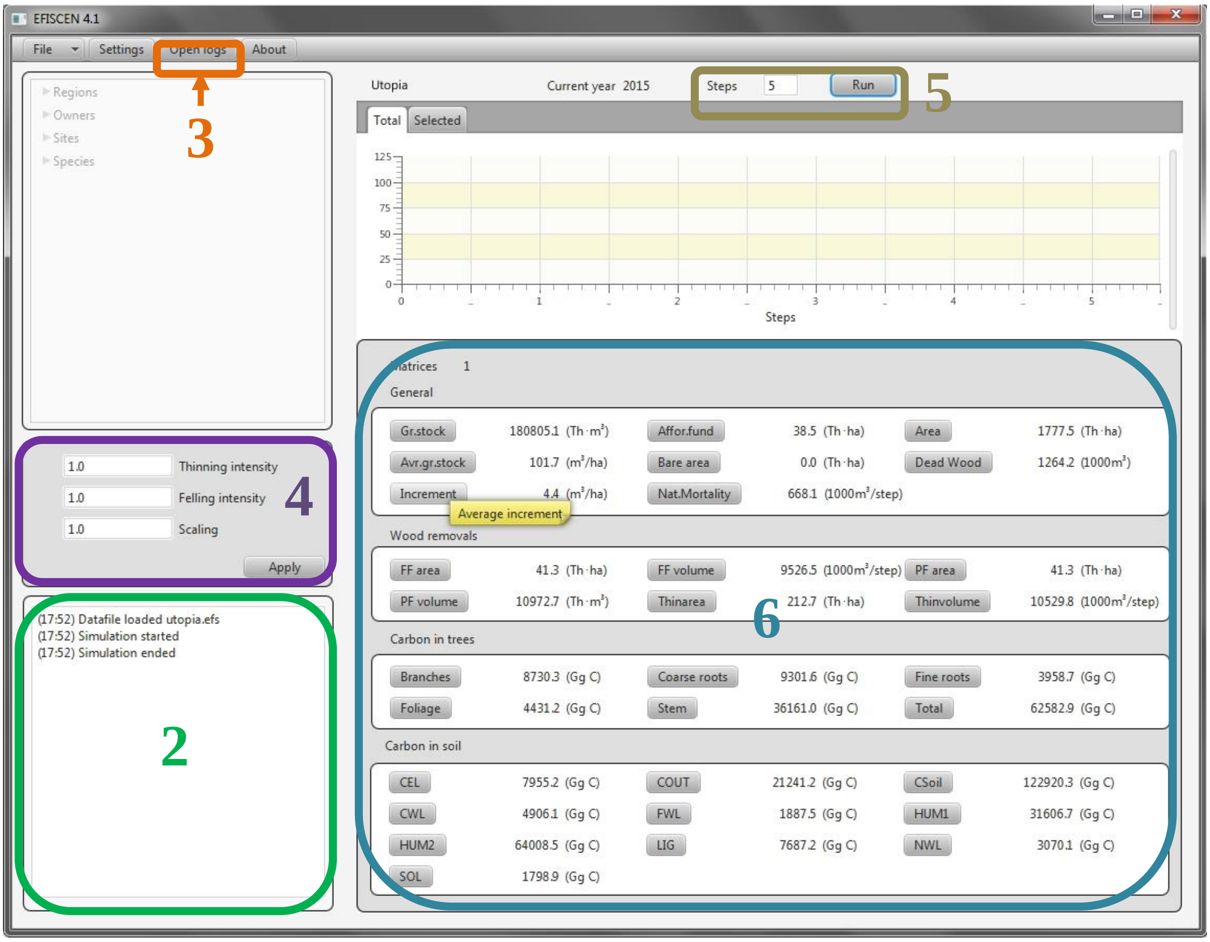

Figure 4.2: The interface after data is loaded and simulation has been run. Dead wood and national mortality have been chosen and are shown in the graph.

Under the **Selected** tab you can display graphs for different datasets (Figure 4.3, number 6). When you click the tab, a selection tree opens on the left (Figure 4.3, number 7). **Region**, **owner**, **site** and **species** can be expanded to show all the items under that category by clicking on the triangle next to them. Multiple entries can be selected on the lists by pressing *Ctrl-button* when clicking on the items. If nothing is selected under some category, for example owners-category, or the user has selected a category-box, then data is shown for all owners. Selection only affects what is shown in the selected data-tab, the total data-tab always shows values for the whole dataset.

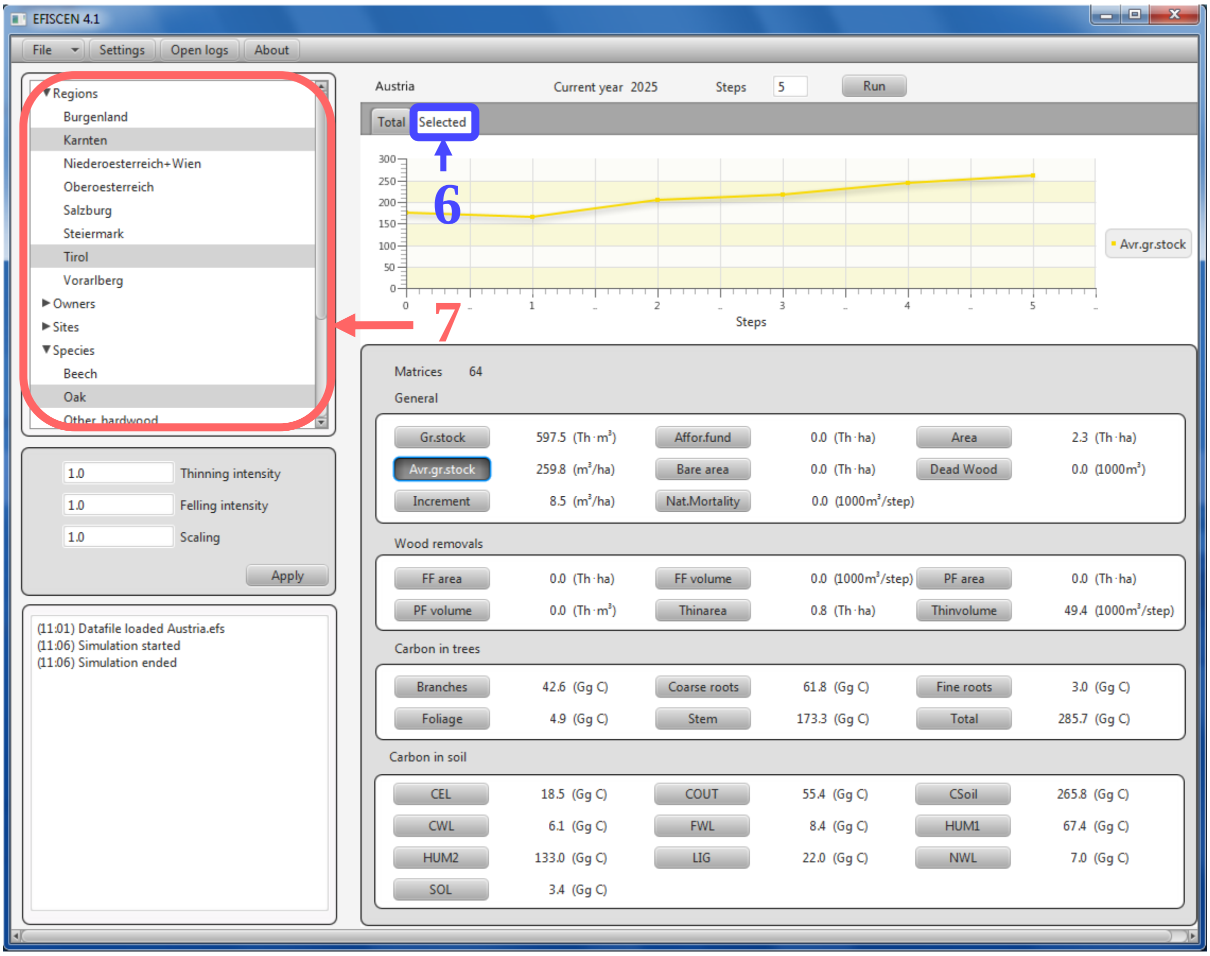

Figure 4.3: Selected –tab has been selected. Karnten and Tirol have been selected from Regions and Oak has been selected from Species. The results shown in the chart area and the data buttons show the aggregated results for Oak in Karnten and Tirol for all owners and age-classes.

Simulation results can be saved under **File**-menu by choosing **Output** (Figure 4.1). This opens the output window (Figure 4.4). Under the tab **Files** you can save results to files. From the selection tree on the right side of the window you can to select which outputs to save. Under the tab **Database**, it is possible to save output data to a database. Currently database types Microsoft Access, MySQL and PostgreSQL are supported (see section 3.5.3 for details).

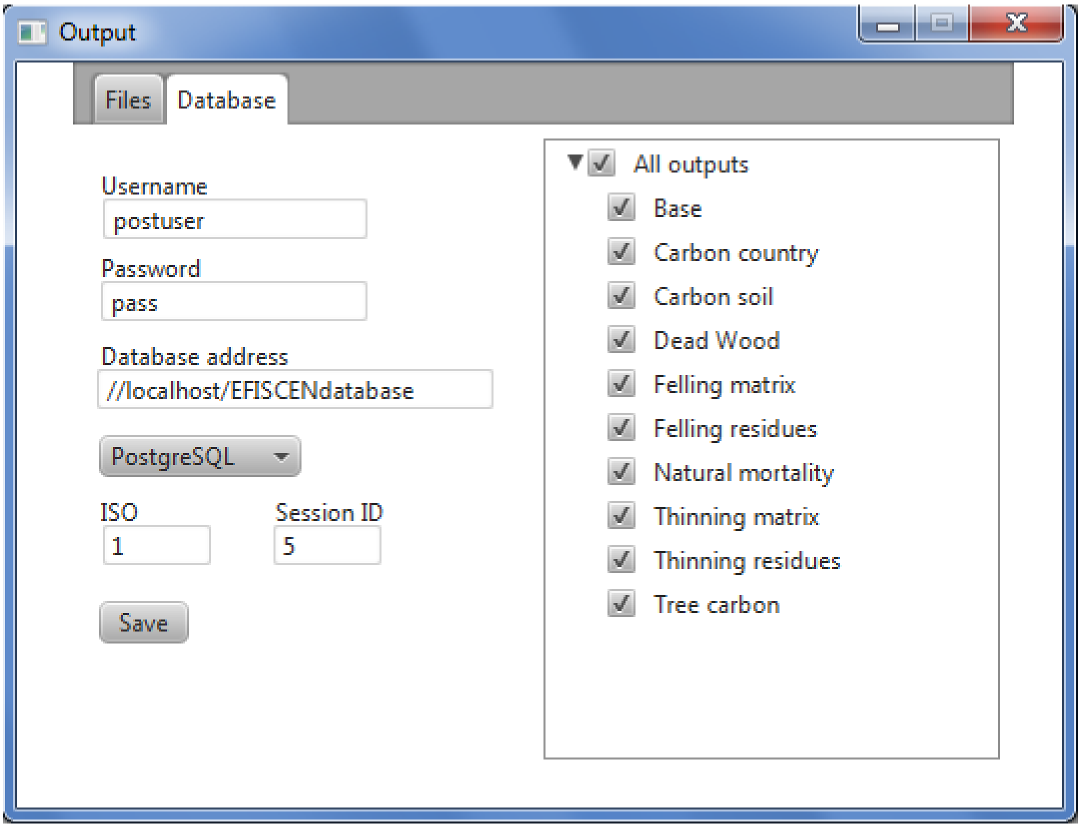

Figure 4.4: Output window. All data is selected to be saved to a PostgreSQL-database, which is running locally.

4.2 Command line

EFISCEN 4.1 can be used from the command line by opening the command prompt and then specifying the command:

```
java –cp Efiscen_guifx.jar int_.efi.efiscen.cli.EfiscenCLI variable1=argument1 variable2=argument2...
```

Where variable1, variable2 etc. are the argument variables and argument1, argument2 etc. are the values for these arguments.

EFISCEN 4.1 can provide outputs as comma separated value (csv) files or outputs can directly be saved to an external database. In both approaches, it is possible to select which outputs should be saved. When running from the command line the user can select which outputs to save by using a simple text file. The name of the text file is given as a parameter to the command line interface. Outputs are defined with a name and either 1 or 0. 1 means the output will be saved while 0 means it is not. If an output name is not present in the file, then it will not be saved. If outputs are saved both into database and files the selections in the text file apply to both, meaning that only the selected outputs are saved. The output file must have ".txt" – extension to work properly.

Table 4.1: Output options

Output name	Description
base	general data
carbon_country	carbon country data
carbon_soil	carbon soil data
gdat	general by regions (note: this table is not saved into database even if it is specified)
gspec	general by species (note: this table is not saved into database even if it is specified)
deadwood	deadwood data (note: this table is not saved into database even if it is specified)
felling_matrix	felling matrix data even if it is specified
felling_residues	felling residue data
natmort	natural mortality
thinning_matrix	thinning matrix data
thinning_residues	thinning residue data
treec_matrix	tree carbon data

An example of an output selection file is given in Box 4.2.

```
base 1
carbon_country 0
carbon_soil 1
gdat 1
gspec 1
deadwood 1
felling_matrix 1
felling_residues 1
natmort 1
thinning_matrix 0
thinning_residues 1
treec_matrix
```

Box 4.2: Example of an output selection file

4.2.1 Arguments for running EFISCEN and saving outputs as files

When running EFISCEN from command line and saving simulation results to a file, there are 6 required arguments and 2 optional arguments (Table 4.2).

Table 4.2: Command line arguments to run EFISCEN and saving results as files

Variable name	Description	Type	Required/Optional
1. steps	Number of steps to run the simulation.	Integer	Required
2. thinning	Proportion of available felling potential that is actually thinned	Decimal number	Required
3. felling	Proportion of available felling potential that is actually felled	Decimal number	Required
4. experiment	File path to an experiment file. Must include the file name	Text	Required
5. scaling	Factor with which all area in all matrix cells is multiplied when loading the initial input data to modify the forest area	Decimal number	Required
6. scenario	File path to a scenario file. The scenario file name must end with ".scn". Path must include the file name.	Text	Optional
7. outputfile	File path to where the output files will be saved. Path must include a file name (for example C:\Folder\FileName would save the outputs in C:\Folder\ and the files would have names starting with FileName).	Text	Required
8. selected	File path to a text file containing definitions about which outputs to save. The name must end with ".txt".	Text	Optional

The following example shows how to run EFISCEN tool from the command line with only the required parameters.

```
java –cp Efiscen_guifx.jar int_.efi.efiscen.cli.EfiscenCLI steps=2 thinning=1.0
felling=1.5 experiment=C:\Path\Utopia.efs scaling=1.0
outputfile=C:\OutputPath\Utopia
```

The next example has all the required and optional parameters used.

```
java –cp Efiscen_guifx.jar int_.efi.efiscen.cli.EfiscenCLI steps=2 thinning=1.0
felling=1.0 experiment=C:\Path\Utopia.efs scaling=1.0 scenario=C:\Path\Utopia.scn
outputfile=C:\OutputPath\Utopia selected=C:\Path\selections.txt
```

In case a file path or database address has spaces in them, quotation marks can be used to enter them (e.g. "C:\Path\name with spaces.efs").

4.2.2 Arguments for running EFISCEN and saving to database

The command lines arguments to run EFISCEN and save results in a database are shown in Table 4.3.

Table 4.3: Command line arguments to run EFISCEN and saving results in a database

Variable name	*Description*	*Type*	*Required/Optional*
1. steps	Number of steps to run the simulation.	Integer	Required
2. thinning	Proportion of available felling potential that is actually thinned	Decimal number	Required
3. felling	Proportion of available felling potential that is actually felled	Decimal number	Required
4. experiment	File path to an experiment file. File name must be included.	Text	Required
5. scaling	Factor with which all area in all matrix cells is multiplied when loading the initial input data to modify the forest area	Decimal number	Required
6. scenario	File path to a scenario file. The file name must be included and the name must end with ".scn".	Text	Optional
7. outputfile	File path to where the output files will be saved. Path must include a file name (for example C:\Folder\FileName would save the outputs in C:\Folder\ and the files would have names starting with FileName).	Text	Optional
8. databaseaddress	Address to a database where outputs will be saved. In case ODBC drivers are used to connect to database, configured ODBC data source name can be entered as the database address. A PostgreSQL or MySQL database address is entered as follows: //database_address/database_name.	Text	Required
9. username	User name used to log into the database specified in the address.	Text	Required
10. password	Password used to log into the database specified in the address.	Text	Required
11. sid	Session id that will be present in all data entries saved into a database. Can be used for example to identify data from certain run of the EFISCEN tool.	Integer	Required
12. ciso	ISO country-code is used to identify that the output data concerns a certain country.	Integer	Required
13. selected	File path to a text file containing definitions about which outputs to save. The Path must include the file name and the name must end with ".txt". The same selections are used for saving outputs to files and to a database. If this file is not used then all outputs are saved.	Text	Optional
14. pid	Project id that can be used to group simulations together. If this is not entered, project id will be set as 0.	Integer	Optional

Notice that you can save to either files or to a database or at both of these the same time. Just specify both outputfile and databaseaddress.

In case a file path or database address has spaces in them, quotation marks can be used to enter them. For example: experiment="C:\Path\name with spaces.efs".

The following example shows how to run EFISCEN tool from the command line with only the parameters required for database use.

```
java –cp Efiscen_guifx.jar int_.efi.efiscen.cli.EfiscenCLI steps=2 thinning=1.0
felling=1.0 experiment=C:\Path\Utopia.efs scaling=1.0
databaseaddress=mysql:mysql.database.com/database username=user password=password
sid=1 ciso=40
```

The next example runs EFISCEN and saves only the selected outputs to both database and files. All required and optional parameters are used.

```
java –cp Efiscen_guifx.jar int_.efi.efiscen.cli.EfiscenCLI steps=2 thinning=1.0
felling=1.0 experiment=C:\Path\Utopia.efs scaling=1.0 scenario=C:\Path\Utopia.scn
outputfile=C:\OutputPath\Utopia databaseaddress=mysql:mysql.database.com/database
username=user password=password sid=1 ciso=40 selected=C:\Path\selections.txt
pid=100
```

The following example demonstrates saving all outputs only to a database and a path to save output files is therefore not specified. Project id is not specified, so it will be set to 0 for this simulation.

```
java –cp Efiscen_guifx.jar int_.efi.efiscen.cli.EfiscenCLI steps=2 thinning=1.0
felling=1.0 experiment=C:\Path\Utopia.efs scaling=1.0 scenario=C:\Path\Utopia.scn
databaseaddress=mysql:mysql.database.com/database username=user password=password
sid=1 ciso=40
```

Database type is selected by prefixing the address with the type name. Valid type names are MYSQL, odbc and PostgreSQL. This example saves data into Access (odbc) database.

```
java –cp Efiscen_guifx.jar int_.efi.efiscen.cli.EfiscenCLI steps=2 thinning=1.0
felling=1.0 experiment=C:\Path\Utopia.efs scaling=1.0
databaseaddress:odbc:someOdbcDatabase username=user password=password sid=1
ciso=40
```

5. Model outputs

5.1 Conventions

The output of EFISCEN consists of a series of files, all starting with a user defined string (for example test1), here represented as *x*. 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 variables are given for the total area and some also per tree species and/or region. The output structure is the same for all countries, but the number of lines and/or columns might vary due to varying numbers of regions, owner classes, site classes and tree species.

All files are comma separated text files (.csv). They can be analysed in spreadsheet software like MS Excel, and they can be imported to database software for the management of a large number of output files and more advanced queries.

All variables concerning carbon start with a C, except for soil variables which always concern carbon. The term *trees* always refers to the total biomass of trees, including foliage, branches and roots.

5.2 Output as text files

5.2.1 Detailed volume output file

The detailed volume output file (x.csv) file contains detailed information on growing stock, increment and forest area per region, owner, site class, and tree species (Table 5.1). Forest area and volume per age classes is also given in this file. Bare forest land is not included in the lowest age class (0-10), but it is included in the total area.

Table 5.1: Description of variables in detailed volume output (x.csv) file

Column heading	Explanation	Unit
M_ID	Matrix ID number (for internal purposes)	
REG	Region	Number
OWN	Owner class	Number
ST	Site class	Number
SP	Species	Number
Step	Time step (end year)	Year
GrStock	Volume of growing stock	1000 m^3
Area	Forest area (including regeneration area (=bare forest land))	1000 ha
DeadWood	Volume of standing dead wood	1000 m^3
NatMort	Volume of natural mortality	1000 m^3 per time step
ThinHarvest	Volume of removals from thinnings	1000 m^3 per time step
FelHarvest	Volume of removals from final fellings	1000 m^3 per time step
FelAv	Volume of total removals (thinnings + final fellings) per ha	m^3 per ha
GrStockAv	Growing stock per ha	m^3 per ha
IncrAv	Net annual increment per ha	m^3 per ha
A_0 – 10	Forest area per 10 year age class	1000 ha
A_10 – 20		
…		
V_0 – 10	Growing stock per 10 year age class	1000 m^3
V_10 – 20		
…		

5.2.2 Volume output by regions

The volume output by regions file (x_gdat.csv) contains aggregated information on forest area, growing stock, increment and harvest for each region that is specified by the user in the input files (Table 5.2). Each row represents one time-step, where the first row shows the initial situation, the second row the state at the end of first time step etc. The first block of columns contains the results for the first region, characterised by the region name or its ID. The last set of columns refers to the totals at country level.

Table 5.2: Description of variables in olume output by regions (x_gdat.csv) file

Column heading	Explanation	Unit
Step	Time step (end year)	Year
Area	Forest area (including regeneration area (=bare forest land)	1000 ha
GrStock	Volume of growing stock	1000 m3
ThinHarvest	Volume of removals from thinnings	1000 m^3 per time step
FelHarvest	Volume of removals from final fellings	1000 m^3 per time step
FelAv	Volume of total removals (thinnings + final fellings) per ha	m^3 per ha per year
GrStockAv	Growing stock per ha	m^3 per ha
IncrAv	Net annual increment per ha	m^3 per ha per year
C_GrStock	Carbon in growing stocks	Gg C
C_DWood	Carbon in standing dead wood	Gg C
C_ThRem	Carbon removed in thinnings (including foliage and branches)	Gg C
C_FelRem	Carbon removed in final fellings (including foliage and branches)	Gg C

5.2.3 Volume output by tree species (x_gspec.csv)

The volume output by tree species file (x_gspec.csv) contains aggregated information on forest area, growing stock, increment and harvest for each tree species that is specified by the user in the input files (Table 5.3). Each row represents one time-step, where the first row shows the initial situation, the second row the state at the end of first time step etc. The first block of columns contains the results for the first tree species, characterised by its number as defined in the efs file. The last set of columns refers to the totals at country level.

Table 5.3: Description of variables in Volume output by tree species (x_gspec.csv) file

Column heading	Explanation	Unit
Step	Time step (end year)	Year
Area	Forest area (including regeneration area (=bare forest land)	1000 ha
GrStock	Volume of growing stock	1000 m3
ThinHarvest	Volume of removals from thinnings	1000 m^3 per time step
FelHarvest	Volume of removals from final fellings	1000 m^3 per time step
FelAv	Volume of total removals (thinnings + final fellings) per ha	m^3 per ha per year
GrStockAv	Growing stock per ha	m^3 per ha
IncrAv	Net annual increment per ha	m^3 per ha per year
C_GrStock	Carbon in growing stocks	Gg C
C_DWood	Carbon in standing dead wood	Gg C
C_ThRem	Carbon removed in thinnings (including foliage and branches)	Gg C
C_FelRem	Carbon removed in final fellings (including foliage and branches)	Gg C

5.2.4 Removals by age classes

The removals by age-class files for final fellings (x_fell_matr.csv) and thinnings (x_thin_matr.csv) give information on the total removal volume and removal volume and area by age-class from final fellings and thinnings (Table 5.4).

Table 5.4: Description of variables in removals by age classes files (x_fell_matr.csv and x_thin_matr.csv)

Column heading	Explanation	Unit
M_ID	Matrix ID number (for internal purposes)	
REG	Region	Number
OWN	Owner class	Number
ST	Site class	Number
SP	Species	Number
Step	Time step (end year)	Year
FelRem/ThinRem	Volume of removals from final fellings c.q. thinnings	1000 m^3 per time step
A_0 – 10 A_10 – 20 …	Forest area on which final fellings c.q. thinnings have been executed, by 10 year age class	1000 ha in time step
V_0-10, V_10-20 …	Volume of removals from final fellings c.q. thinnings by 10 year age class	1000 m^3 per time step

5.2.5 Natural mortality

The natural mortality file (x_natmort.csv) contains information on the amount of mortality that occurred and on the standing deadwood pool (Table 5.5).

Table 5.5: Description of variables in Natural mortality (x_natmort.csv) file

Column heading	Explanation	Unit
M_ID	Matrix ID number (for internal purposes)	
REG	Region	Number
OWN	Owner class	Number
ST	Site class	Number
SP	Species	Number
Step	Time step (end year)	Year
Nmort	Total volume of mortality	1000 m^3 per time step
DWood	Total volume of standing dead wood	1000 m^3
C_DWood	Carbon in standing dead wood	Gg C
DW_0 – 10 DW_10 – 20 …	Volume of standing dead wood by 10 year age class	1000 m^3
NM_0-10, NM_10-20 …	Volume of mortality by 10 year age class	1000 m^3 per time step

5.2.6 Detailed soil carbon output

The detailed soil carbon output file (x_carbon_soil.csv) contains detailed information on carbon in different soil compartments per region and tree species (Table 5.6)

Table 5.6: Description of variables in detailed soil carbon output (x_carbon_soil.csv) file

Column heading	Explanation	Unit
S_ID	Soil ID number (for internal purposes)	
REG	Region	Number
OWN	Owner class	Number
ST	Site class	Number
SP	Species	Number
Step	Time step (end year)	Years
C_Trees	Carbon in trees	Gg C
CWL	Carbon in coarse woody litter	Gg C
FWL	Carbon in fine woody litter	Gg C
NWL	Carbon in non-woody litter	Gg C
SOL	Carbon in soluble compounds	Gg C
CEL	Carbon in holocellulose	Gg C
LIG	Carbon in lignin-like compounds	Gg C
HUM1	Carbon in first humus compartment	Gg C
HUM2	Carbon in second humus compartment	Gg C
C_Soil	Total carbon stock in soil	Gg C
COUT	Carbon released to atmosphere (gross)	Gg C per year
LITIN	Litter input to soil carbon pool	Gg C per time step

5.2.7 Detailed tree carbon outputs

The detailed tree carbon output (x_treeC_matr.csv) file contains more detailed information on carbon in different tree compartments per region, owner class, site class and tree species (Table 5.7).

Table 5.7: Description of variables in detailed tree carbon output (x_treeC_matr.csv) file

Column heading	Explanation	Unit
M_ID	ID number	
REG	Region	Number
OWN	Owner class	Number
ST	Site class	Number
SP	Species	Number
Step	Time step (end year)	Year
C_Trees	Carbon in tree biomass	Gg C
C_St_0 - 10, ...	Carbon in stems per 10 year age class	Gg C
C_Br_0 – 10, ...	Carbon in branches per 10 year age class	Gg C
C_Lv_0 - 10, ...	Carbon in foliage per 10 year age class	Gg C
C_Cr_0 - 10, ...	Carbon in coarse roots per 10 year age class	Gg C
C_Fr_0 - 10, ...	Carbon in fine roots per 10 year age class	Gg C

5.2.8 Aggregated carbon outputs by country

The aggregated carbon output by country file (x_carbon_country.csv) contains aggregated information on carbon stocks in biomass and soil (Table 5.8). Time steps in rows, first row initial situation, second row state at the end of first time step etc.

Table 5.8: Description of variables in aggregated carbon output by country (x_carbon_country.csv) file

Column heading	Explanation	Unit
Step	Time step (end year)	Year
C_Trees	Carbon in total tree biomass	Gg C
C_Stem	Carbon in tree stems	Gg C
C_Leaves	Carbon in foliage	Gg C
C_Branches	Carbon in branches	Gg C
C_CRoots	Carbon in coarse roots	Gg C
C_FRoots	Carbon in fine roots	Gg C
CWL	Carbon in coarse woody litter	Gg C
FWL	Carbon in fine woody litter	Gg C
NWL	Carbon in non-woody litter	Gg C
SOL	Carbon in soluble compounds	Gg C
CEL	Carbon in Holocellulose	Gg C
LIG	Carbon in lignin-like compounds	Gg C
HUM1	Carbon in first humus compartment	Gg C
HUM2	Carbon in second humus compartment	Gg C
C_Soil	Total carbon in soil	Gg C
COUT	Carbon released to atmosphere (gross)	Gg C per year

5.2.9 Residues from management operations

The residues from management operations output files contain information on carbon quantities in stem, branch and foliage residues removed or added to the soil model during final fellings (x_fell_residues.csv) and thinnings (x_thin_residues.csv) (Table 5.9). Age class information is for now only available for residues from branches and foliage.

Table 5.9: Description of variables in Residues from management operations file

Column heading	Explanation	Unit
M_ID	Matrix ID number (for internal purposes)	
REG	Region	Number
OWN	Owner class	Number
ST	Site class	Number
SP	Species	Number
Step	Time step (end year)	Year
C_TopsRes	Carbon in stem residues added to the soil	Gg C
C_BrRes	Carbon in residues from branches added to the soil	Gg C
C_LvRes	Carbon in residues from foliage added to the soil	Gg C
C_TopsRem	Carbon removed in topwood residues	Gg C
C_BrRem	Carbon removed in branches residues	Gg C
C-LvRem	Carbon removed in foliage residues	Gg C
0 – 10 10 - 20	Carbon in residues from branches and foliage removed from the forest per 20 year age class	Gg C

5.3 Output database

Outputs can also directly be saved to an external database. The database needs to be created by the user, i.e. it is not created by the model. Databases that are currently supported are MySQL, PostgreSQL and Microsoft Access. A technical description of the tables and scripts to generate the required tables is available upon request from the developers.

EFISCEN 4.1 writes results in the tables listed in Table 3.13. These tables are the equivalents of the text files described in Tables 3.4 and 3.7-3.12. Values for IDs and steps must be *integers* and all other value types must be *float*.

Table 3.13: Overview of tables with simulation results

Table name	Description	Equivalent output file(s)
base	Basic results by matrix.	x.csv
natmort	Natural mortality results by matrix.	x_natmort.csv
carbonsoil	Carbon in the soils.	x_carbon_soil.csv
fellingmatrix	Felling results by matrix.	x_fell_matr.csv
thinningmatrix	Thinning results by matrix.	x_thin_matr.csv
treec	Carbon in the trees results by matrix.	x_treeC_matr.csv
fellresidues	Felling residues by matrix.	x_fell_residues.csv
thinresidues	Thinning residues by matrix.	x_thin_residues.csv
carboncountry	Carbon results by country.	x_carbon_country.csv
simulation	Simulation metadata description	-

EFISCEN prints simulation results to these tables. The table *simulation* contains metadata of one run. A unique identification number is given to simulation and IDs of scenario, country and project related to this simulation are saved. Description can be added later to make notes of the simulation run.

In addition to the simulation results tables, several look-up tables are part of the database (Table 3.14). Values for IDs are *integers* and descriptions are of the type *varchar*. The table 'matrix' is the only lookup table which EFISCEN writes to. Other lookup tables store relevant information about the simulation data, but EFISCEN does not alter these tables.

Table 3.14: Overview of look-up tables

Table name	Description
matrix	Region, owner, site and species for a country.
scenario	Scenario names and descriptions.
country	Information about EFICSEN countries.
species	Species information for countries.
owner	Owners information for countries.
region	Regions information for countries.
site	Sites information for countries.
countrygroup	List of groupings for countries.
countryregion	List of country regions.
project	List of project names and descriptions.

5.4 Error logs

When loading experiment and scenario files input loading process EFISCEN 4.1 writes three log files and they can be found in the two folders located at "C:\Users***\EFISCEN". In case the folders do not exist, they are created during the first run.

In the folder "logs", two log files start with the name of the country, followed by timestamp. Both log files are simple text files. The first file has "events" in its name and logs input loading processes events, mainly starting and finishing the reading of a file. The other has "errors" in its name and contains all the errors encountered by the input loading process. If using the graphical user interface the user is informed when errors are encountered during the loading.

In the folder "debug" a log file is created that contains information mainly useful for developers and is used for debugging purposes. Debug log is named by timestamp and inside the log information can be found about the files that caused the debug message.

6. Manual history

This manual is continuously being updated in accordance with improvements made to EFISCEN 4.1. This chapter contains an overview of improvements made to this manual.

Table 6.1: Overview of improvements made to this manual

Date	Improvements
17 June 2016	First version of the manual published

Improvements to EFISCEN 4.1 are reported at: https://github.com/EuropeanForestInstitute/efiscen

References

Böttcher, H., Verkerk, P.J., Gusti, M., Havlík, P., Grassi, G., 2012. Projection of the future EU forest CO2 sink as affected by recent bioenergy policies using two advanced forest management models. GCB Bioenergy 4, 773-783.

Crouzat, E., Mouchet, M., Turkelboom, F., Byczek, C., Meersmans, J., Berger, F., Verkerk, P.J., Lavorel, S., 2015. Assessing bundles of ecosystem services from regional to landscape scale: insights from the French Alps. Journal of Applied Ecology 52, 1145-1155.

Eggers, J., Lindner, M., Zudin, S., Zaehle, S., Liski, J., 2008. Impact of changing wood demand, climate and land use on European forest resources and carbon stocks during the 21st century. Global Change Biology 14, 1-16.

Elbersen, B., I. Staritsky, G. Hengeveld, M.J. Schelhaas, H. Naeff, H. Böttcher 2012. Atlas of EU biomass potentials. Deliverable 3.3: Spatially detailed and quantified overview of EU biomass potential taking into account the main criteria determining biomass availability from different sources. Biomass Futures. http://www.biomassfutures.eu/work_packages/WP3%20Supply/D_3_3__Atlas_of_technical_and_economic_biomass_potential_FINAL_Feb_2012.pdf

Hanewinkel, M., Cullmann, D.A., Schelhaas, M.-J., Nabuurs, G.-J., Zimmermann, N.E., 2013. Climate change may cause severe loss in the economic value of European forest land. Nature Climate Change 3, 203-207.

Karjalainen, T., Pussinen, A., Liski, J., Nabuurs, G.J., Eggers, T., Lapveteläinen, T., Kaipainen, T., 2003. Scenario analysis of the impacts of forest management and climate change on the European forest sector carbon budget. Forest Policy and Economics 5, 141-155.

Nabuurs, G., Pussinen, A., van Brusselen, J., Schelhaas, M., 2007. Future harvesting pressure on European forests. European Journal of Forest Research 126, 391-400.

Nabuurs, G.J., Paivinen, R., Schanz, H., 2001. Sustainable management regimes for Europe's forests - a projection with EFISCEN until 2050. Forest Policy and Economics 3, 155-173.

Nabuurs, G.-J., Schelhaas, M.-J., Pussinen, A., 2000. Validation of the European Forest Information Scenario Model (EFISCEN) and a projection of Finnish forests. Silva Fennica 34, 167-179.

Nilsson, S., O. Sallnäs and P. Duinker (1992). A report on the IIASA forest study: Future forest resources of Western and Eastern Europe, The Parthenon Publishing Group, UK.

Pussinen, A., Schelhaas, M.J., Verkaik, E., Heikkinen, E., Liski, J., Karjalainen, T., Päivinen, R., Nabuurs, G.J., 2001. Manual for the European Forest Information Scenario Model (EFISCEN 2.0). European Forest Institute, Joensuu, Finland, p. 49.

Sallnäs, O., 1990. A matrix model of the Swedish forest. Studia Forestalia Suecica 183, 23.

Schelhaas, M.-J., Eggers, J., Lindner, M., Nabuurs, G.J., Päivinen, R., Schuck, A., Verkerk, P.J., Werf, D.C.v.d., Zudin, S., 2007. Model documentation for the European Forest Information Scenario model (EFISCEN 3.1.3). Alterra report 1559 and EFI technical report 26. Alterra and European Forest Institute, Wageningen and Joensuu, p. 118.

Schelhaas, M.J., Hengeveld, G., Moriondo, M., Reinds, G.J., Kundzewicz, Z.W., ter Maat, H., Bindi, M., 2010. Assessing risk and adaptation options to fires and windstorms in European forestry. Mitigation and Adaptation Strategies for Global Change 15, 681-701.

Schelhaas, M.-J., Nabuurs, G.-J., Hengeveld, G., Reyer, C., Hanewinkel, M., Zimmermann, N., Cullmann, D., 2015. Alternative forest management strategies to account for climate change-induced productivity and species suitability changes in Europe. Regional Environmental Change 15, 1581-1594.

Seidl, R., Schelhaas, M.-J., Rammer, W., Verkerk, P.J., 2014. Increasing forest disturbances in Europe and their impact on carbon storage. Nature Climate Change 4, 806-810.

Thürig, E., Schelhaas, M.-J., 2006. Evaluation of a large-scale forest scenario model in heterogeneous forests: a case study for Switzerland. Canadian Journal of Forest Research 36, 671-683.

Verkerk, P.J., Anttila, P., Eggers, J., Lindner, M., Asikainen, A., 2011. The realisable potential supply of woody biomass from forests in the European Union. Forest Ecology and Management 261, 2007-2015.

Verkerk, P.J., Lindner, M., Zanchi, G., Zudin, S., 2011. Assessing impacts of intensified biomass removal on deadwood in European forests. Ecological Indicators 11, 27-35.

Verkerk, P.J., Mavsar, R., Giergiczny, M., Lindner, M., Edwards, D., Schelhaas, M.J., 2014. Assessing impacts of intensified biomass production and biodiversity protection on ecosystem services provided by European forests. Ecosystem Services 9, 155-165.