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EFORWOOD

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Deliverable PD2.5.2
Framework for the description of forest modelling tools currently available with identification of their ability to estimate sustainability indicators

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EFORWOOD

Sustainability Impact Assessment of the Forestry - Wood Chain

Deliverable PD 2.5.2

Framework for the description of forest modelling tools currently available with identification of their ability to estimate sustainability indicators

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Abstract

This deliverable is a working paper written with the objective to provide a methodology/framework for the description of forest modelling tools in a straightforward, simple and standardized way. This objective was achieved through the identification of the topics that should be described and of the options in relationship to each one of the selected topics. In the proposed framework, the information to be provided by users for each one of the topics can be text (for instance, model identification or region of applicability), however an effort has been made in order to provide most of the information by one-to-one or multiple selection from a list of items that can be easily implemented in the database. The present version of the framework – FORMODELS – is not definitive and it will be improved in an iterative way as new models are described.

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Sustainability Impact Assessment of the Forestry - Wood Chain

Executive Summary

The objective of this project deliverable is to propose a methodology/framework to describe forest modelling tools in a straightforward, simple and standardized way. Model description should clearly catalogue the ability of models to estimate sustainability indicators as well as the improvements needed in order to improve model performance in this respect. The ultimate objective is to provide the information about each model in a structured way that can be easily implemented into a relational database (FORMODELS database).

A previous inventory and description of existing growth models clearly showed the differences among models, not only in relation to model type and structure but also on the nomenclature used by the different researchers. Therefore, as a starting point, it was important to agree on definitions and terminology related to the forest modelling tools.

Most forest growth models, even if not published as such, have several publications related either with the development of some of the modules or with their integration into simulators and/or decision support systems. It was decided that the description of the models should not be a repetition of the related publications but rather a standardized characterization of several topics, such as model range of applicability, model type, description of model structure, etc, that can be easily stored in a relational database with free access. The data base should also identify most of the relevant publications as well as the description of their content.

The following topics, each with several sub-topics, were selected for the description of forest growth models:

1. Model identification
2. Modelling approach
3. Range of applicability
4. Model structure – modules for state variables
5. Model structure – sub-modules for natural processes
6. Model structure – sub-modules for silvicultural practice
7. Model structure - sub-modules for environmental driving variables
8. Inputs
9. Outputs
10. Stand simulator
11. Landscape/region simulators/decision support system (dss)
12. References

Being a project deliverable, this document is not definitive and still needs to be improved. It is expected that some incoherencies and/or omissions will be detected during the process of describing the models and integrating them into the database. In particular the list that is presented here is incomplete and will need to be updated whenever new models, either with new modules or involving new species, are described. This will give impetus to an iterative process of improvement of the present version of the framework.

1 Introduction and background

The objective of this project deliverable is to propose a methodology/framework to describe forest modelling tools in a straightforward, simple and standardized way. Model description should clearly catalogue the ability of models to estimate sustainability indicators as well as the improvements needed in order to improve model performance in this respect. The ultimate objective is to provide the information about each model in a structured way that can be easily implemented into a relational database (FORMODELS database).

The description of existing forest growth models is not an easy task because each model is, in fact, different from any other model. Existing models in the partner countries were identified and briefly described in D2.5.1. An EXCEL form was prepared and circulated among partners for description of the models available in their regions/countries. This inventory clearly showed the differences between models, not only in terms of model type and structure but also on the nomenclature used by the different researchers. Therefore, as a starting point, it was important to agree on definitions and terminology related to the forest modelling tools.

Most forest growth models, even if not published as such, have several publications related to either the development of some of the modules or their integration into simulators and/or decision support systems. It was decided that the description of the models should not be a repetition of these publications but rather a standardized characterization of several topics, such as model range of applicability, model type, description of model structure, etc, that can be easily stored in a relational database of free access. The data base should also note most of the relevant publications as well as the description of their content.

Being a project deliverable, this document is not definitive and still needs to be improved. It is expected that some inconsistencies and/or omissions will be detected during the model description procedure and its implementation into the database. In particular the list that is presented here is incomplete and will need to be updated as far as new models, with new modules or involving new species, are described. This will give impetus to an iterative process of improvement of the present version of the framework.

2 Methodology

The first stage was the agreement on definitions and terminology related to forest growth models which was achieved during a workshop that took place in Vila Nova, Spain, February 13, 2007.

The definition of a methodology for forest growth models description was based on the critical review of previous works with a similar objective:

- IEFC database: the data base for forest growth models available in the European Institute of Cultivated Forests (IEFC) website (www.IEFC.net)
- Hasenauer, 2006: chapter 3 of the book "Sustainable Forest Management", pp. 39-57 (Hasenauer, 2006);
- Excel form: the Eforwood WP 2.5 description form for models in excel;

Each of these works proposed/implemented frameworks for the description of forest growth models considering a list of topics such as model approach, range of applicability, description of modules or implementation into simulators, among others.

The proposed framework has been designed taking into account the topics considered in these three works but following a hierarchical structure, easy to implement into a relational database. Special emphasis has been given to the description of the model modules and of the references that were not considered in detail in the previous works.

The information to be provided by users for each one of the topics can be text (for instance, model identification or region of applicability), however an effort has been made to provide most of the information by one-to-one or multiple selection from a list of items that can be easily implemented in the database. One-to-one selection will be implemented as pop-up menus while multiple selections will imply the association of a new table with multiple entries for each model. The items included in each list were carefully selected among the ones appearing in the three works identified above, adding additional items when needed. The final lists were as simple as possible; most of the special cases identified in the previous studies were included under one of the most general cases. In order to avoid different interpretations and therefore guarantee the quality of the data base, a definition was provided for each one of the cases included in the final lists.

A notable difference from the IEFC data base is the fact that in the present framework/database it is not anticipated that users can freely add items to the lists provided. This was possible in the IEFC data base and led to some incoherence in the information with some users introducing items that were really model modules as model types (e.g., wood quality models, biomass models). In the present frameworks users have to propose to the database manager the addition of items to the list and the final decision will come from the database management team.

3 Results

3.1 Definitions and terminology related to the forest modelling tools

State variables
Set of variables (at stand and/or tree level) that characterize the forest at a given moment and whose evolution in time is the result (output) of the model. State variables can be

- Principal variables if they are the output of the growth modules
- Derived variables if they are indirectly predicted based on the values of the principal variables

Driving variables
Variables that are not part of the forest but that influence its behaviour:

- Environnemental variables (e.g. climate and soil variables)
- Human induced variables/processes (e.g. silvicultural treatments)
- Hazards (e.g. pests and diseases, storms, fire)

Forest model
A dynamic representation of the forest and its dynamics, at whatever level of complexity, based on a set of (sub-) models or modules that together determine the dynamic of the forest as defined by the values of a set of state variables. The forest responses to changes in the driving variables are reflected by the predicted dynamic of the forest. Modules, and therefore the models, can be deterministic or stochastic.

Model module
Set of equations and/or procedures that led to the prediction of the future value of a state variable.

Module sub-module or component
Equation or procedure that is part of a model module, contributing to the prediction of a state variable but not having a state variable as output.

Forest management alternative (prescription)
Sequence of silvicultural operations that are applied to a stand during the projection period.

Scenario
Conditions (climate, forest policy measures, management alternatives, etc) present during the projection period.

Forest simulator
Computer tool that, based on a set of forest models, makes long term predictions of the status of the forests within a well defined region under a certain scenario of climate, forest policy or management alternatives.
Forest simulators usually predict, at each point in time, wood and non-wood products from the forest. An objective of EFORWOOD is that simulators produce indicator estimations.

Stand simulator
Forest simulator focused on the simulation of a stand

Landscape simulator
Forest simulator focused on the simulation of all the stands included in a certain well defined region in which the stands are spatially described in a GIS. The simulation is made on a stand by stand basis but outputs for the whole landscape are also provided, namely sustainability indicators. It allows for the testing of the effect of spatial restrictions such as maximum or minimum harvested areas or maximization of edges.

Regional/National simulator – not spatialized
Forest simulator focused on the simulation of a large region, based on forest inventory data, without individualizing each stand, not connected to a GIS. Outputs are usually given by forest type but focused on the whole region.

Regional/National simulator – spatialized through a grid
Forest simulator focused on the simulation of a large region, based on forest inventory data aggregated according to a spatial grid connected to a GIS. Outputs are usually given by forest type but focused on the whole region.

Decision support system
Computational infrastructure integrating database management systems with analytical and operational research models, graphic display, tabular reporting capabilities and expert knowledge. The model base management system includes simulators and optimization algorithms that point out for a solution – list of forest management alternatives for each stand.

3.2 Framework for the description of forest modelling tools

The topics to be described include model identification, modelling approach, range of applicability, description of model structure and the respective inputs and outputs. The implementation of the forest growth model into simulators and/or decision support systems should also be identified and the references listed, with an indication of their content.

The structure of a model is given by the modules that it encompasses as well as the relationships between them. Flow charts or equivalent diagrams may be useful to understand the structure of a model. The model modules can be related to the description of the system, if they refer to state variables, or to the environment and related hazards, as well as to the outputs. Different types of modules imply the need of distinct items to be described, therefore they were considered separately.
Finally, the following topics and sub-topics were selected for the description of forest growth models:

1 Model identification
2 Modelling approach
    2.1 Model type
    2.2 Model sub-type
    2.3 Primary unit of simulation
    2.4 Time step
    2.5 Time scale
    2.6 Stochasticity
3 Range of applicability
    3.1 Region
    3.2 Site
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4 Model structure – modules for state variables

5 Model structure – sub-modules for natural processes
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  11.4 Estimation of sustainability indicators
12 References

The results of the analysis are presented for each one of the selected topics through a table showing the full list of items that will be considered under each topic or sub-topic.

3.2.1 Model identification

Model identification includes the items that identify the model within the data base.

Model identification	
Model name	Acronym given to the model
Year of publication	Year when the model was released/published
Contact	Email of the person to contact for additional information

3.2.2 Modelling approach

Model characterization describes the modelling approach.

Modelling approach	
Model type	Model type identifies the modelling philosophy behind the model development (one-to-one selection from a list).
Model sub-type	Model sub-type describes the spatial level of the principal state

	variables – growth modules (one-to-one selection from a list).
Primary unit of simulation	Primary unit of simulation describes the unit in which tree/stand growth is modelled. For empirical models it is given by the model sub-type but for process-based model primary unit of simulation is usually at a lower level than the growth module (one-to-one selection from a list).
Time step	Indicates the period associated with a growth prediction (one-to-one selection from a list).
Time scale	Indicates the projection length for which the model was developed.
Stochasticity	Indicates if at least one of the model modules is stochastic or if the model is deterministic

Modelling approach – model type list	
Empirical growth and yield models	Developed using statistical techniques, calibrated for comprehensive data-sets and using site index as the main driving variable. They are adequate for describing growth for a range of silvicultural practices and site conditions. Growth and yield models exist for practically all of the most important forest types and tree species identified for EFORWOOD (PD 2.1.1).
Process-based models	A process-based model implies a model of a system and its behaviour, at whatever level of complexity, based on the (sub-)models of the constituent processes that together determine the behaviour of the system (Landsberg, 2003). These models are developed to understand forest behaviour from a description of plant-soil and carbon-nutrient-water interactions and therefore useful for long-term predictions, especially under changing management and climate. Some of the state variables may be predicted with empirical functions, however growth is predicted on the basis of processes, such as photosynthesis, transpiration, etc, and the driving variables are environmental variables.

Modelling approach – model sub-type list	
Stand model	Growth modules refer to stand variables, there is no identification of individual trees except for their number.
Stand model with simulation of diameter distribution	Growth modules refer to stand variables, but information about size class distributions, usually diameter distributions, is also provided.
Distance dependent tree model	Growth modules refer to individual trees, but without using information on tree positions (coordinates).
Distance independent tree model	Growth modules refer to individual trees and the information on tree positions is used for tree growth prediction.

Modelling approach – primary unit of simulation list	
Stand/plot	Growth is directly predicted at stand/plot level
Tree	Growth is directly predicted at tree level
Organ	Growth is predicted based on processes that occur at organs level (leaves, roots, etc).

Modelling approach – time step list	
Year	Growth of principal state variables is predicted for every year
Month	Growth of principal state variables is predicted for every month
Day	Growth of principal state variables is predicted for every day
Hour	Growth of principal state variables is predicted for every hour

Modelling approach – time scale list	
Short-term	Short-term predictions for forest inventory
Long term	Long term predictions
Succession model	Simulation of species succession through regeneration and ingrowth

Modelling approach – stochasticity list	
Deterministic	None of the model modules is stochastic
Stochastic	At least one of the model modules is stochastic

3.2.3 Range of applicability (calibration specifications)

Range of applicability specifies the conditions for which the model was calibrated.

Range of applicability	
Region	Geographical region to which the model is applicable.
Site	Description of site specifications for which the model is applicable.
Forest composition	Multiple selection.
Forest structure	Multiple selection.
Tree species	Multiple selection from a list of species.
Silvicultural system	Multiple selection.
Tree range	Range for tree variables
Stand range	Range for stand variables

Range of applicability – forest composition list	
Monospecific	Model applies only to single species stands.
Multispecific	Model applies to stands composed of many species.

Range of applicability – forest structure list	
Even	Model applies to even aged stands.
Uneven	Model applies to uneven aged stands.

Range of applicability – tree species list	
Maritime pine	*Pinus pinaster*
Radiata pine	*Pinus radiata*
Scots pine	*Pinus sylvestris*
Corsican pine	*Pinus nigra ssp laricio*
Austrian pine	*Pinus nigra ssp nigra*
Sitka spruce	*Picea sitchensis*
Norway spruce	*Picea abies*
Atlas cedar	*Cedrus atlantica*
Douglas fir	*Pseudotsuga menziesii*
European silver fir	*Abies alba*
Blue gum	*Eucalyptus globulus.*
Pedunculate oak	*Quercus robur*
Sessile oak	*Quercus petraea*
Cork oak	*Quercus suber*
Beech	*Fagus sylvatica*
Birch spp.	*Betula pubescens, B. pendula*
Sweet chestnut	*Castanea sativa*

Range of applicability – silvicultural system list	
Clear cutting	Silvicultural system where the mature trees are cleared by a single cutting
Clearcutting+coppice	Crops originating from stool shoots and removed by clearcut
Uniform system	Successive regeneration cuttings distributed over whole compartments evenly
Group system	Successive regeneration cuttings distributed over whole compartments by scattered gaps
Conversion system	Change from one silvicultural system to another
Selection system	Single trees or small groups of trees are selected and removed throughout the forest

3.2.4 Model structure – modules for state variables

Modules for state variables may be one equation or a set of equations or procedures that allow for the prediction of a state variable. They can be: a) growth modules, for simulation of growth of principal state variables; b) initialization modules, for predicting initial values for the principal state variables; c) prediction modules, for prediction of derived variables on the basis of the predicted values of the principal variables.

For the description of the modules for state variables, the user needs to enumerate them, by multiple selection from the lists of state variables, and to indicate, for each state variable enumerated if it is part of a growth module (**Growth**), an initialization module (**Init**) or a prediction module (**Pred**) and if it is deterministic or stochastic (**Stoch**).

Model structure – lists of state variables: stand variables				
	Growth	**Init**	**Pred**	**Stoch**
Dominant height	yes/no	yes/no	yes/no	yes/no
Number of trees per ha	yes/no	yes/no	yes/no	yes/no
Basal area	yes/no	yes/no	yes/no	yes/no
Aboveground biomass	yes/no	yes/no	yes/no	yes/no
Stem wood biomass	yes/no	yes/no	yes/no	yes/no
Stem bark biomass	yes/no	yes/no	yes/no	yes/no
Branches biomass	yes/no	yes/no	yes/no	yes/no
Leaves biomass	yes/no	yes/no	yes/no	yes/no
Root biomass	yes/no	yes/no	yes/no	yes/no
Total biomass	yes/no	yes/no	yes/no	yes/no
Leaf area	yes/no	yes/no	yes/no	yes/no

Model structure – lists of state variables: diameter distributions variables				
	Growth	**Init**	**Pred**	**Stoch**
Weibull parameters	yes/no	yes/no	yes/no	yes/no
Truncated Weibull parameters	yes/no	yes/no	yes/no	yes/no
Johnson-SB parameters	yes/no	yes/no	yes/no	yes/no

Model modules –lists of state variables: tree variables				
	Growth	**Init**	**Pred**	**Stoch**
Tree identification	yes/no	yes/no	yes/no	yes/no
Tree coordinates	yes/no	yes/no	yes/no	yes/no
Tree life status (alive/dead)	yes/no	yes/no	yes/no	yes/no
Diameter at breast height	yes/no	yes/no	yes/no	yes/no
Tree height	yes/no	yes/no	yes/no	yes/no
Stem height	yes/no	yes/no	yes/no	yes/no
Crown length/crown ratio	yes/no	yes/no	yes/no	yes/no
Crown diameter	yes/no	yes/no	yes/no	yes/no
Branching description	yes/no	yes/no	yes/no	yes/no
Taper functions	yes/no	yes/no	yes/no	yes/no
Volume over bark with stump	yes/no	yes/no	yes/no	yes/no
Volume over bark without stump	yes/no	yes/no	yes/no	yes/no
Volume under bark with stump	yes/no	yes/no	yes/no	yes/no
Volume under bark without stump	yes/no	yes/no	yes/no	yes/no
Stump volume over bark	yes/no	yes/no	yes/no	yes/no
Merchantable volumes over bark to a top d	yes/no	yes/no	yes/no	yes/no

Merchantable volumes under bark to a top d	yes/no	yes/no	yes/no	yes/no
Aboveground biomass	yes/no	yes/no	yes/no	yes/no
Stem wood biomass	yes/no	yes/no	yes/no	yes/no
Stem bark biomass	yes/no	yes/no	yes/no	yes/no
Branches biomass	yes/no	yes/no	yes/no	yes/no
Leaves biomass	yes/no	yes/no	yes/no	yes/no
Root biomass	yes/no	yes/no	yes/no	yes/no
Total biomass	yes/no	yes/no	yes/no	yes/no
Leaf area	yes/no	yes/no	yes/no	yes/no
Cork thickness	yes/no	yes/no	yes/no	yes/no
Cork quality	yes/no	yes/no	yes/no	yes/no
Total debarking height	yes/no	yes/no	yes/no	yes/no
Vertical debarking height	yes/no	yes/no	yes/no	yes/no
	yes/no	yes/no	yes/no	yes/no
	yes/no	yes/no	yes/no	yes/no
	yes/no	yes/no	yes/no	yes/no
	yes/no	yes/no	yes/no	yes/no
	yes/no	yes/no	yes/no	yes/no

3.2.5 Model structure – sub-modules for natural processes

Modules for natural processes are usually sub-modules as they contribute for the prediction of a state variable. These sub-models are grouped into different lists: a) growth processes, if they contribute for the growth modules; b) regeneration at stand level, if they are related with the simulation of the regeneration at stand level; c) regeneration at tree level; d) hazards.
At the moment they are indicated by multiple selection (details have to be obtained from the literature).

Model structure – lists of natural processes: growth processes	
Light interception	
Photosynthesis	
Gross primary production	
Net primary production	
Respiration	
Carbohydrate allocation	
Litter fall	
Precipitation interception	
Transpiration	
Soil water balance	

Model structure – lists of natural processes: regeneration processes at stand level	
Seed dispersal	
Regeneration	Number of trees regenerated in the period

Seedling mortality	Number/proportion of seedligs* that die in every growth period
Sapling mortality	Number/proportion of saplings* that die in every growth period
Ingrowth (number)	Number of saplings that grow into the lowest inventoried diameter class during the growth period.

* seedling: <1.3m tall
sapling:>=1.3m tall and dbh<dlim
dlim depends on the country and/or species

Model structure – lists of natural processes: regeneration processes at sapling level	
Height growth	
Mortality	
Diameter prediction	

Model structure – lists of natural processes: hazards	
Browsing	Prediction of the impact of the hazards on the values of state variables
Pests and diseases	
Wind throw	
Snow	
Fire	

3.2.6 Model structure – sub-modules for silvicultural practices

As natural processes, silvicultural practices are also sub-modules as they are simulated by modification of the values of the state variables. At the moment they are simply indicated as a yes/no variable, without indication of the methodology used (details are reported to the literature).

Model structure – lists of silvicultural practices	
Site preparation	Prediction of the impact of the silvicultural practices on the values of state variables.
Fertilization at planting	
Initial density (seedling, plantation)	
Fertilization	
Genetic effects	
Selection of crop (or future) trees	
Pruning	
Weed control	
Thinning	
Debarking	

3.2.7 Model structure – sub-modules for environmental driving variables

Modules for environmental driving variables consist in the simulation of variables when they are not available. At presented they are described by a yes/no variable. The environmental variables are indicated through a yes/no list. The periodicity will coincide with the model time step.

Model structure – lists of environmental variables: climate	
Site index	Prediction of site index
Total solar radiation	Simulation of climate variables when they are not available.
PAR	
Mean temperature	
Maximum temperature	
Minimum temperature	
Precipitation	
Number of rain days	
Number of frost days	
Vapor pressure deficit	
Fertility rating	Simulation/prediction of soil variables when they are not available
Maximum available soil water	
Soil texture	
Nutrient content – N	
Nutrient content – K	
Nutrient content – P	

3.3 Inputs

3.3.1 State variables

The state variables needed as inputs are selected by multiple choices from the lists of state variables (presented under 5.2.4). They are associated with a yes/no variable that indicates if the variable belongs to the minimum allowed input (required).

3.3.2 Human induced driving variables

The human induced driving variables depend on the parameters involved in the modules for simulation of silvicultural treatments that are not yet standardized. Therefore it is difficult, at the moment, to present the lists this type of input.

3.3.3 Environmental driving variables

The environmental driving variables needed as inputs are selected by multiple choices from the lists environmental variables (presented under 5.2.7). They are associated with a yes/no variable that indicates if the variable belongs to the minimum allowed input (required).

3.4 Outputs

3.4.1 State variables

As with the inputs, the state variables present in the output are also selected by multiple choices from the lists of state variables (presented under 5.2.4). They are associated with a yes/no variable that indicates if the user wants the value of this variable to be included in the outputs.
The users are usually interested in more outputs than the values of the state variables, namely: the prediction of products.

3.4.2 Products

Products prediction, both quantity and quality are essential for the use of forest models in practice. Either the amount of the product and/or its quality may be predicted by the model. At the moment the products are selected from a list and, for some products, there is an associated list indicating the quality variables that are available (**Quality**).

Product prediction – list for products		
		Quality
Pulp wood		yes/no
Wood for construction		yes/no
Wood for fibreboard		yes/no
Wood for carcassing		yes/no
Wood for fencing		yes/no
Cork		yes/no

Products prediction – list for pulp wood quality	
Wood density	
Wood composition	
Heartwood percentage	
Fibre dimensions	
Colour	

Products prediction – list for wood quality for construction and other uses	
Wood density	
Boards grading	
Log grading	
Peeling/sliced pattern	
Sawing pattern	
Knot (shape, number, type…)	
Grain angle	
Biomechanical properties	

Products prediction – list for cork quality	
Cork thickness distribution	
Cork quality distribution	

3.5 Stand simulator

The evaluation of a forest growth model implies its implementation into a computer program that allows for the analysis of the adequacy of the model predictions when all the modules are jointly used for several simulations representative of most of the combinations of conditions that can be found in practice. This is the reason why there is almost always a stand simulator associated with each forest growth model.
The stand simulator provides output that is not part of the model but that is relevant for forest management, namely the estimation of sustainability indicators. Several stand simulators include also a visualization module that is very useful for model evaluation, especially when the model is of the distance-dependent individual tree type, as well as a way to make it more user friendly.

3.5.1 Software and hardware requirements

Software and hardware requirements	
Software name	
Current version	
Hardware requirements	
Memory capacity	
Operating system	
Programming language	

3.5.2 Software characteristics

Software characteristics	
Interface with other programs	yes/no
Interactive use	yes/no
Batch-mode use	yes/no
Possibilities of stopping the program to change silvicultural treatments	yes/no
Possibilities of stopping the program to change the values of driving variables	yes/no
Interactive changing of equations	yes/no
Interactive changing of coefficients	yes/no
Saving of interim results with continuation	yes/no

3.5.3 Estimation of sustainability indicators

The estimation of sustainability indicators is of the utmost importance for today's forest management and in particular, for the Eforwood project. In deliverable D2.5.1 the Eforwood indicators ((lead+, additional and M2 specific indicators) were analysed for identification of those that could be estimated, either directly or indirectly, with the forest modelling tools. For all those indicators a yes/no answer is required in order to specify if it can be predicted by the stand simulator. The indicators are classified in economic, social and environmental indicators.

Estimation of sustainability indicators – economic indicators	
	Prediction
Total production (Additional)	yes/no
Production costs (Lead)	yes/no
Resources/material use (Lead)	yes/no
Revenue (Additional)	yes/no
Increments and fellings (Module 2)	yes/no
Non timber forest products (Module 2)	yes/no
Ecosystem Services (Module 2)	yes/no
	yes/no

Estimation of sustainability indicators – social indicators	
	Prediction
Employment (Lead)	yes/no
Wages and salaries (Lead)	yes/no
	yes/no
	yes/no
	yes/no
	yes/no
	yes/no

Estimation of sustainability indicators – environmental indicators	
	Prediction
Energy generation and use (Lead)	yes/no
Greenhouse gas balance (Lead)	yes/no
Transport (Lead)	yes/no
Water (Lead)	yes/no
Forest resources (Lead)	yes/no
Growing stock (Module 2)	yes/no
Age structure and diameter distribution (Module 2)	yes/no
Forest damage (Module 2)	yes/no
Tree species composition (Module 2)	yes/no
Regeneration (Module 2)	yes/no
Deadwood (Module 2)	yes/no
Protected forests (Module 2)	yes/no
Protective forests (Module 2)	yes/no
Landscape pattern (Module 2)	yes/no

3.5.4 Visualization module

When it exists, the visualization module is described through a series of yes/no variables.

Visualization module	
Tree crowns projection map	yes/no
2D visualization	yes/no
Virtual walk inside the stand/plot	yes/no

3.6 Landscape/region simulators/dss

Stand simulators can be used to support decisions at owner level in a small forest property, however most applications require the linkage of forest growth models with landscape or regional simulators.
Therefore it is important to identify and describe the simulators and/or decision support systems (simulators/dss) in which each forest growth model is implemented.
The description of the implementation into simulators/dss implies: the identification of the simulators, the simulator type, the outputs, the type of optimizations that can be considered, the optimization algorithms.

3.6.1 Software and hardware requirements

The same as in 5.5.1.

3.6.2 Software characteristics

The same as in 5.5.2.

3.6.3 Estimation of sustainability indicators

The same as in 5.5.3.

3.6.4 Visualization module

The same as in 5.5.4.

3.7 References

Each bibliographic reference entry is complemented with the information of what the users can obtain from that reference.

References	
Model equations	yes/no
Model modules/components	yes/no
Model development methodology	yes/no
Methodologies used in evaluation	yes/no
Evaluation statistics	yes/no
Sensitivity analysis	yes/no

4 Discussion and conclusions

The objective of the present deliverable was to propose a methodology/framework for the organization of the information already available about existing forest growth models (see deliverable 2.5.1) in a structured way that will allow its implementation into a relational database.

The framework that is proposed is based on the description of the most relevant topics for model description through one-to-one or multiple selections from a series of lists relative to each topic. In some cases, for instance in the description of the sustainability indicators provided as an output of the simulators, it was decided to use yes/no variables instead of multiple choices from a list in order to have an immediate idea not only of what is provided by the model but also of what is not provided.

In the present framework/database it is not anticipated that users can freely add items to the lists provided. This was possible in the IEFC data base and led to some inconsistency in the information with some users introducing items that were really model modules as model types (e.g., wood quality models, biomass models). In the present frameworks users have to propose to the database manager the addition of items to the list and the final decision will come from the database management team.

As mentioned before, the present version of the framework is not definitive and still needs to be improved. It is expected that some incoherencies and/or omissions will be detected during the model description procedure and its implementation into the database. In particular the list that is presented here is almost certainly incomplete and will need to be updated as far as new models, with new modules or other species not considered in Section 5.2.3, will be described. This will give impetus to an iterative process of improvement of the present version of the framework.

5 References

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