HETEROFOR 1.1
User Manual

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2. Introductory remarks

HETEROFOR is a tree-level model developed according to a spatially-explicit process-based approach to explore the response of structurally-complex stands (uneven-aged, mixed) to changing environmental conditions. Since 2012, HETEROFOR has been progressively elaborated through the integration of various modules (light interception, phenology, water balance, photosynthesis and respiration, carbon allocation, mineral nutrition and nutrient cycling) within CAPSIS, a collaborative modelling platform dedicated to tree growth and stand dynamics (Dufour-Kowalski *et al.*, 2012). A general overview of the model functioning and a detailed description of the carbon-related processes of HETEROFOR (photosynthesis, respiration, carbon allocation and tree dimensional growth) can be found in Jonard *et al.* (2020). For the light interception, HETEROFOR is coupled to the SAMSARALIGHT library first developed by Courbaud *et al.* (2003) and further adapted by Ligot *et al.* (2014) and André *et al.* (2021). The phenology and water balance module of HETEROFOR are presented in de Wergifosse *et al.* (2020) and the regeneration module in Ryelandt (2019). The mineral nutrition and nutrient cycling module must still be improved and will be published later.

HETEROFOR was designed to be particularly suitable for the level II plots of ICP Forests. The processes were described at a scale that facilitates the comparison between model predictions and observations. Many data collected in these plots can be used to initialize and run the model or to calibrate and evaluate it. HETEROFOR can also be seen as a tool for integrating forest monitoring data and quantifying non-measured processes.

3. Installation of HETEROFOR under CAPSIS

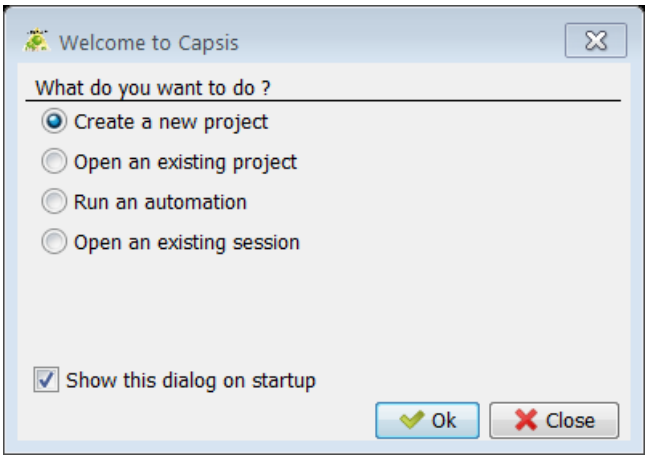
The source code of CAPSIS and HETEROFOR is accessible to all the members of the CAPSIS co-development community. Those who want to join this community are welcome but must contact François de Coligny (francois.decoligny@inrae.fr) and sign the CAPSIS charter (http://capsis.cirad.fr/capsis/charter). This charter grants access on all the models to the modellers of the CAPSIS community. The modellers may distribute the CAPSIS platform with their own model but not with the models of the others without their agreement. CAPSIS4 is a free software (LGPL licence) which includes the kernel, the generic pilots, the extensions and the libraries. For HETEROFOR, we also choose an LGPL license and decided to freely distribute it through an installer containing the CAPSIS4 kernel and the latest version (or any previous one) of HETEROFOR upon request from Mathieu Jonard (mathieu.jonard@uclouvain.be). The source code for the modules published in Geoscientific Model Development (Jonard *et al.,* 2020*;* de Wergifosse *et al.*, 2020) can be downloaded from https://github.com/jonard76/HETEROFOR-1.0_LGPL_REVISED (DOI: 10.5281/zenodo.3591348).

The end-users can install CAPSIS from an installer containing only the HETEROFOR model while the modellers who signed the CAPSIS charter can have access the complete version of CAPSIS with all the models. Depending on your status (end-user vs modeller or developer), the instructions to install CAPSIS are given on the CAPSIS website (http://capsis.cirad.fr/capsis/documentation).

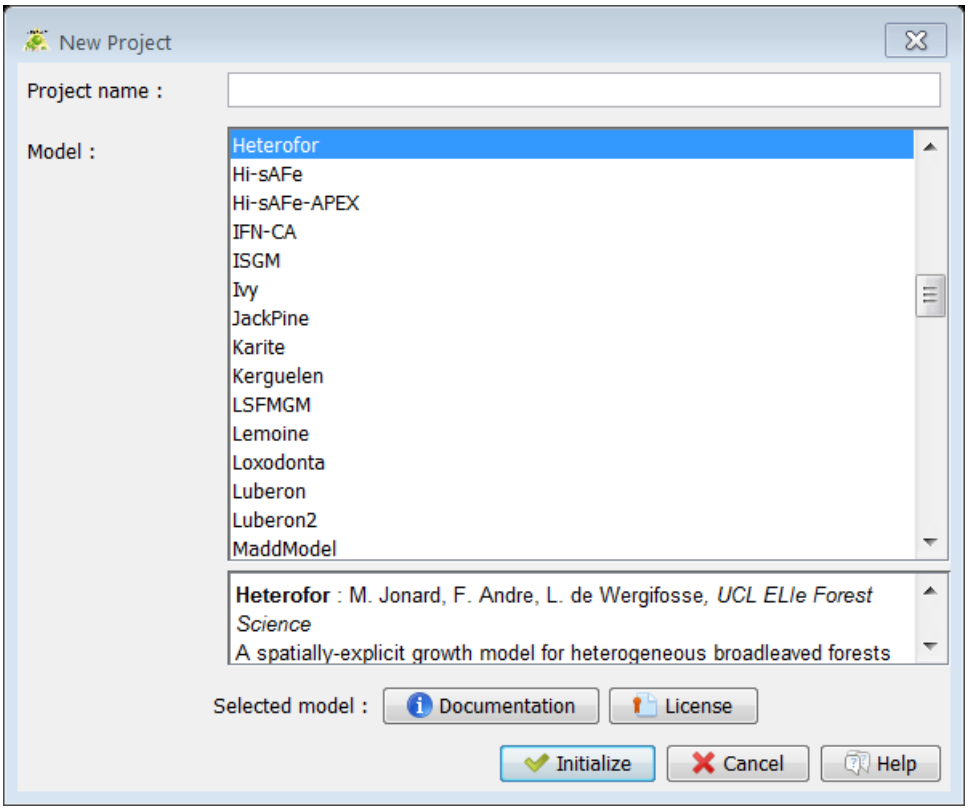
Here is a brief explanation for installing CAPSIS under Windows using an installer. First, create/choose a directory where the CAPSIS files will be stored. This can be called “Capsis”. Then, click on the CAPSIS Installer (e.g., capsisHETEROFOR1.0 _setup.jar), follow the instructions and use the Capsis directory for the installation. Open a command prompt and reach the Capsis directory using the “cd” command (cd.. and cd directoryName). Allocate memory with the command “setmem 8000” and finally launch Capsis from the Capsis directory using the command: “capsis -l en”.

4. Initialization of HETEROFOR

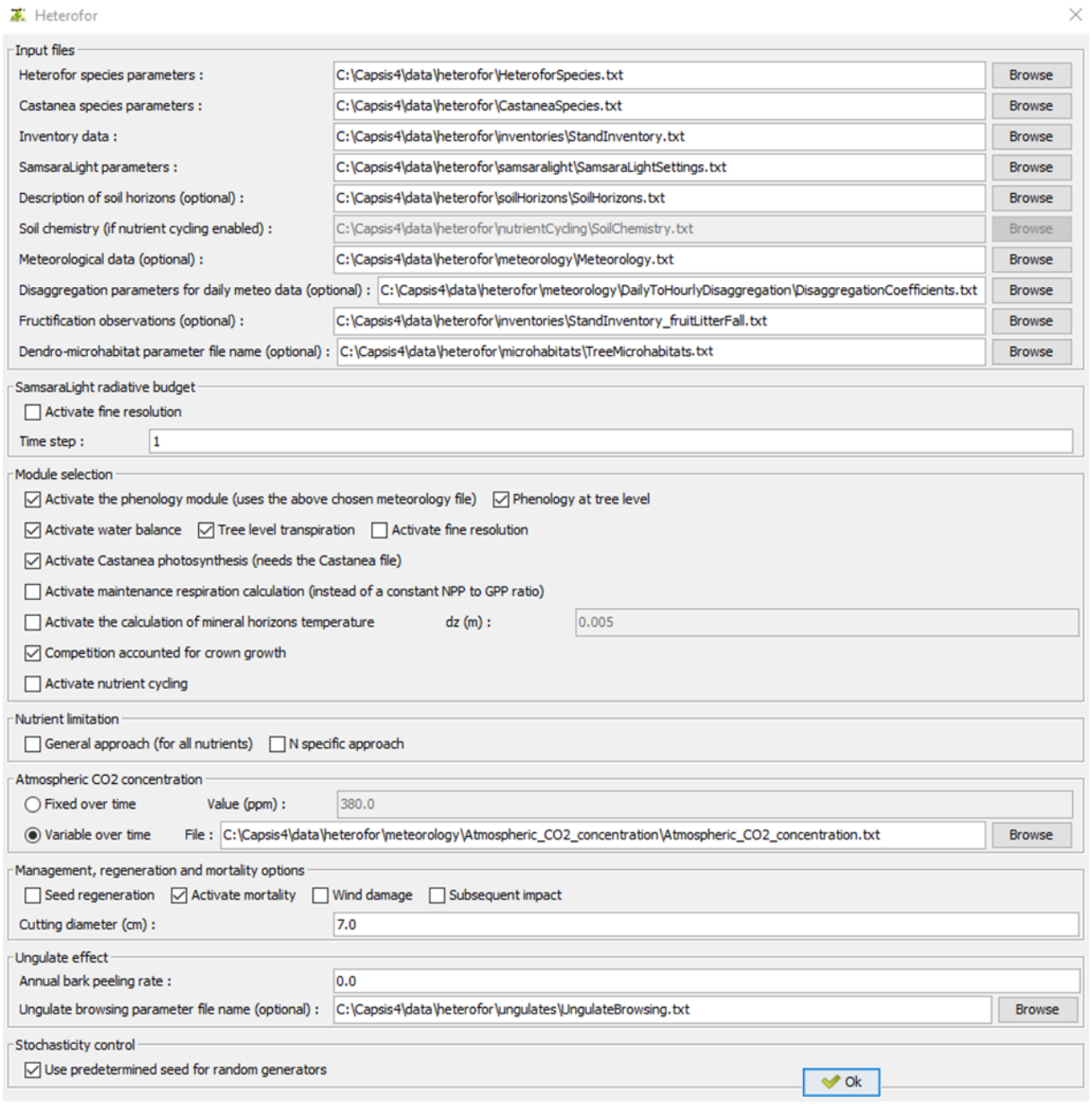
When CAPSIS is started, a first window appears and one can create a new project or open an existing one. The user can also open an existing session containing several projects.



If “Create a new project” is chosen, a second window opens from which the HETEROFOR model can be selected among the list of models available in CAPSIS. When an installer is used, only a subset of models are available. To launch the model initialization, click on the Initialize button.



Initializing HETEROFOR requires a series of information provided by loading files and selecting model options through the initial dialog.



Here are some indications for the option selection. The user can define the time step at which the radiative budget must be performed and whether the fine resolution must be used. The simplified radiative budget calculates radiation absorption by trees for the whole vegetation period while the fine resolution approach does it hourly. Some tests were made and showed that model performances were not improved with the fine resolution while the calculation time substantially increased.

If the phenology module is not activated, the vegetation period is defined based on the budburst and the leaf shedding dates provided in the setting file of SAMSARALIGHT. Otherwise, the phenology dates are calculated yearly based on the meteorological data. The phenology module is operating either at the species level (default option for which all the trees of a same species have the same phenology) or at the tree level (the trees of a same species have a phenology depending on their size, see de Wergifosse *et al.* (2020)).

The basic mode of HETEROFOR (gross primary production calculated with a radiation use efficiency approach) is not used anymore and was not correctly parametrised for all tree species. We therefore recommend to always activate the CASTANEA photosynthesis option. In this case, the water balance must be activated too, either at the tree (fine resolution) or stand level (default option). To limit the calculation time, we advise performing the water balance at the stand scale but to calculate transpiration at the tree level.

We generally do not activate the maintenance respiration calculation (based on a Q_{10} function dependent on temperature) since the model was not calibrated for this option which provided less accurate predictions. When this option is not activated, the net primary production (npp) is determined based on a carbon use efficiency approach (npp to gpp ratio calculated based on tree characteristics, local competition for light and mean annual air temperature). The soil horizon temperature calculation is only necessary for the maintenance respiration and can be deactivated when the maintenance respiration routine is not used.

The crown extension can be described based on empirical relationships (default option) or by a distance-dependent approach accounting for the local environment.

The model can also account for the nutrient cycling and the nutrient limitation of tree growth with the possibility to select an approach particularly adapted to nitrogen. These nutritional aspects being still under testing, we recommend not using this option for the moment.

For the photosynthesis estimated with CATANEA, the model can either consider a fixed atmospheric CO_2 concentration or load a file describing its temporal change according to various IPCC scenarios (yearly time step).

Several options can be selected regarding the regeneration and mortality processes. Regeneration can be initiated cell-by-cell by describing the seedling cohort characteristics (tree species, height and collar diameter) in the inventory file. Alternatively, the user can select the seed regeneration option which generates seedling cohorts from the seed bank. This seed bank is updated each year by accounting for seed production, consumption by ungulate and other animals, germination and mortality. The user can activate the tree mortality which occurs when the tree defoliation reaches a given threshold (90%). A tree becomes defoliated when it has not a sufficient npp to produce all the leaves it could have given its size. This can result from light competition, water stress or senescence. There is also the possibility to account for the mortality due to windstorms (box 'wind damage') by comparing the wind speed at the top of the tree to the critical wind speed leading to overturning or stem breakage (ForestGales approach, Hale *et al.* 2015), and their impact on seedlings and neighbouring trees (box 'subsequent impact'). For the wind mortality option, the model will evaluate the wind damage on a daily basis from meteorological data, but the wind damage routine can also be run punctually to simulate a windstorm in a given year using the intervention menu (see Section 5).

The silvicultural interventions are managed during the simulation (see Section 5) but the branch and trunk diameter under which the wood is not harvested and left in the forest is fixed in the initial dialog. This has implications for the nutrient budget.

Finally, the ungulate effect on regeneration and ground vegetation can be taken into account by the model according to a descriptive or a process-based approach (e.g. consumption of seeds and seedling). For this, an optional file specifying the approach, the ungulate species involved, their population density as well as various parameters about their diet must be provided. A bark peeling rate can also be specified and allow to account for the associated wood depreciation.

In order to repeat exactly a same simulation, the user has the possibility to fix the seed for the random generators.

Besides this selection of options, three parameter/setting files must be provided since two CAPSIS libraries (SAMSARALIGHT for light interception and CASTANEA for photosynthesis) are used in addition to HETEROFOR. For HETEROFOR and CASTANEA, the parameters are mostly species specific; they are defined in Jonard *et al.* (2020) and de Wergifosse *et al.* (2020) for European species and in Guignabert *et al.* (*to be submitted*) for North-Eastern American species regarding HETEROFOR, and in Dufrêne *et al.* (2005) for CASTANEA. The setting parameters needed to initialize SAMSARALIGHT as well as the description of the functioning of this library are presented on the CAPSIS website at http://capsis.cirad.fr/capsis/help_en/samsaralight.

Then, the user must provide an inventory file containing the relative position (*x, y, z*) and the main dimensions of each tree: girth at breast height (*gbh* in cm), height (*h* in m), height of maximum crown extension (*hlce* in m), height to crown base (*hcb* in m) and crown radii in the four cardinal directions (*cr* in m). This file also specifies the site name, the starting date, the cell size for the radiation transfer module, the maximum leaf area index for the whole ecosystem, the tree compartments (leaves, branches, stem, roots) and litter nutrient concentrations, the latitude, longitude and slope of the site (in degrees), the clockwise angle of the slope bottom from the North (site aspect, in degrees) and the clockwise angle between North and the x axis (in degrees). The regeneration cohorts can be specified in this file, either for the whole stand or cell-by-cell, with the species, age, mean height and diameter, and the seedling density for each cohort. The user can also specify the year of first occurrence of this cohort and the periodic emergence time step when the cohort is supposed to be created periodically. For example, one-year-old seedlings can be created every year. A zero for the periodic emergence time step means that the cohort is just created once. When data on fruit litterfall are available, a file providing the amount of fruit litterfall per year and per tree species can be loaded and used to adapt the allometric equations predicting fruit production at the individual level.

When the water balance module is activated, two additional files must be loaded: a file describing soil horizon properties and another one for the meteorology. For each horizon, the following properties are provided: upper and lower horizon limits (m), total (m^3 total stone m^{-3} total soil) and sampling (m^3 stone in Kopecky m^{-3} Kopecky) coarse fraction, bulk density (kg m^{-3}), sand, silt and clay contents (g g^{-1}), organic carbon (mg g^{-1}), mean, wilting point and saturated water content (m^{-3} m^{-3}), soil solution pH, log pCO_2 (with pCO_2 in atm), fine root proportion (%) and tortuosity factor (m m^{-1}). The meteorological data are read by a loader and stored in hourly meteo line objects containing the date split in four fields (year, month, day, hour) and seven meteorological variables: radiation (W m^{-2}), air temperature (°C), soil surface temperature (°C), rainfall (l m^{-2} or mm), relative humidity (% or hPa / 100 hPa), wind speed ($m.s^{-1}$) and wind direction (degrees). If hourly data are not available, it is possible to load a file with daily records along with a file containing coefficients to convert daily data into hourly values.

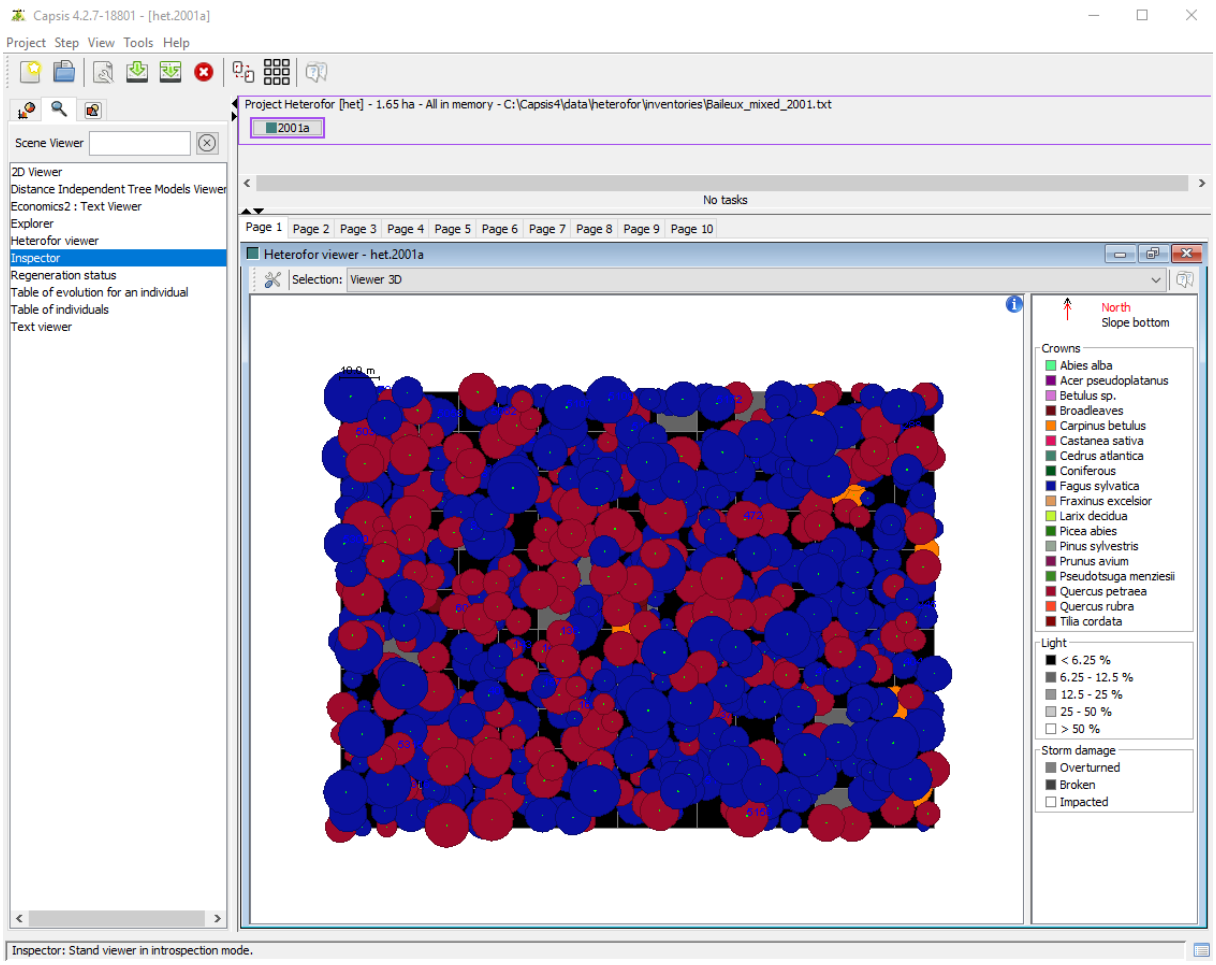
The soil chemistry input file must be provided when the nutritional limitation is considered. This file contains 6 parts:

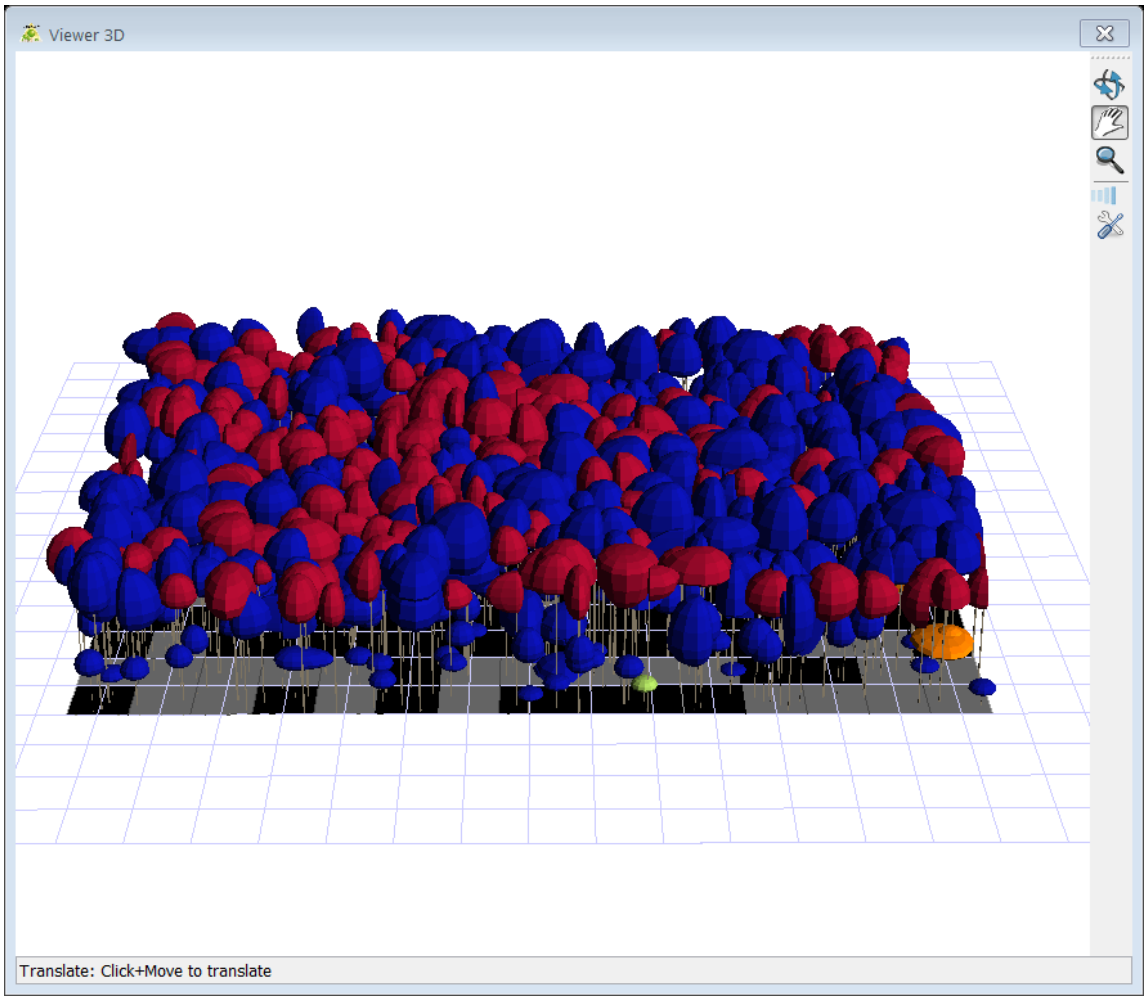
- a list with all the chemical elements, their charge and atomic mass,
- the element concentrations in the soil solution for each soil horizon (K, Ca, Mg, Na, Nam, Al, Mn(2), Fe(3), Cl, Nnit, S(6), P, Si, Cit, C(4) in $mg.l^{-1}$),
- the exchangeable cation concentrations for each cation exchanger (Xo, Xm, Xs) and soil horizon (e.g. HXo, KXo, CaXo2, MgXo2, NaXo, NamH4Xo, AlXo3, MnXo2, FeXo3, HXm, KXm, CaXm2, MgXm2, NaXm, NamH4Xm, AlXm3, MnXm2, FeXm3, HXs, KXs, CaXs2, MgXs2, NaXs, NamH4Xs, AlXs3, MnXs2, FeXs3 in $cmole.kg^{-1}$),

- the exchangeable anion concentrations for each anion exchanger (Ya) and soil horizon (e.g. YaCl, YaNnitO3, Ya2SO4, YaH2PO4, YaH3SiO4, Ya3Cit, YaHCO3, YaOH in cmole kg^{-1}),
- the mineral properties: mineral type (e.g., quartz, K-feldspar, K-mica, illite, albite, anorthite, chlorite(14A), Vrm, kaolinite, variscite, Ca-Montmorillonite, manganite, Fe(OH)3(a)), concentration in mole/kg, weathering type (1 for equilibrium and 2 for kinetics), target saturation index as log(IAP/Ks) with IAP: ion activity product and Ks: solubility product of the mineral (all dimensionless), reaction type (d for dissolution, p for precipitation and b for both), kinetics parameters depending on the formula mentioned in the PHREEQC database,
- the atmospheric deposition (in kg ha^{-1} $year^{-1}$).

Finally, an optional file about tree-related dendro-microhabitats (TreM) can be loaded to simulate the formation of TreM depending on tree characteristics (e.g. species, diameter, crown dimension). More information on the modelling framework of TreM and the factors influencing their formation can be found in Courbaud *et al.* 2017 and Courbaud *et al.* 2022.

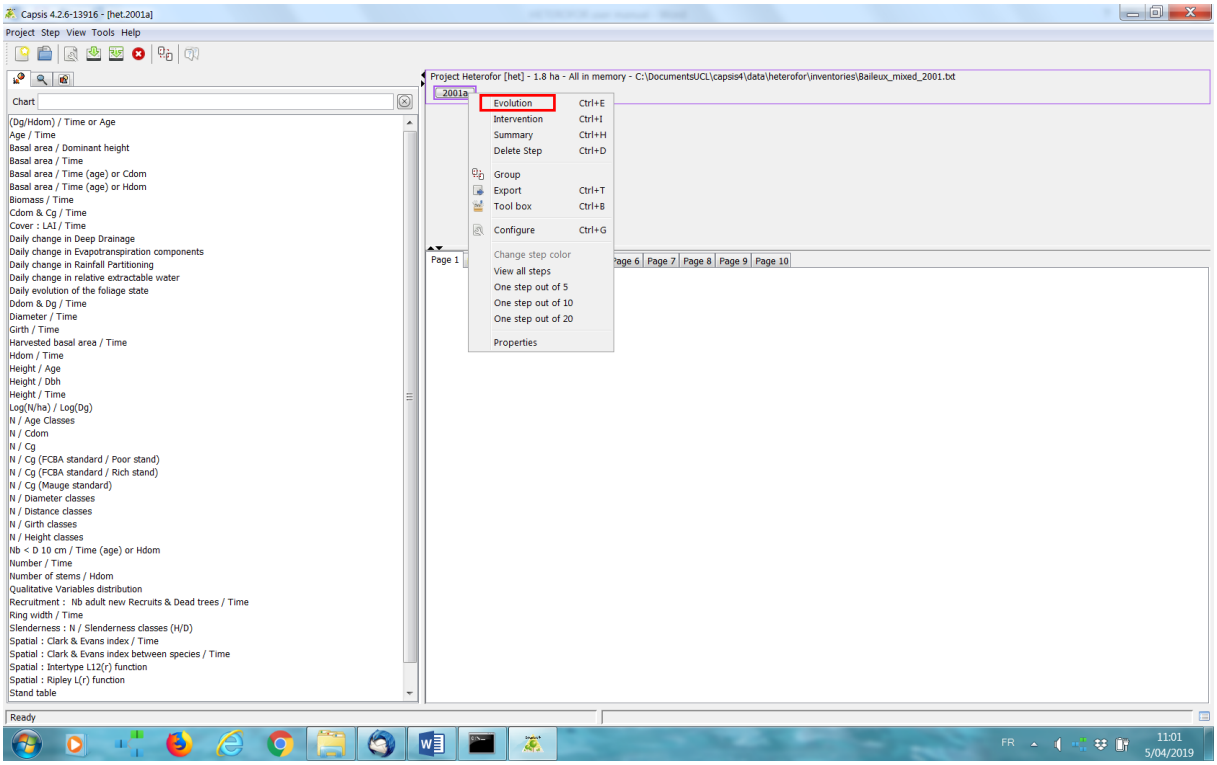
After selecting the desired options and specifying the paths to the input files, the initialization can be launched by pressing on the “Ok” button. The model creates then a new project with only the initial step corresponding to the state of the forest stand at the starting date mentioned in the inventory file. The stand can be visualized in 2D by selecting the “scene viewer” tab (choose Heterofor viewer) on the left panel. This viewer shows the tree crowns and the relative light transmitted to the ground cells. To obtain a 3D representation of the stand, the user must choose the 3D viewer in the lower right panel and select the trees with the mouse (right click).



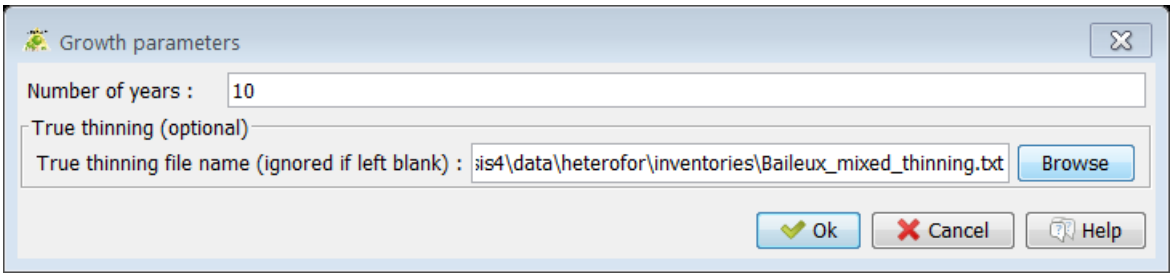

Viewer 3D
Translate: Click+Move to translate

5. Launching an evolution and planning silvicultural interventions

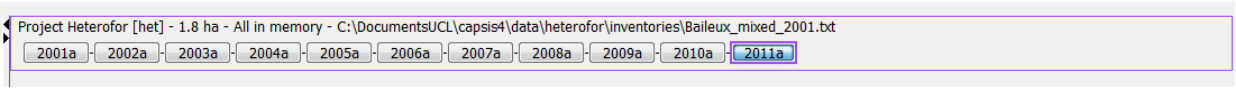
Right-click on the initial step and select “Evolution” in the drop-down menu to launch a simulation.



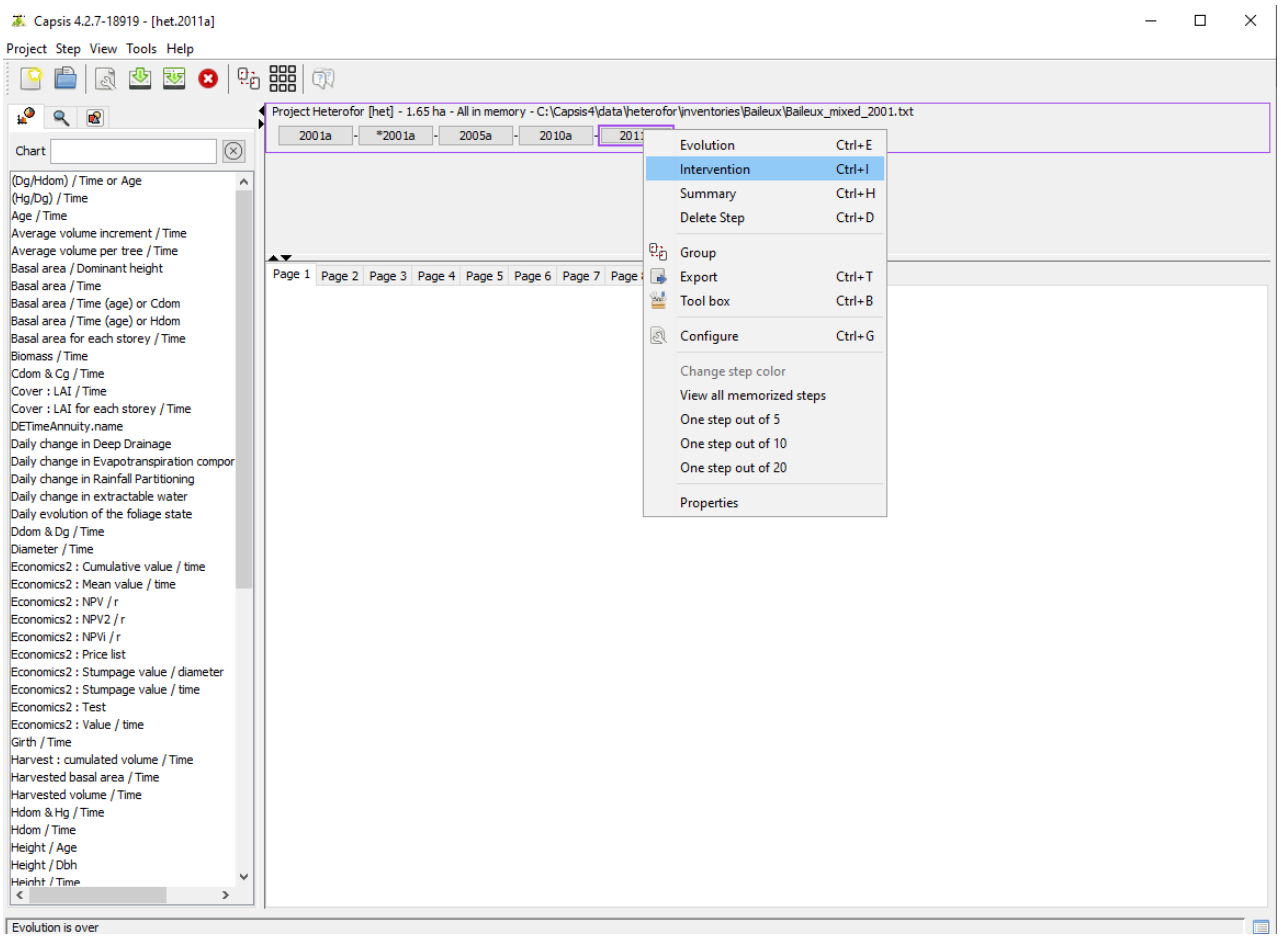
A window appears and allows the user to specify the length of the simulation and to load a file listing the trees to be thinned and their last year of presence in the stand.



The simulation can take several minutes depending on its length. When the evolution is finished, the project is composed of as many steps as years in the evolution. Each step correponds to a year and contains the state of the stand at the end of this year (after the vegetation period).



The thinning file is optional and, alternatively, thinning can also be achieved by right clicking on the step after which the thinning must be done and selecting “Intervention” in the drop-down menu. In the window that appeared, choose “Selective thinning” in the intervention type. You will then have access to all the routines created in CAPSIS to achieve a thinning as far as they are compatible with HETEROFOR. The user is referred to the documentation of CAPSIS for a detailed description of these thinning routines called interveners (http://capsis.cirad.fr/capsis/documentation/interventions).


Capsis 4.2.7-18919 - [het.2011a]
Project Step View Tools Help
Project Heterofor [het] - 1.65 ha - All in memory - C:\Capsis4\data\heterofor\inventories\Baileux\Baileux_mixed_2001.txt
2001a
*2001a
2005a
2010a
Evolution Ctrl+E
Intervention Ctrl+I
Summary Ctrl+H
Delete Step Ctrl+D
Group
Export Ctrl+T
Tool box Ctrl+B
Configure Ctrl+G
Change step color
View all memorized steps
One step out of 5
One step out of 10
One step out of 20
Properties
Page 1
Page 2
Page 3
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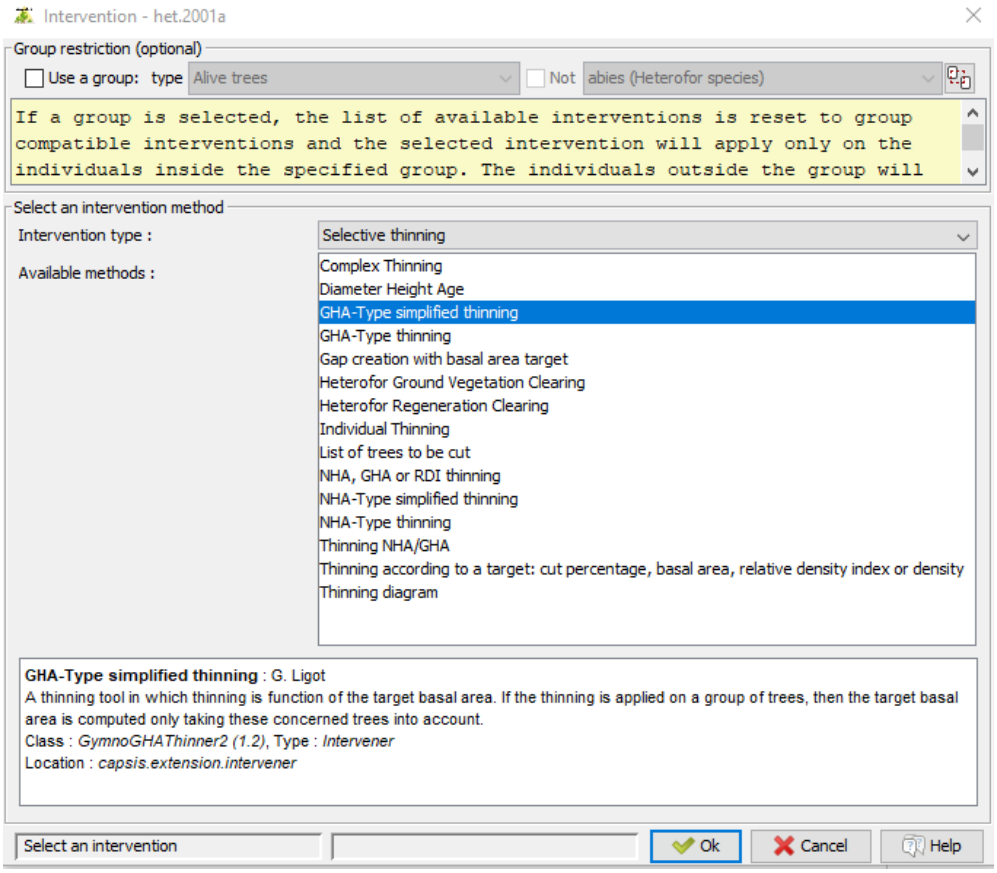
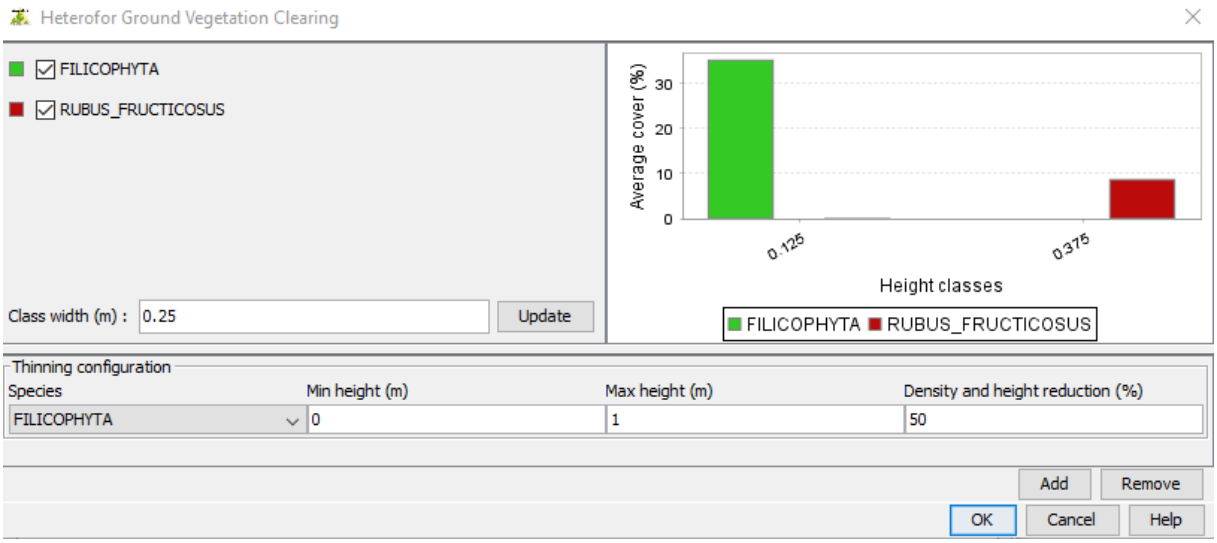
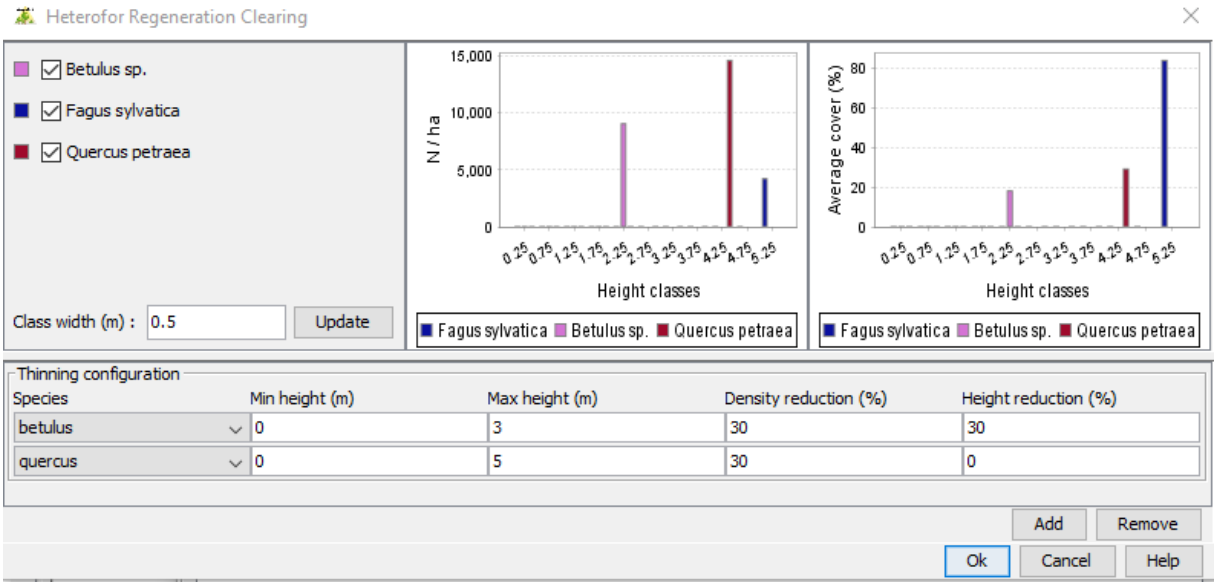
Page 5
Page 6
Page 7
Chart
(Dg/Hdom) / Time or Age
(Hg/Dg) / Time
Age / Time
Average volume increment / Time
Average volume per tree / Time
Basal area / Dominant height
Basal area / Time
Basal area / Time (age) or Cdom
Basal area / Time (age) or Hdom
Basal area for each storey / Time
Biomass / Time
Cdom & Cg / Time
Cover : LAI / Time
Cover : LAI for each storey / Time
DETimeAnnuity.name
Daily change in Deep Drainage
Daily change in Evapotranspiration compor
Daily change in Rainfall Partitioning
Daily change in extractable water
Daily evolution of the foliage state
Ddom & Dg / Time
Diameter / Time
Economics2 : Cumulative value / time
Economics2 : Mean value / time
Economics2 : NPV / r
Economics2 : NPV2 / r
Economics2 : NPVi / r
Economics2 : Price list
Economics2 : Stumpage value / diameter
Economics2 : Stumpage value / time
Economics2 : Test
Economics2 : Value / time
Girth / Time
Harvest : cumulated volume / Time
Harvested basal area / Time
Harvested volume / Time
Hdom & Hg / Time
Hdom / Time
Height / Age
Height / Dbh
Evolution is over

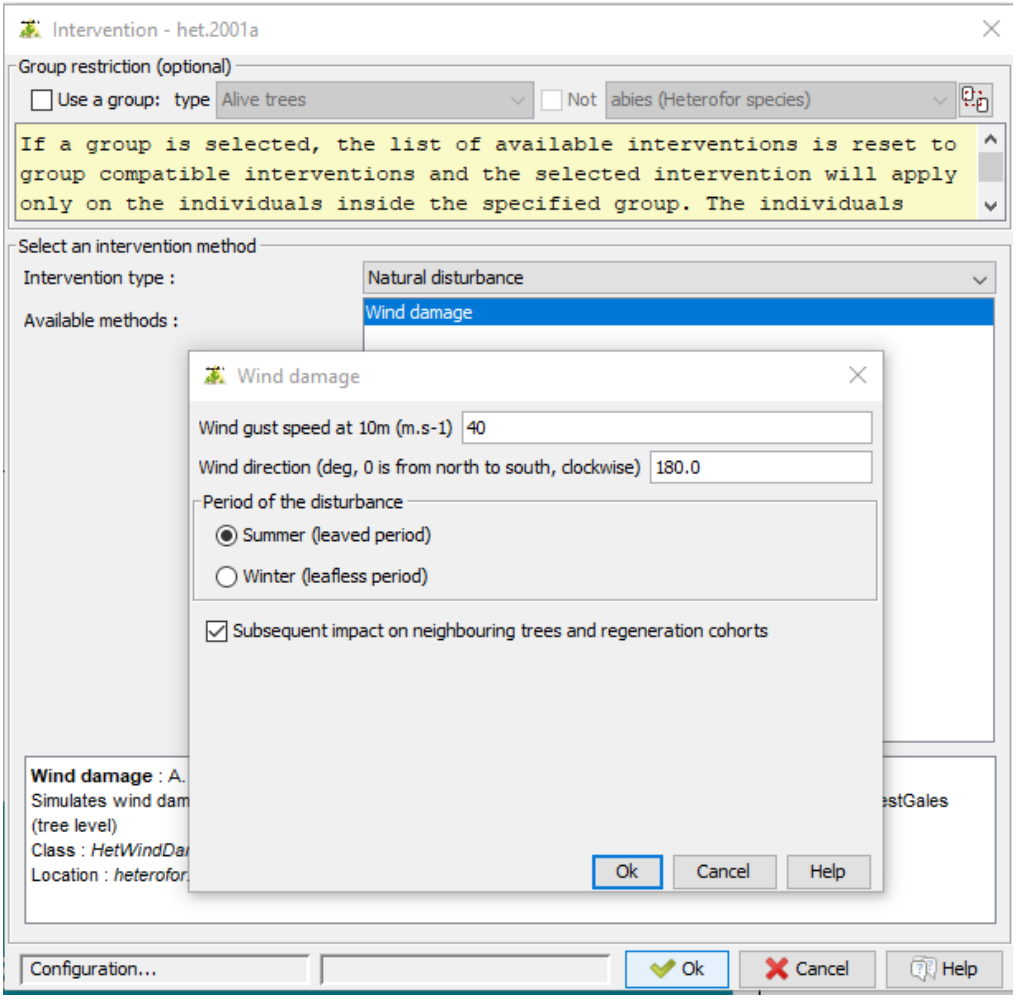

Intervention - het.2001a
Group restriction (optional)
Use a group: type Alive trees
Not abies (Heterofor species)
If a group is selected, the list of available interventions is reset to group compatible interventions and the selected intervention will apply only on the individuals inside the specified group. The individuals outside the group will
Select an intervention method
Intervention type : Selective thinning
Available methods :
Complex Thinning
Diameter Height Age
GHA-Type simplified thinning
GHA-Type thinning
Gap creation with basal area target
Heterofor Ground Vegetation Clearing
Heterofor Regeneration Clearing
Individual Thinning
List of trees to be cut
NHA, GHA or RDI thinning
NHA-Type simplified thinning
NHA-Type thinning
Thinning NHA/GHA
Thinning according to a target: cut percentage, basal area, relative density index or density
Thinning diagram
GHA-Type simplified thinning : G. Ligot
A thinning tool in which thinning is function of the target basal area. If the thinning is applied on a group of trees, then the target basal area is computed only taking these concerned trees into account.
Class : GymnoGHAThinner2 (1.2), Type : Intervener
Location : capsis.extension.intervener
Select an intervention
Ok
Cancel
Help

In addition to different types of thinning, it is also possible to carry out a clearing of the ground vegetation ('Heterofor Ground Vegetation Clearing') or tree regeneration ('Heterofor Regeneration Clearing'). For each species affected by the clearing, the minimum and maximum height of the cohorts to be considered must be given, and the reduction in height and/or density (in %) must be specified.



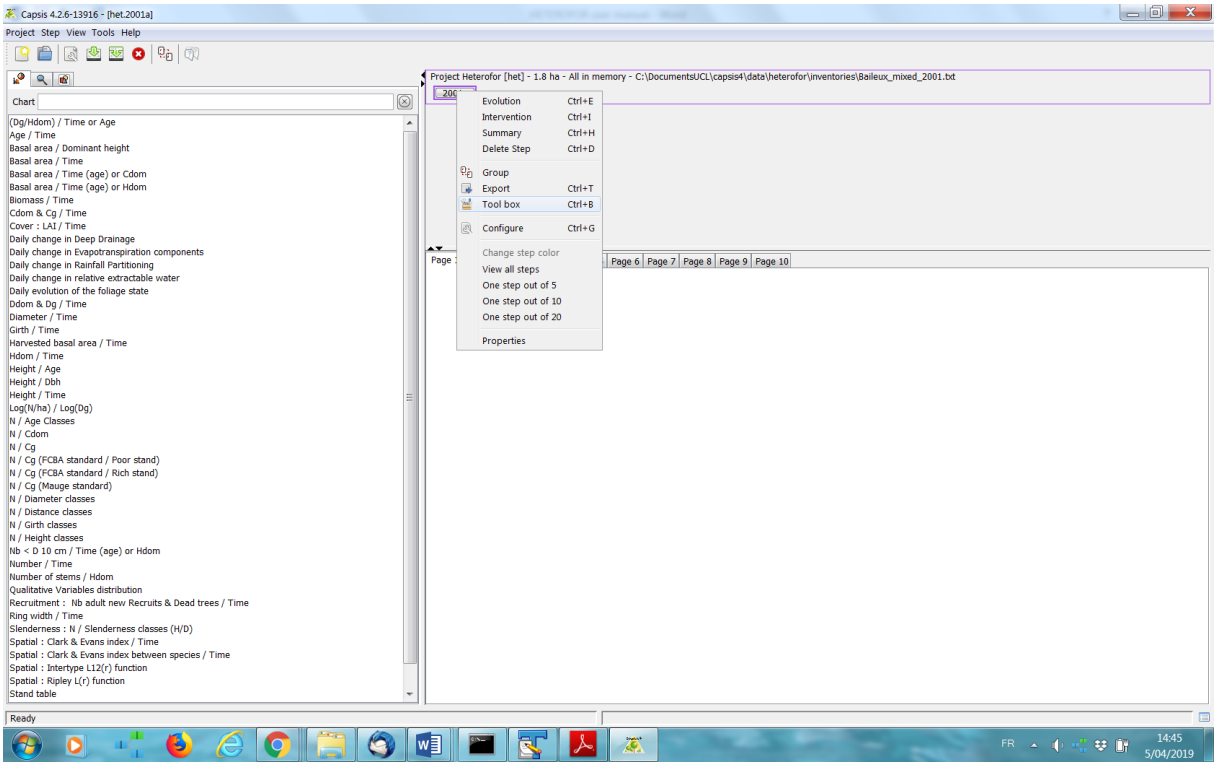


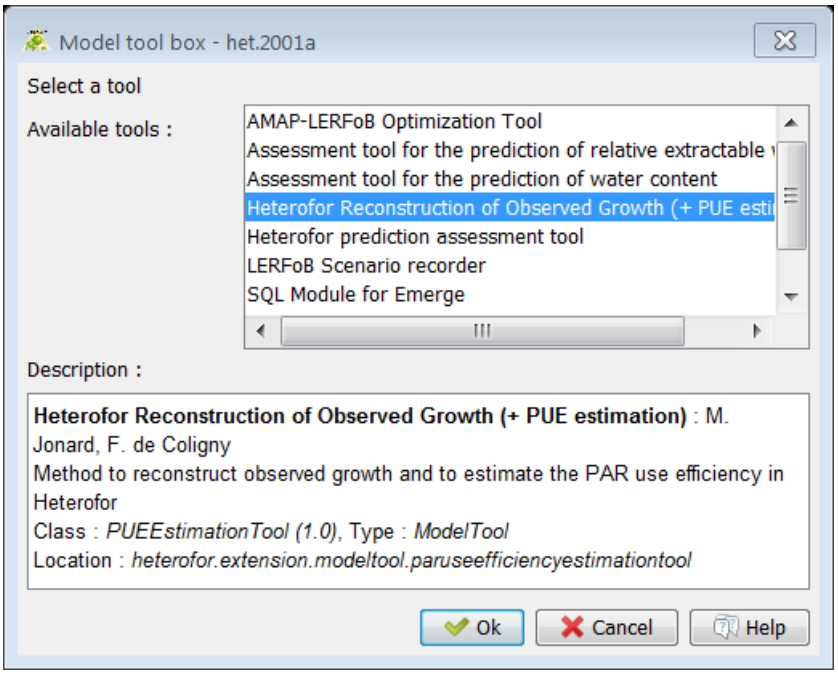
In the intervention menu, you can scroll down the “intervention type” list and select “Natural disturbance” to simulate a windstorm event and damage on trees. In the newly opened window, you will need to specify the wind gust speed of the event (in m s^{-1}), the wind direction (in deg), the period of the event (to take into account the presence of leaves or not), and if you want to consider the subsequent impact on neighbouring trees and regeneration cohorts.

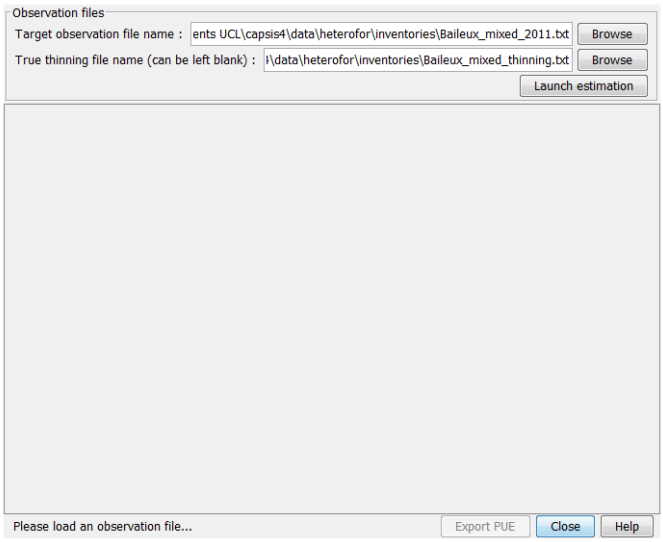


6. Launching a reconstruction

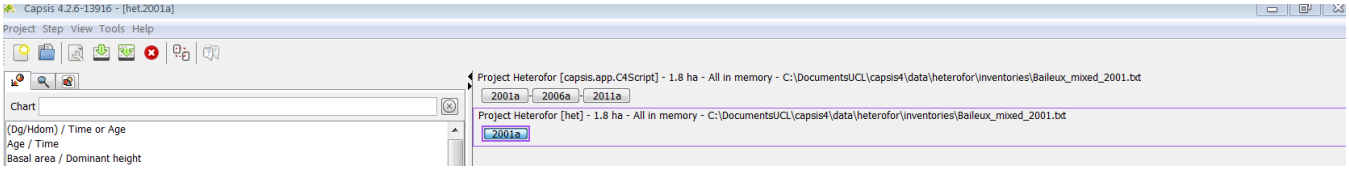
HETEROFOR was adapted to allow the user to run it in reverse mode starting from the known increments in girth and height to reconstruct individual tree growth using exactly the same parameters and equations as in the normal mode. To achieve a reconstruction, an inventory file with tree measurements must be loaded to create the initial step (see sect. 5.). The reconstruction tools can be launched by right-clicking on the initial step and select “Tool box” in the drop-down menu. Then, the user must choose the reconstruction tool (Heterofor Reconstruction of Observed Growth) and provide an inventory file with tree measurements achieved one or several years later as well as the thinning file. Based on these files, HETEROFOR calculates the mean girth and height increments for each tree and use the model equations to reconstruct each step. Do not forget to click on the “Launch estimation” button.





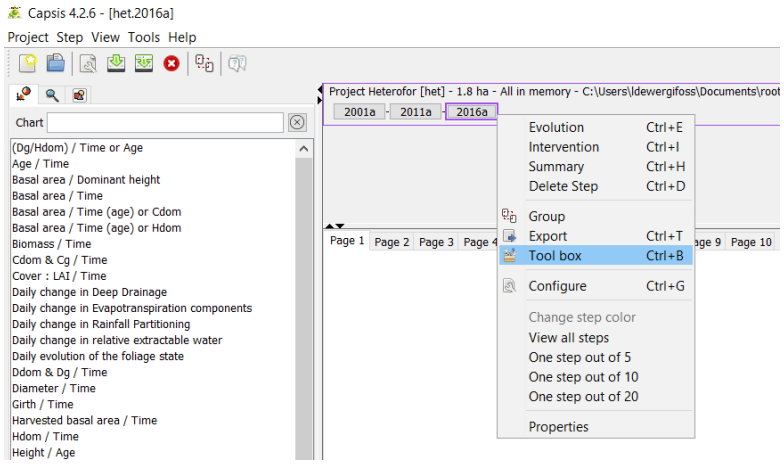


After a while, a graph showing the PAR use efficicency as a function of the light competition index will appear. The project corresponding to the growth reconstruction will appear after clicking on the initial step.

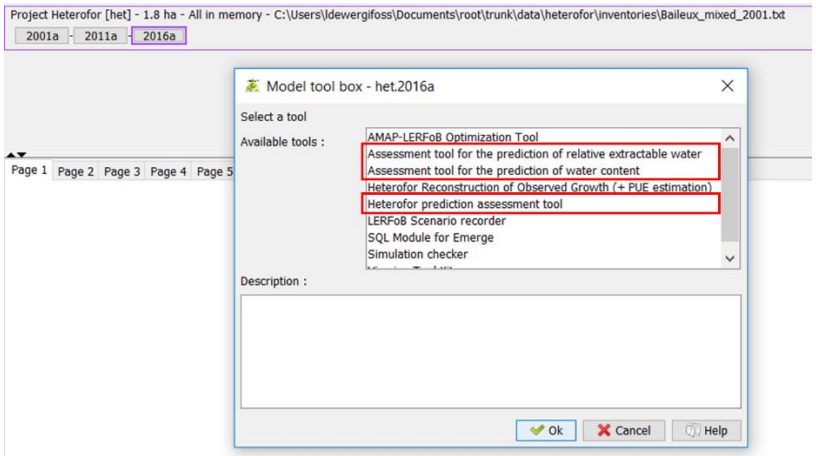


7. Evaluation tools

Different evaluation tools can be used in HETEROFOR to compare the model predictions with the observations. A visual comparison is proposed by default but a txt file and a table with the corresponding predictions and observations can be created and opened, respectively. The visualisation tools can be access with a right-click on the step for which or until which observations are available and by selecting “Tool box” (Ctrl+B).



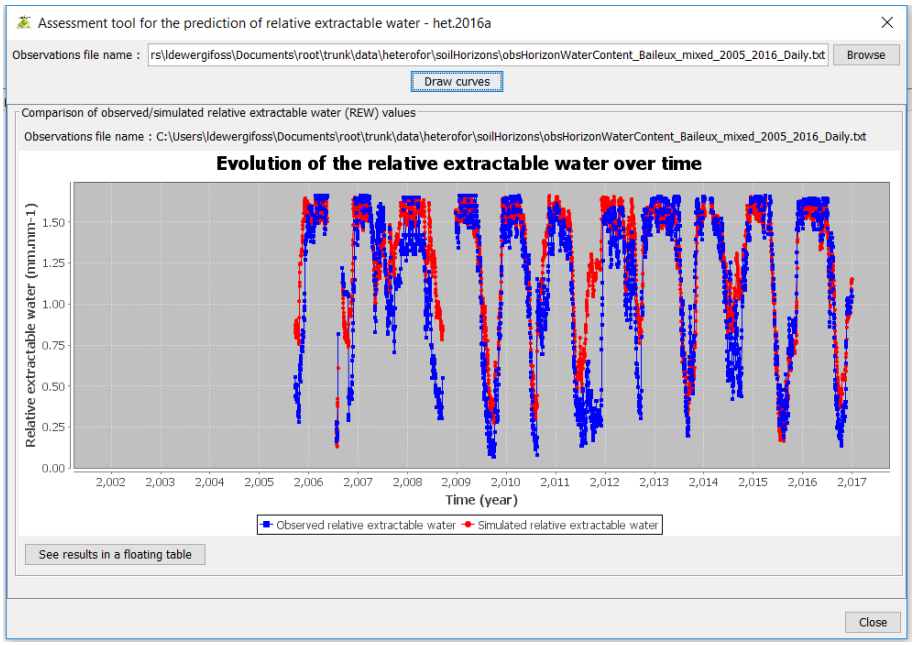
Different toolboxes are available but only three are evaluation tools: the assessment tool for the prediction of relative extractable water (REW), the assessment tool for the prediction of water content and the HETEROFOR prediction assessment tool which is dedicated to the evaluation of tree dimensional growth.



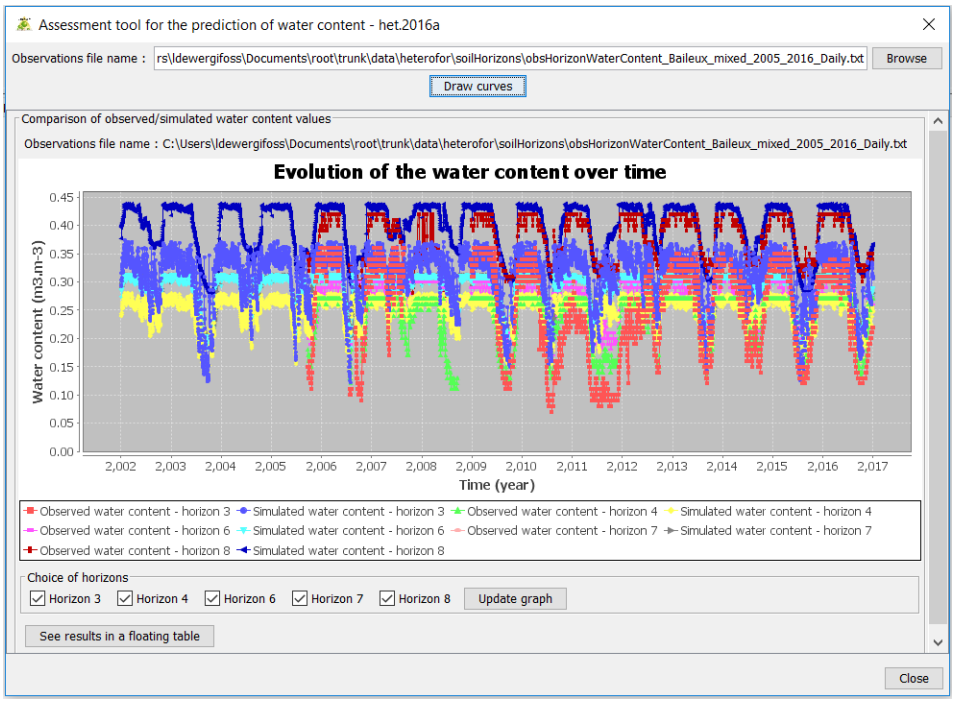
Evaluation based on soil water content data

Both evaluation tools for REW and water content predictions require the same observational file. This file is a table providing the water content (in $m^3.m^{-3}$) per soil horizon for each day or hour. The date is indicated based on three or four fields: Year, Month, Day, Hour.

For the REW evaluation tool, the resulting graph displays the temporal evolution of the predicted and observed REW. The REW is calculated according to de Wergifosse *et al.* (2020) by considering only the horizons for which water content data are available. Missing data do not prevent the evaluation tool to run but it will generate discontinuities in the graph.



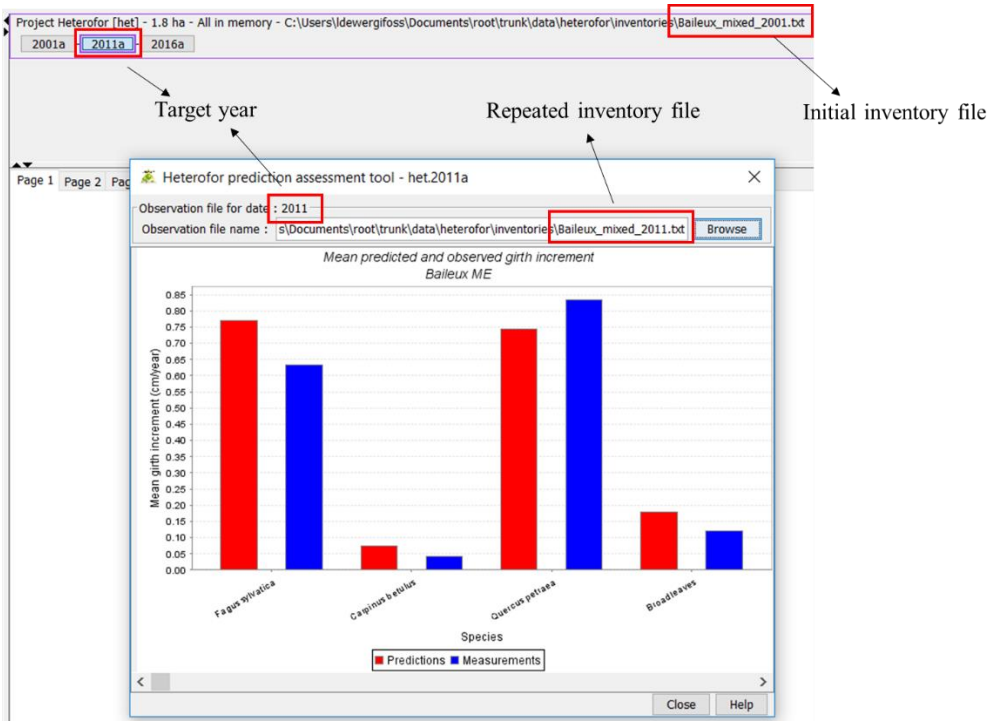
The second tool displays the temporal variability of predicted and observed water content per soil horizon. For better legibility, it is recommended to select one horizon at a time.



For both evaluation tools, the data can be visualized in a table by clicking on “See results in a floating table”.

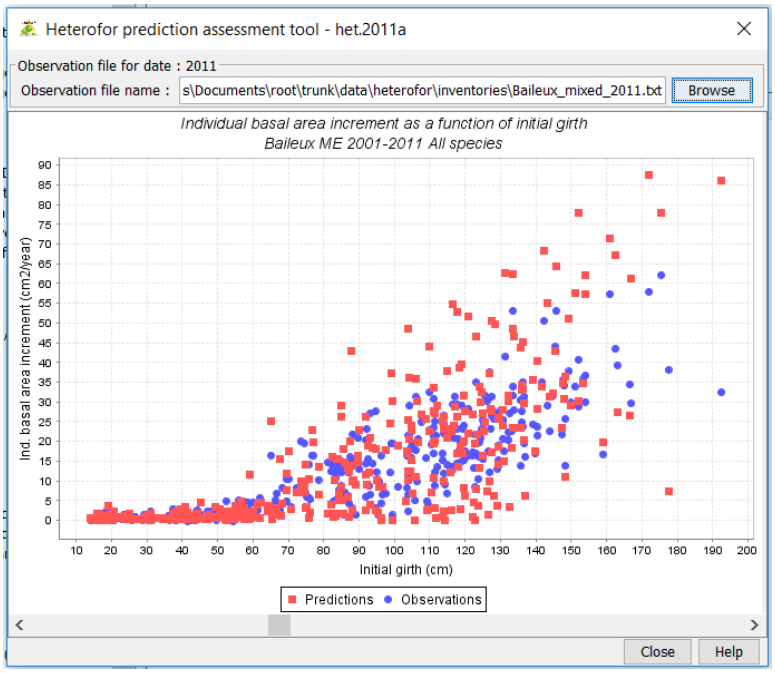
Evaluation based on tree growth data

The tool to assess tree growth requires an inventory file similar to the one used for the initialization but for a later date in order to calculate the increments in girth, height and crown dimensions. The user must select the step for which a repeated inventory is available and load the corresponding file.

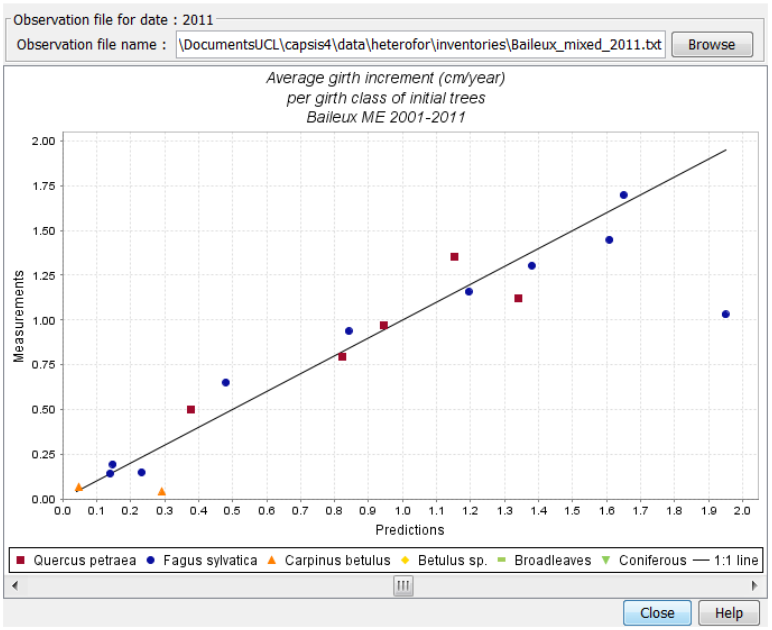


A large amount of graphs is displayed after a short calculation time. The data corresponding to these graphs can be obtained by right-clicking on them and select “extract in a table”.

Three types of evaluation graphs are proposed. First, bar charts compare mean predictions and observations for the various tree species (see previous figure). Such graphs are available for the girth increment ($cm.yr^{-1}$), basal area increment ($cm^2.yr^{-1}$), height increment ($m.yr^{-1}$), crown base height increment ($m.yr^{-1}$), largest crown extension increment ($m.yr^{-1}$) and the quadratic crown radius increment. Second, scatter plots compare predicted *vs* observed size-growth relationships. Two types of relationships are available: the height increment ($m.yr^{-1}$) as a function of initial height (m) and the basal area increment ($cm^2.yr^{-1}$) as a function of initial girth (cm).

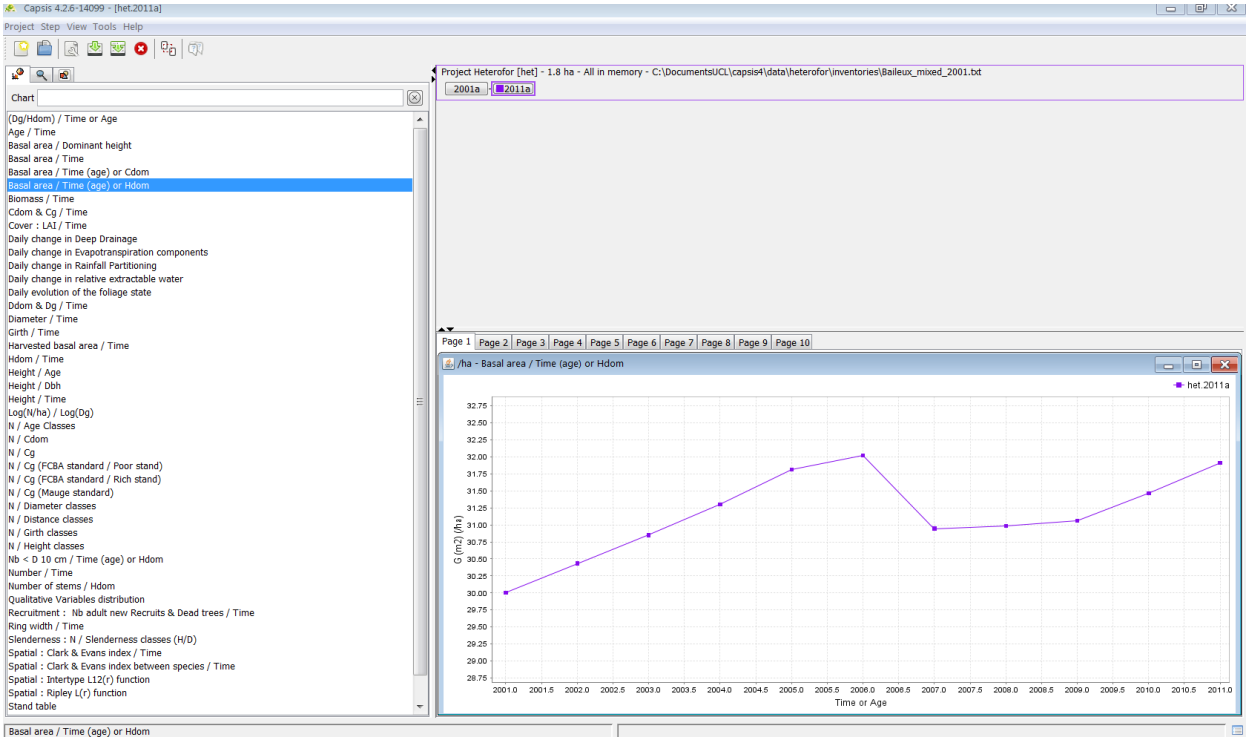


Third, scatter plots comparing observations with predictions enable to assess the quality of the predictions (with reference to the 1:1 line) and detect some eventual biases. For some graphs, trees are grouped per girth class while, for others, the observations and predictions correspond to individual trees. Such graphs are available for the girth increment ($cm.yr^{-1}$), the basal area increment ($cm^2.yr^{-1}$), the height increment ($m.yr^{-1}$), the crown base height increment ($m.yr^{-1}$), the largest crown extension increment ($m.yr^{-1}$) and the crown radius increments in the four cardinal directions (with and without log transformation).

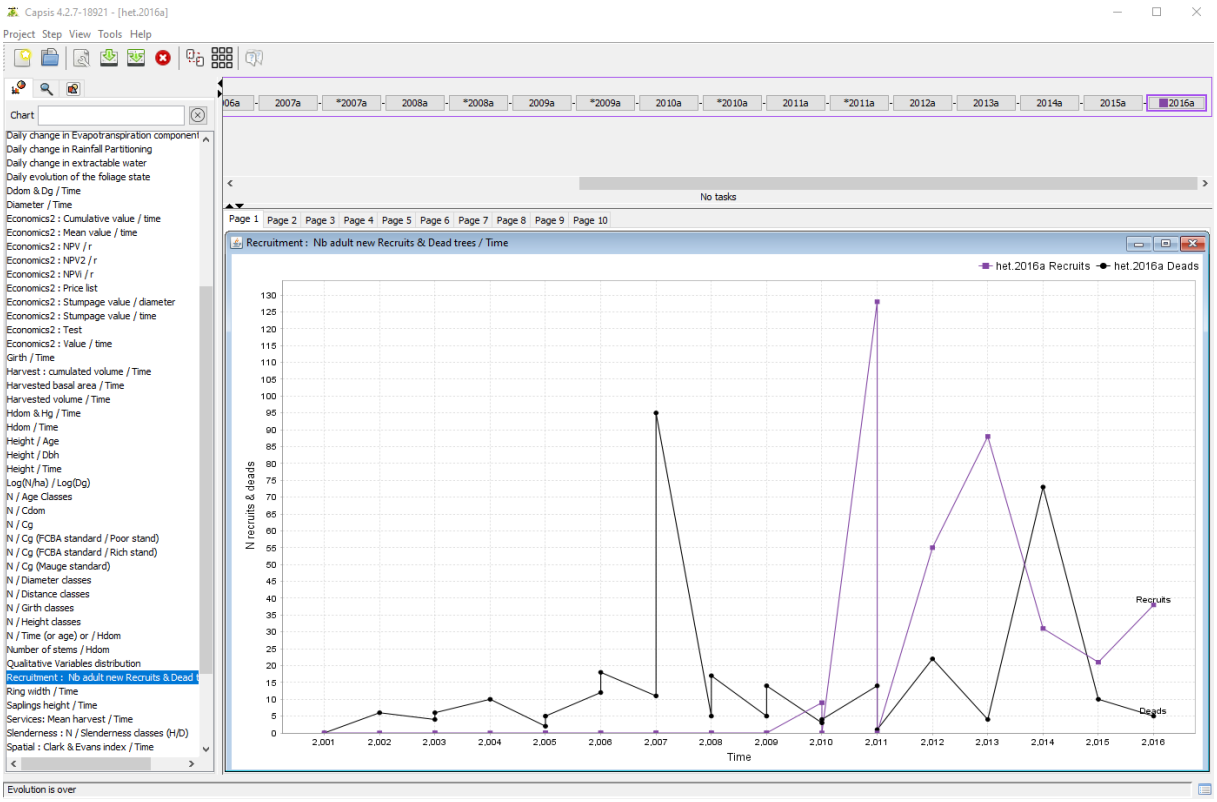


8. Model outputs (graphs and tables)

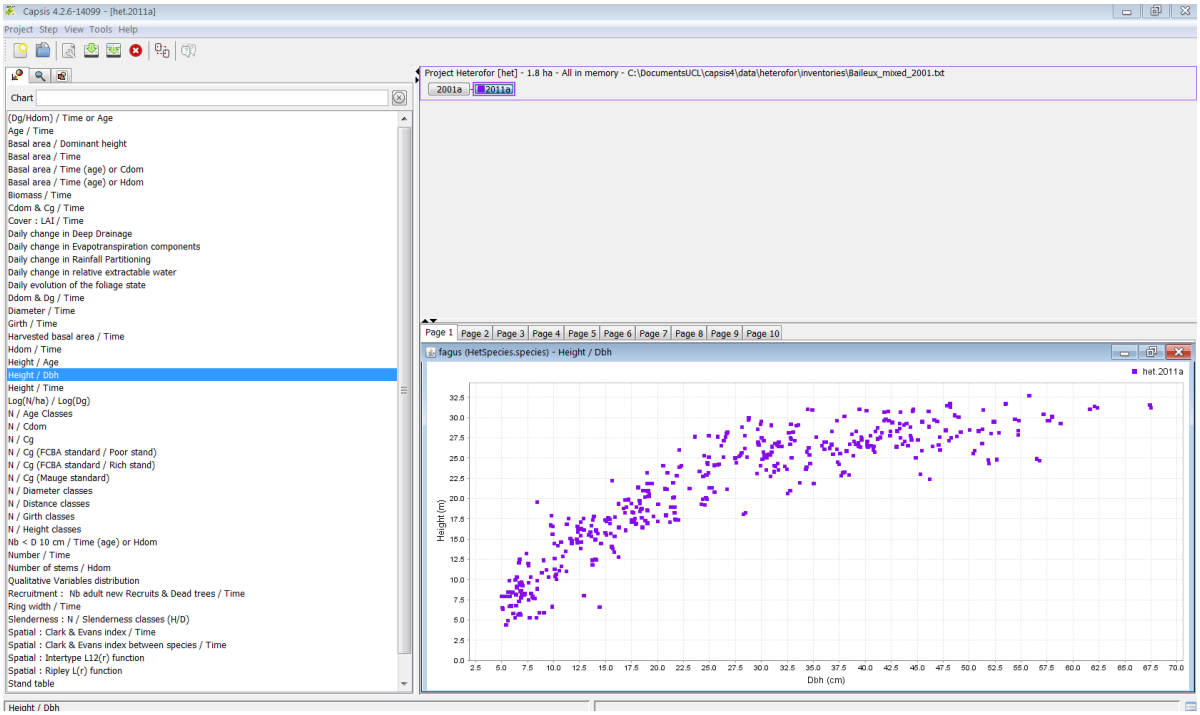
The user has at his disposal a whole series of graphs created for all individual-based models in CAPSIS. These graphs are listed on the left panel when the “Chart” tab is selected. To create a graph for a given simulation, select the corresponding project in the upper right panel and double-click on the graph name in the list. It will then appear in the lower right panel. For example, a graph shows the temporal trend in basal area or its evolution with dominant height. The layout of this graph can be modified by right-clicking on it and selecting “Configure”. For the basal area graphs, one can choose the unit for the basal area (in m^2 or in m^2 ha^{-1}) or the variable of the X axis (Time or Dominant height).

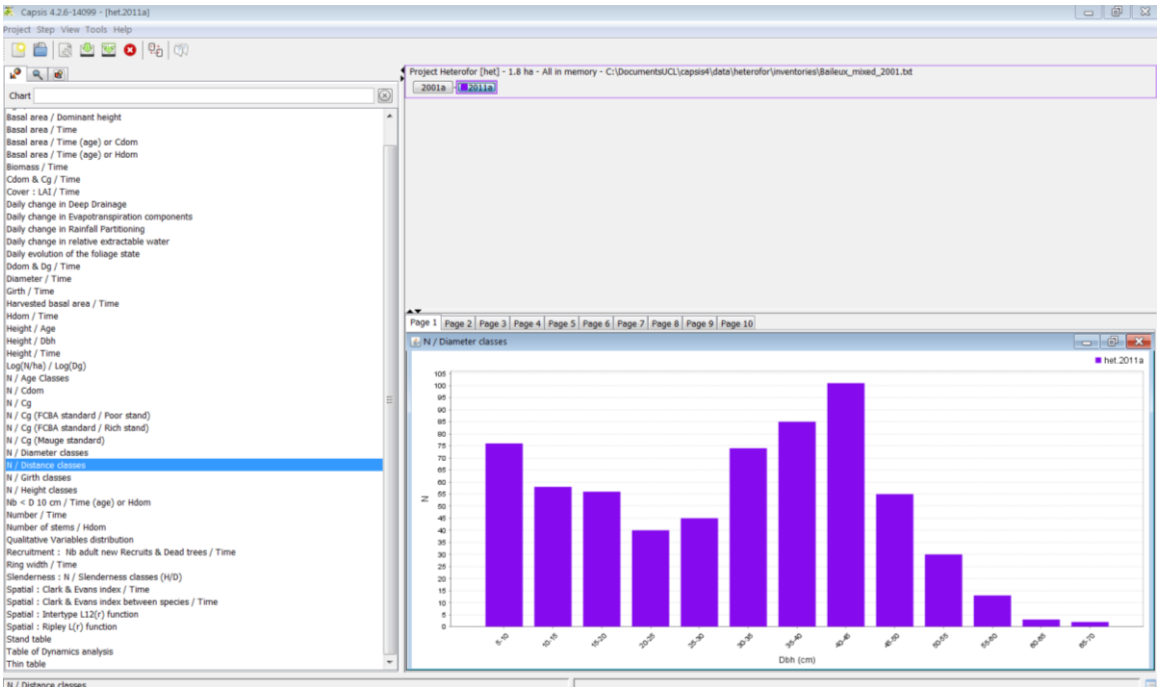


Graphs displaying temporal trends can also be obtained for other variables: geometric mean or dominant girth/dbh, girth/dbh of selected trees (right-click on the graph and choose “Configure” to select the trees of interest), LAI, dominant height, or number of recruited and dead trees (in number or number ha^{-1}). Some graphs are present in the list but do not appear correctly when selected. This happens for the graphs showing an evolution with tree age because tree age is not considered in HETEROFOR.



Other graphs are showing relationships between tree dimensions (e.g., height *vs* dbh) or between stand variables (e.g., log N *vs* log mean dbh). One can also create tables with stand characteristics or histograms showing the distribution of trees per size class.

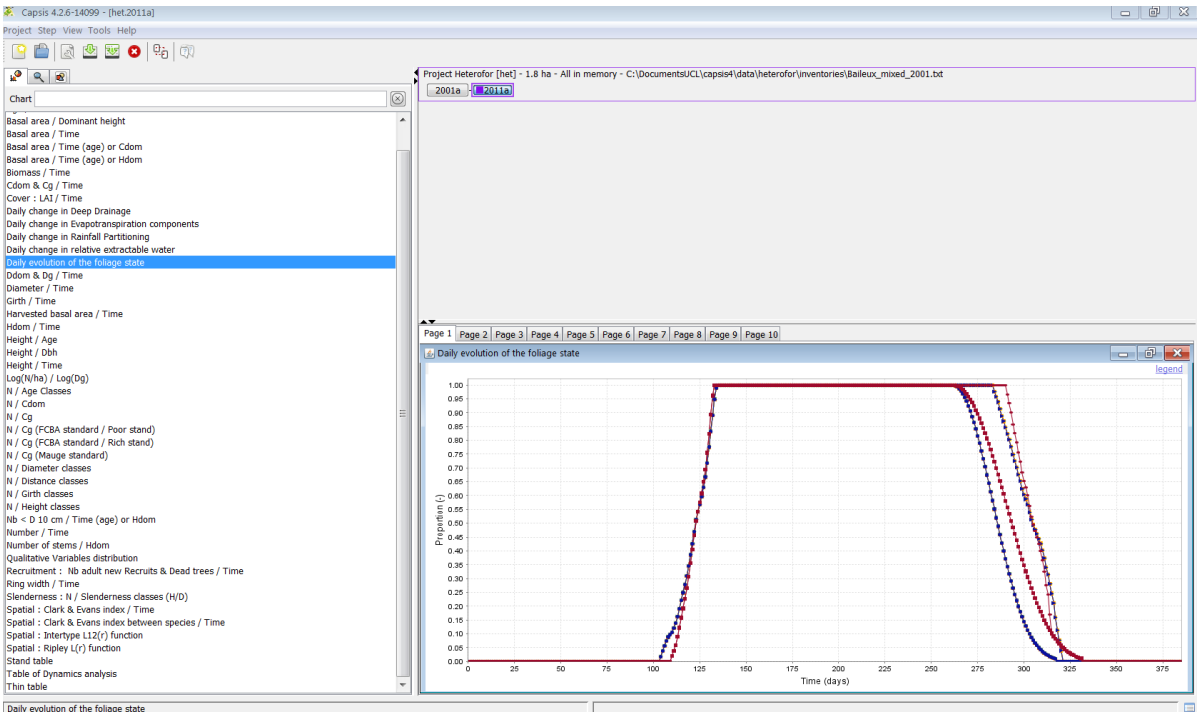


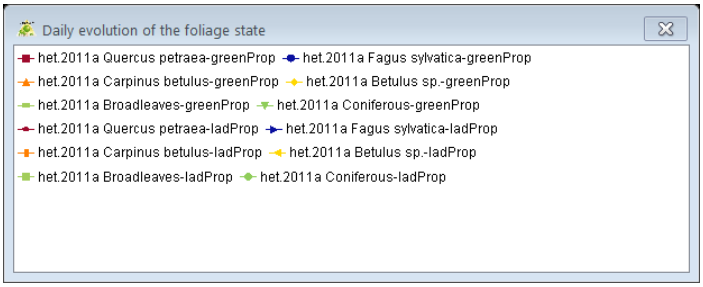

Capsis 4.2.6-14099 - [het.2011a]
Project Step View Tools Help
Chart
Basal area / Dominant height
Basal area / Time
Basal area / Time (age) or Cdom
Basal area / Time (age) or Hdom
Biomass / Time
Cdom & Cg / Time
Cover : LAI / Time
Daily change in Deep Drainage
Daily change in Evapotranspiration components
Daily change in Rainfall Partitioning
Daily change in relative extractable water
Daily evolution of the foliage state
Ddom & Dg / Time
Diameter / Time
Girth / Time
Harvested basal area / Time
Hdom / Time
Height / Age
Height / Dbh
Height / Time
Log(N/ha) / Log(Dg)
N / Age Classes
N / Cdom
N / Cg
N / Cg (FCBA standard / Poor stand)
N / Cg (FCBA standard / Rich stand)
N / Cg (Mauge standard)
N / Diameter classes
N / Distance classes
N / Girth classes
N / Height classes
Nb < D 10 cm / Time (age) or Hdom
Number / Time
Number of stems / Hdom
Qualitative Variables distribution
Recruitment : Nb adult new Recruits & Dead trees / Time
Ring width / Time
Slenderness : N / Slenderness classes (H/D)
Spatial : Clark & Evans index / Time
Spatial : Clark & Evans index between species / Time
Spatial : Intertype L12(r) function
Spatial : Ripley L(r) function
Stand table
Table of Dynamics analysis
Thin table
Project Heterofor [het] - 1.8 ha - All in memory - C:\Documents\UCL\capsis4\data\heterofor\inventories\Baileux_mixed_2001.txt
2001a
2011a
Page 1
Page 2
Page 3
Page 4
Page 5
Page 6
Page 7
Page 8
Page 9
Page 10
N / Diameter classes
het.2011a
N
Dbh (cm)

Besides these default graphs available for all individual-based models of CAPSIS, some charts are specific to HETEROFOR. Among them, a graph shows the daily evolution in the foliage state for each tree species, if the phenology module was activated at initialization. The state of the foliage is characterized by two variables:

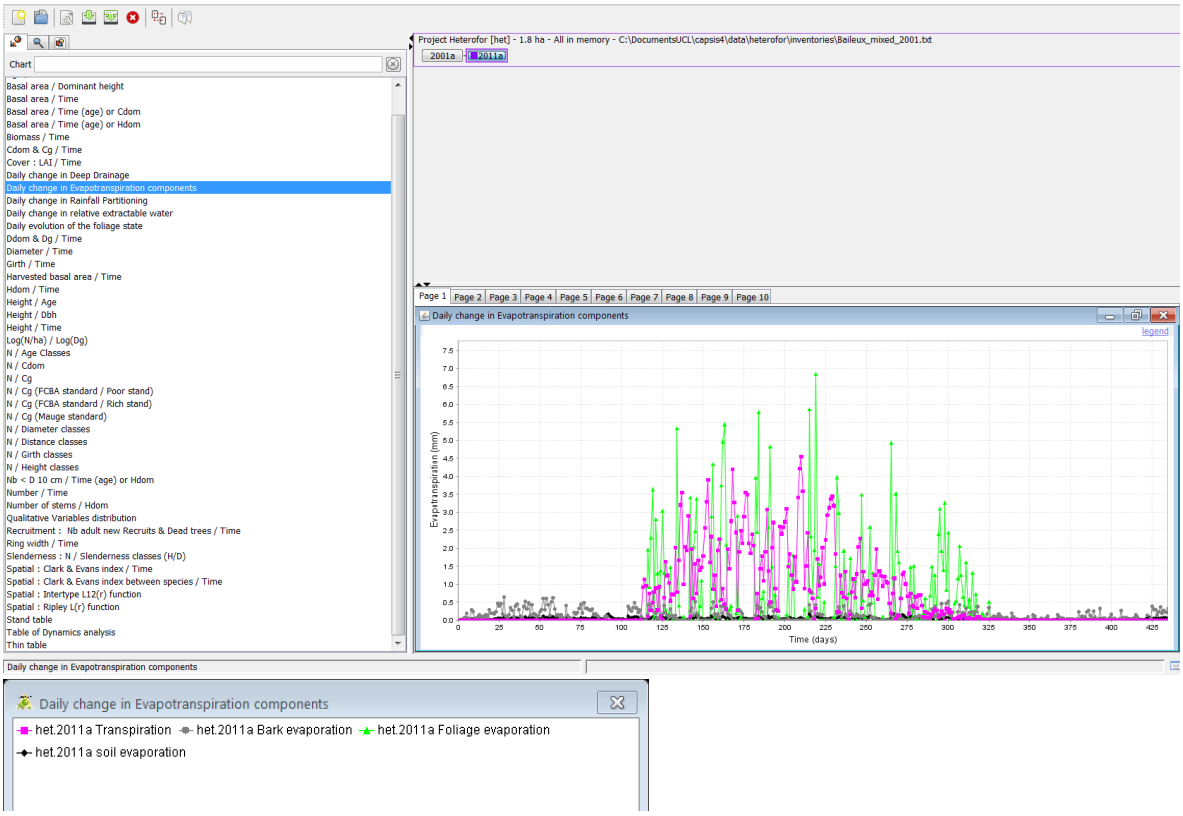
- ladProp: the proportion [0-1] of leaf with reference to the maximum leaf amount when the full leaf development is reached,
- greenProp: the proportion of green leaves with reference to maximum leaf amount.

One can zoom on the graph with the left-click. The data used to create the graph can be obtained by right-clicking on the graph and selecting “open in a floating table”.

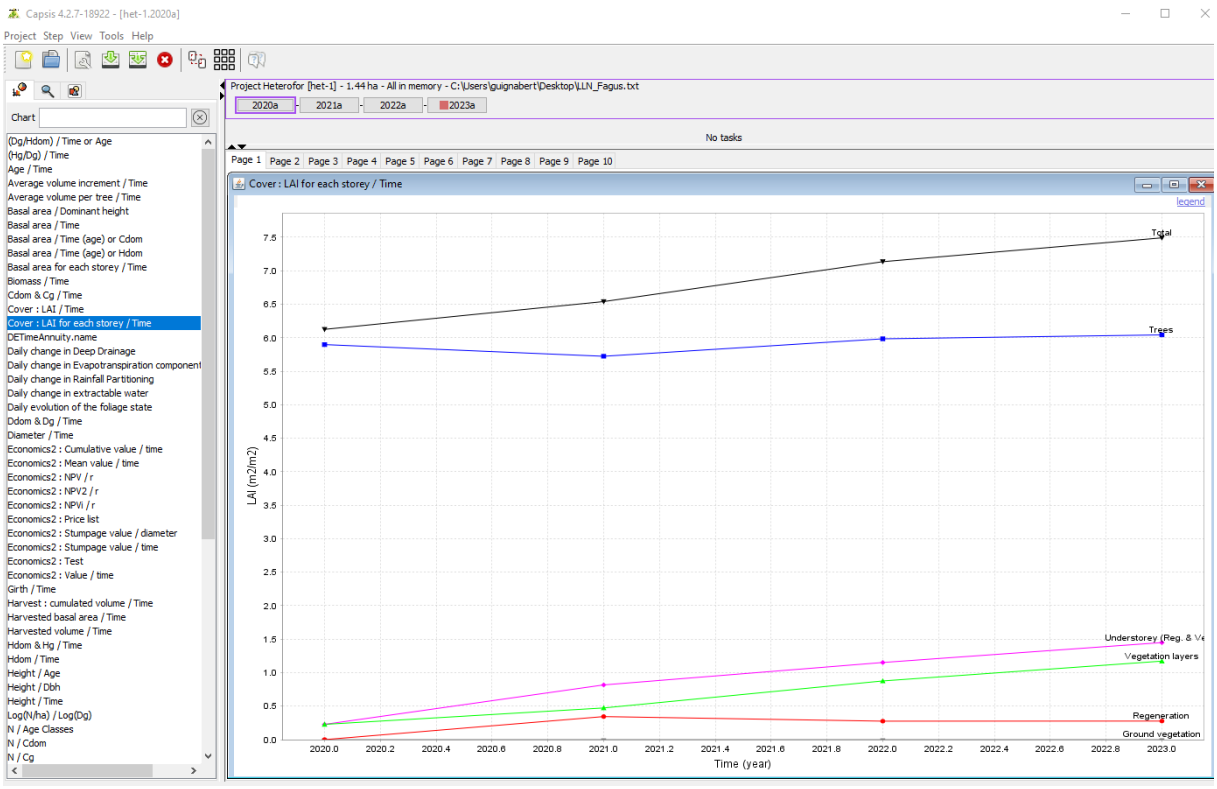




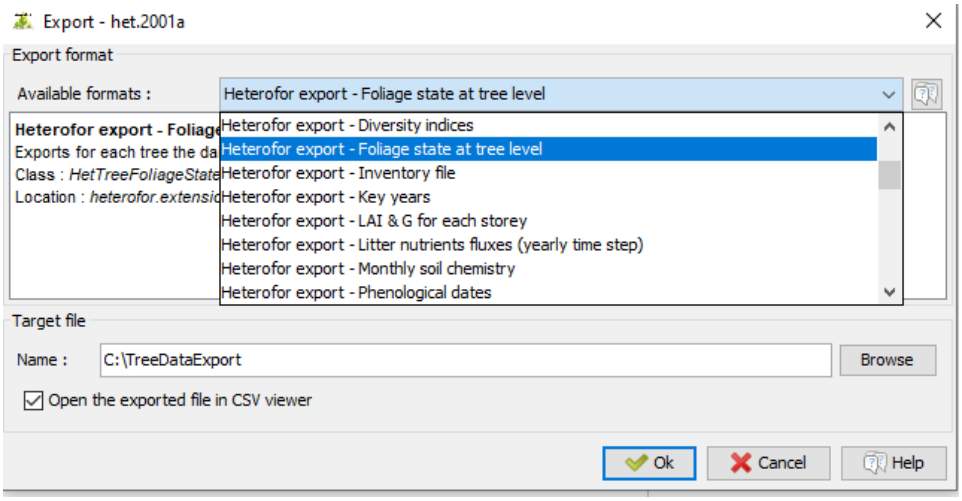
Similar graphs show the daily change in rainfall partitioning, evapotranspiration components, deep drainage and relative extractable water.



Another graph specific to HETEROFOR represents the LAI ($m^2\ m^{-2}$) for each vegetation storey (i.e. trees, vegetation layers, and tree regeneration).

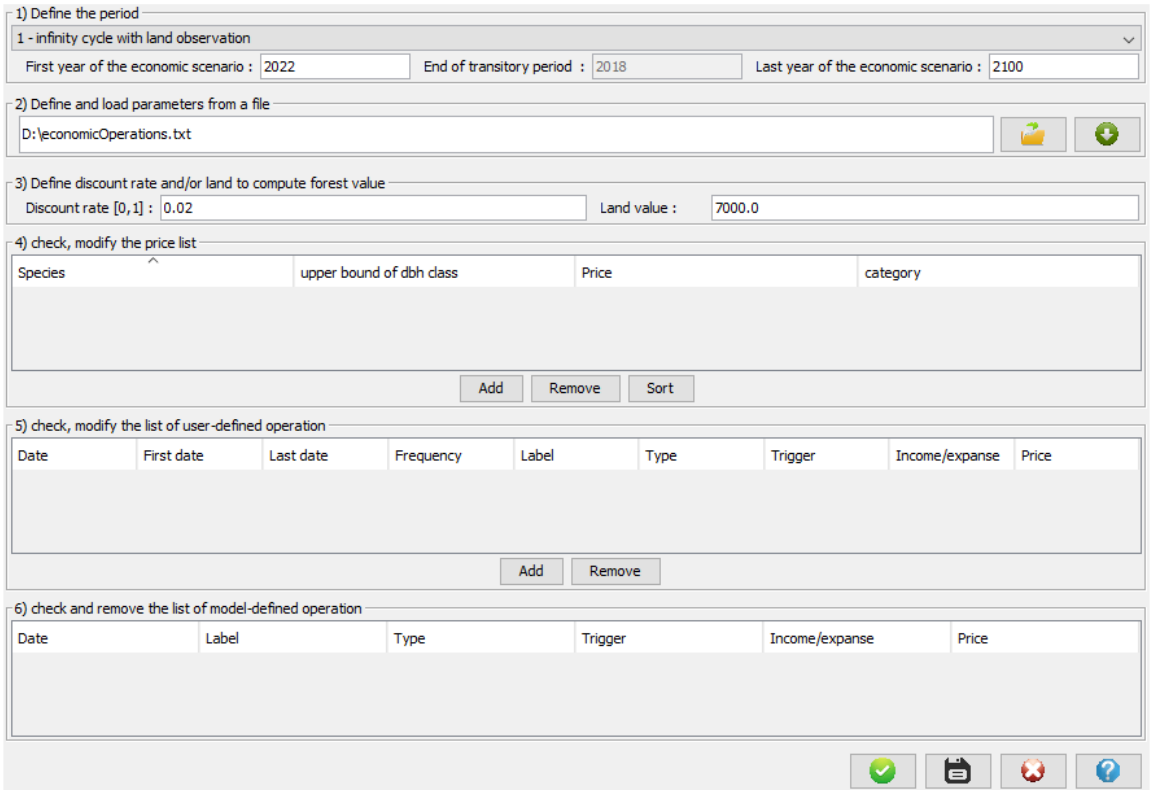


In addition to these graphs, the state variables of HETEOFOR can be visualized in tables and exported in txt files. To generate an export, right-click on the final step of a project and select “Export”. You will have access to a list of exports through the window here below and have to specify where the txt file must be stored.



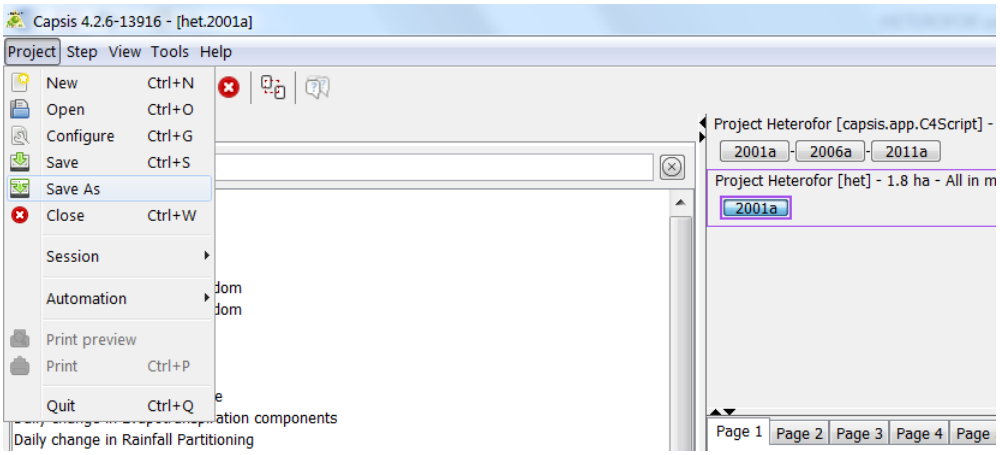
Many variables can be exported and concerns the foliage state (see above), the phenological dates corresponding to the main phenological events, the tree characteristics, the hourly soil temperature, the water fluxes and contents at yearly, monthly, daily or hourly time step, the nutrient fluxes and stocks (in the trees an in the soil) and the soil chemistry.

Economic indicators (wood production) can also be obtained through the coupling of HETEROFOR with ECONOMICS2. ECONOMICS2 is available in the Tool box (right click on the last step of the simulation) and choose “Define economics2 scenario”. The scenario definition can be done directly in the window or by loading a file. Information’s about ECONOMICS2 can be obtained here.

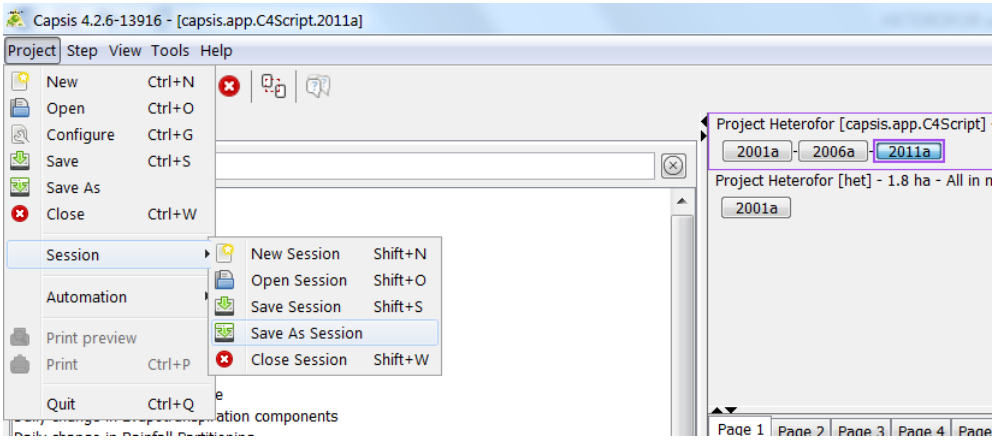


9. Saving the project or the session

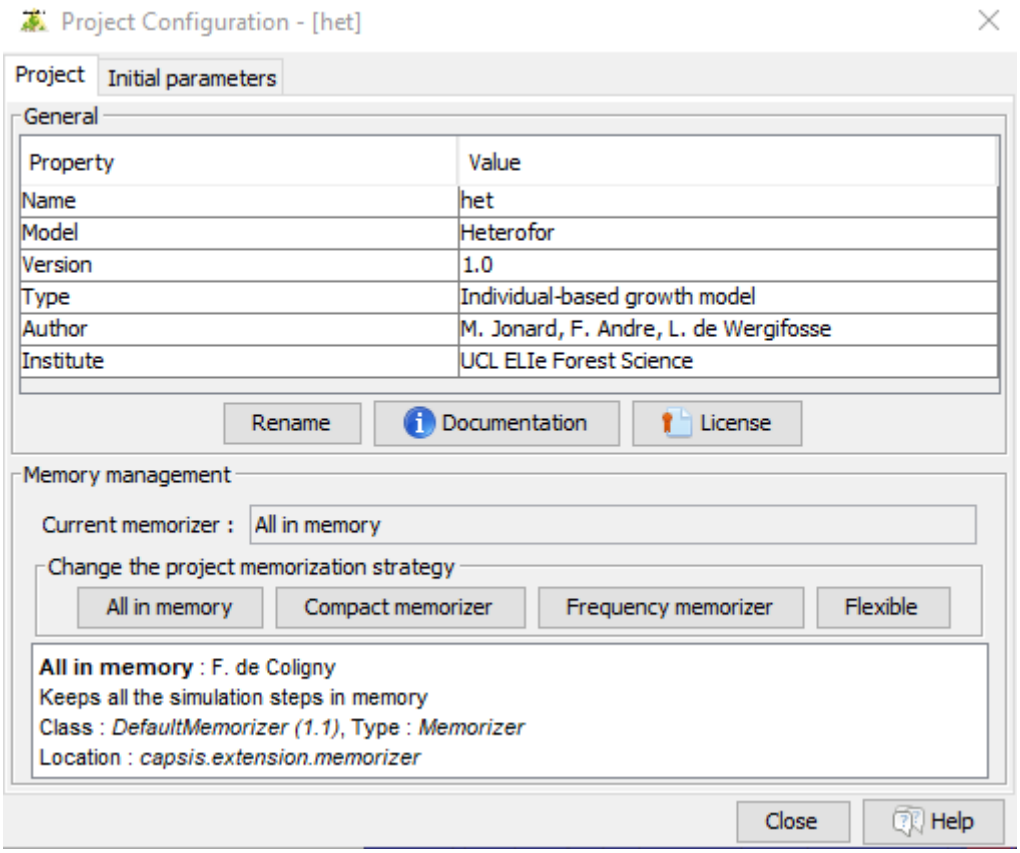
The project can be saved by selecting it and then choose “save” or “save as” in drop-down menu under “Project”.

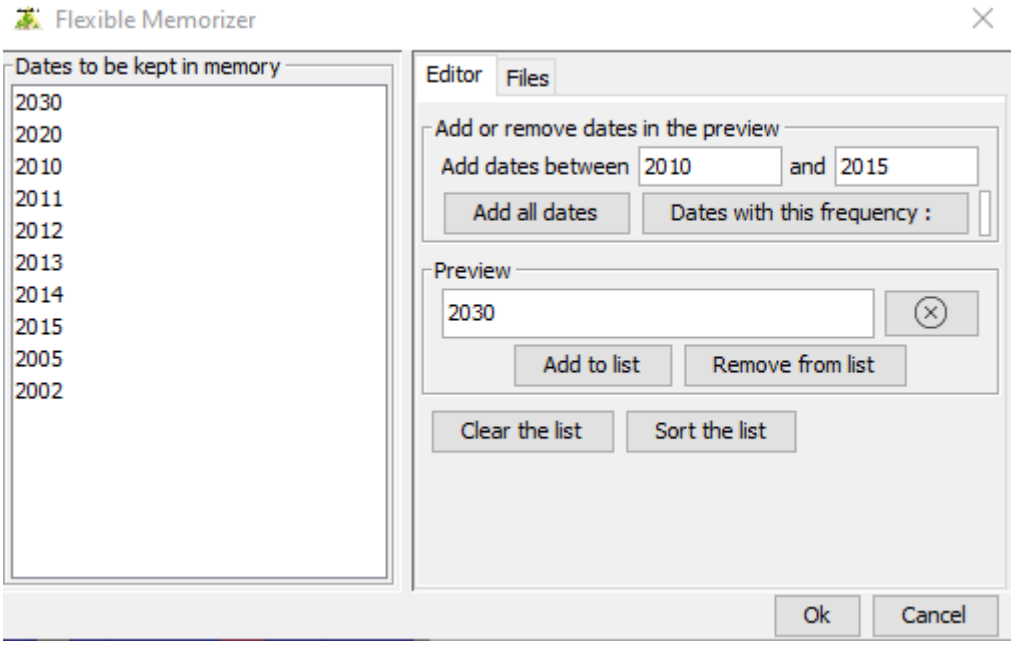


Similarly, the session containing all the projects can be saved.



However, it may not be possible to save the entire simulation regarding big simulations using a lot of memory. To deal with this, you can choose between various memorizing options (called Memorizers) regarding the simulation steps. Memorizers allow keeping in memory only a part of evolution steps, e.g. based on frequency (frequency memorizer) or based on a specific list of dates (flexible memorizer). It is possible to combine several memorizers for a single simulation, e.g. you can save every step during ten years, then switch and save only one step out of five for 50 years, and then save again all steps until the end. Memorizers can be accessed by selecting “Configure” in the drop-down menu under “Project”. More can information can be found here.


Project Configuration - [het]
Project
Initial parameters
General
Property
Value
Name
het
Model
Heterofor
Version
1.0
Type
Individual-based growth model
Author
M. Jonard, F. Andre, L. de Wergifosse
Institute
UCL ELIe Forest Science
Rename
Documentation
License
Memory management
Current memorizer :
All in memory
Change the project memorization strategy
All in memory
Compact memorizer
Frequency memorizer
Flexible
All in memory : F. de Coligny
Keeps all the simulation steps in memory
Class : DefaultMemorizer (1.1), Type : Memorizer
Location : capsis.extension.memorizer
Close
Help


Flexible Memorizer
Dates to be kept in memory
2030
2020
2010
2011
2012
2013
2014
2015
2005
2002
Editor
Files
Add or remove dates in the preview
Add dates between
2010
and
2015
Add all dates
Dates with this frequency :
Preview
2030
Add to list
Remove from list
Clear the list
Sort the list
Ok
Cancel

10. Script mode

CAPSIS is generally used in interactive mode which allows the users to work in a graphical environment with menus and dialogs as described above. Alternatively, the script mode can also be very useful to execute long and repetitive simulations. The results of these simulations are saved in files that can be analysed later in Capsis or with other analysis or statistical tools. The script mode is also very interesting to call CAPSIS from another software (such as R) in order to, for example, perform a calibration of the model parameters. All the information needed to create a script is available at http://capsis.cirad.fr/capsis/documentation/script_mode

11. References

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