An introduction to crop modelling

Practical refresher

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# Practical exercise # 2 - Familiarization with STICS and JavaSTICS environment

## Install the STICS soil-crop model files and required folder

Please follow the instructions:

* If it is not done yet, unzip the folder «IntroductionCropModelling» .
* We recommend to copy-paste the file “JavaSTICS-v131-stics-v850.zip” on the “C:\” directory, or as close as possible as your “C:\” drive. However, it should run from any location on your computer.
* Unzip the file “JavaSTICS-v131-stics-v850.zip” using the native windows un-zipper or using 7‑zip (<https://www.7-zip.org/>).   
  Please, unzip the files **INTO** a folder to avoid to have all sub-folder on your “C:\”. To do so, right-clic on JavaSTICS-v131-stics-v850.zip and select “Extract To JavaSTICS-1.40-stics-8.50\”.

The STICS soil-crop model user interface can be executed immediately from the folder:  
“C:\JavaSTICS-v131-stics-v850\JavaStics.exe” or “C:\...\JavaSTICS-v131-stics-v850\JavaStics.exe” (the \...\ represent the case where JavaStics was not installed on C:\).   
This interface runs the model executable and allows you to change parameter values.

As an executable, the model is therefore ready to be run. However, you still need some operations to run our case study:

* Copy-paste the folder « FirstStepIntoModelling » from « …\IntroductionCropModelling» into “C:\...\JavaSTICS-v131-stics-v850\”.
* Copy-paste the file « WW\_Gbx\_Ideotype\_plt.xml» from « …\IntroductionCropModelling\Plant\ » into “C:\...\JavaSTICS-v131-stics-v850\plant”
* Rename the file by removing “\_Ideotype” so that the plant file name is : “WW\_Gbx\_plt.xml”

Those two plant file are your back-up. But we configured the model to run with only one plant file “WW\_Gbx\_plt.xml”

Finally, we recommend you to add STICS to your taskbar. To do so, right-click on “C:\...\JavaSTICS‑v131‑stics‑v850\JavaStics.exe” and “create a shortcut”. Then, drag-and-drop the shortcut on your taskbar.

## General consideration on STICS and on the running files

The crop model will allow you to perform simulations. However, to run a simulation, you need different input files: Climatic data, initialization data, soil and plant parameters, management itinerary, eventually forcing data.

In the previous section, through miniSTICS, we have discovered the model formalisms related to plant growth and soil water balance. Unfortunately, we will not have time enough to explore soil bio-chemistry changes (C, N, etc.).

In the previous exercise you had the possibility to test various climatic scenarios; in the IP, we will explore climate change scenarios. This course is devoted to *Smart Farming*; in this section, we will use the crop model to modify a plant parameter file and create different management itineraries. Unfortunately, we will not have time to explorer further input files in details.

To run the model, there is a critical concept: the unit of simulation (USM). A USM will allow you to “speak” with the model, and tells what needs to be simulated, i.e.:

* Which plant is grown/which plant is sown,
* Following which management itinerary,
* Under which climatic condition
* On which soil type,
* And what were the soil (and eventually plant) conditions at the time of model initialization

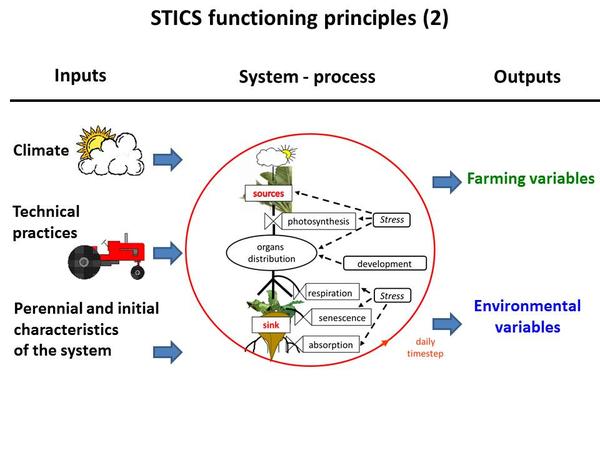


Figure 2: General principle of the model functioning. Source : <https://www6.paca.inrae.fr/stics/>

We propose you an initial set of these files within the folder  
“C:\...\JavaSTICS-v131-stics-v850\ FirstStepIntoModelling”. If you open this folder, here is what you should see.

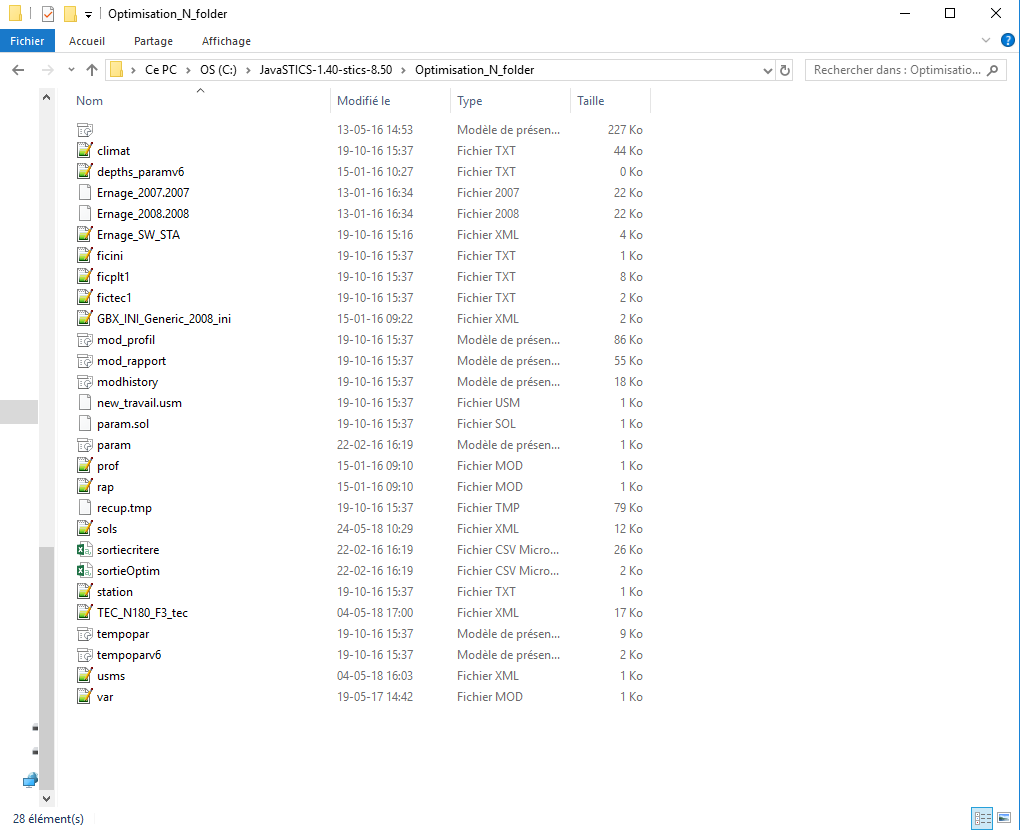


Figure 3: Overview of the FirstStepIntoModelling

We will now have a look at these files within the model user interface. Please run Javastics.exe (or launch it from the taskbar if you have “pinned” it).

The first thing to do is to let the model know in which folder it needs to work. To do so :

* Once the interface is launched go to FILE>OPEN WORKSPACE, select “FirstStepIntoModelling” and press “Open”
* Alternatively, clic on the folder icon, select “FirstStepIntoModelling” and press “Open”.

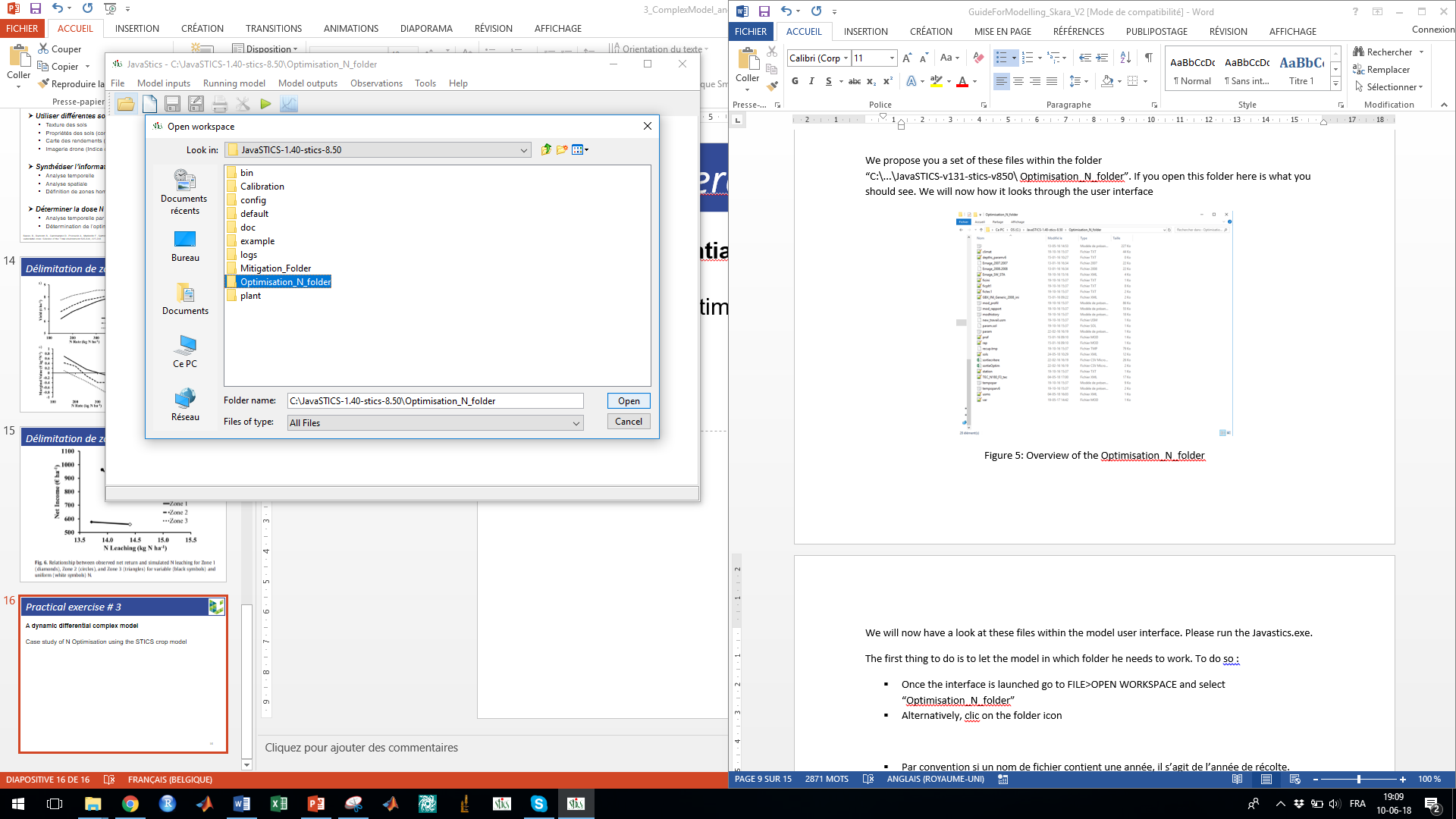


Figure 4: Overview of the opening of the current working folder

Into the “Model inputs” tab of the menu, you will have access to the following options:

* Model inputs
  + Global parameters
    - Plant and genotypes
    - General parameters
  + Local parameters
    - Initializations
    - Soils
    - Crop management
    - Climate
      * Formatting a climate file
      * Weather station

This reflects the model inputs as we describe them earlier. We will go through some of them latter in the practical exercise.

For now, please, go into “RUNNING MODEL > CREATE AND RUN A SINGLE USM”. This is where you specify what the model has to run. Here is what you should see:

### 

Figure 5: Overview of the USM window

### Choose a USM :

We have created for you the first USM. We gave it an explicit name using the following nomenclature  
USM\_YYYY\_sol\_ssssssss\_N\_XXX\_FZ, where

* YYYY is the year of harvest (based on our own specification rule);
* ssssssss is the soil name (Bordia2 In this case);
* XXX is the total amount of N applied (180kgN/ha in this case);
* Z is the number of N splits (3 splits in this case);

In this section, you also define the day of the year (DOY) when the model starts (Begin date) and when you want it to stop the simulation (End date). You need to ensure to start the model before planting (or before any technical operation, like tillage) and to stop it after the crop maturity, if you want to simulate the full cropping season.

You might have seen that End date is superior to 365. Typically for winter crop, like winter wheat, the crop is harvested the year following the planting year.

In this case, the crop was planted in 2007 and harvested in 2008. Therefore, all technical operations that occur after 31 December 2007 are computed in DOY cumulated since 01 Jan. 2007. By example, 01 Jan 2008 is DOY 366, 02 Jan 2008 is DOY 367, etc.

### Initialization

Here you define the file that contains the initial soil status, regarding:

* Soil water content by layer when simulation starts
* Soil N-NO3 and N-NH4 content when simulation starts
* The plant stage and corresponding plant biomass, if you run a simulation where plant are already established (e.g. perennial plants)

As you may now, the initial water status and soil N content might depend on a lot of parameters, such as the previous crop, the fact that a cover crop might have been planted before the main crop, the climatic conditions, etc. Therefore, it is highly recommended to measure them or approximate them as close as possible to reality, prior running the model.

The files must have a name that responds to the general rule: «FileName**\_ini.xml** ».

In this case, it is named as follows: GBX\_INI\_Generic\_YYYY\_ini.xml :

* GBX stand for Gembloux, where the plant was grown
* Generic means in this case that the initialization parameter for soil N content are based on average computed out of a database that summarize different previous crop, different planting dates, etc. The initial soil water content are set up at field capacity in this case.
* YYYY = 2008. Again the year refers to the harvest year, by our own rule/definition. In this case, the crop harvested in 2008 was sown in 2007. The data contained in this GBX\_INI\_Generic\_2008\_ini.xml correspond however well to the planting year.

For now, you only have choice in the drop-down menu.

### Kind of crop

STICS is one of the few soil-crop model that is able to simulate intercropping. In this case, we will however simulate a sole crop, winter wheat in this case.

### Soil

Here you define which soil will be used for the simulation. In this *smart farming* lecture, we have define two soil types.

In the drop-down menu, you have two choices: Bordia2 and Bordia3. They have almost the same sub-soil, but mainly differ by the upper layer:

* Bordia2 is a classic loamy soil type
* Bordia3 has a sandy-loam first layer.

For now, please do not modify the soil type, we will do it in the exercise here below.

### Climate

Here you define which climate file have to be opened by the model, and to which weather station characteristic they refer to.

The weather station parameter file contain different specification, such as the Angstrom coefficient, the fact that you want simulate (or not) climate change, the option you want to use to simulate Evapotranspiration (Penman approach, Shuttleworth and Wallace formalism or Prestley-Taylor approach), etc.

The files must have a name that responds to the general rule: «FileName**\_sta.xml** ».

In this case, we create this Station parameter file for you. The reference weather station where the data comes from is located in the village nearby, named “Ernage”.

Below, the two climate year simulated are mentioned (Ernage\_2007.2007 and Ernage\_2008.2008).

### Main plant and management itinerary

If you have correctly followed the instruction, you should have a plant file name “WW\_Gbx\_plt.xml”. If you have a red frame around an empty box, then go back to the first part of this exercise “Install the STICS soil-crop model files and required folder”. You probably did not follow correctly the instructions to import the plant file into the plant folder of JavaStics, or did not correctly renamed it.

The files must have a name that responds to the general rule: «FileName**\_plt.xml** ». This files contains all the parameter that controls crop growth and crop responses to stresses.

Just below, you have the box where you specify the management itinerary. The files must have a name that responds to the general rule: «FileName**\_tec.xml** ». In this case, we use the following rule to name the technical files: “TEC\_NXXX\_FZ\_tec.xml”

* XXX is the total amount of N applied (180kgN/ha in this case);
* Z is the number of N splits (3 splits in this case).

A optimal way to fertilize the crop is to provide N when the plant needs it the most. Usually the requirements follows the phenology. Typically, in Belgium and in France, N is provided at three critical stages of plant growth.

* After winter, at tillering stage, when wheat will re-growth and produce secondary tillers, usually after the cold winter conditions when climatic conditions because more favorable, when day length increases, and when wheat has meet his vernalization requirements.
* At stem extension stage (Zadok stage 30-31), when the plant will “redress” and stem extend
* At flag-leaf stage (Zadok stage 39) when the final leaf has been emitted and just before wheat flowering that precedes grain filling.

### Running the USM and displaying results

You can now press “Run”. A windows should open mentioning that the execution is in progress. If you correctly followed the instructions, you should have a message telling you that "*the execution has been successfully accomplished*”.

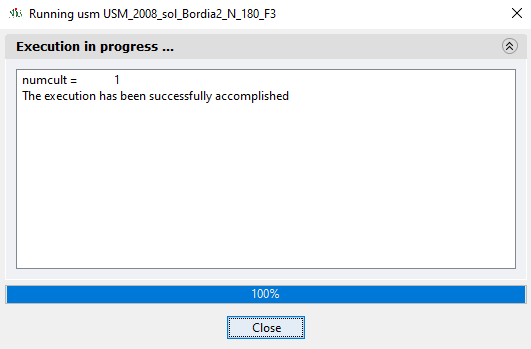


Figure 6: successful simulation!

After a successful simulations, three files are created

* Modhistory.sty : it contains a summary of all your parameters value. You do not need to look at it, it will represent nothing to you at this stage.
* Mod\_b+*yourUSMname*.sti: this files contains a summary of your simulation option, management itinerary and initial conditions, as well as a balance of water and nitrogen reached at the end of the simulation. Please take a few minutes to explore this file and understand what lies in it.
* Mod\_s+*yourUSMname*.sti: this file is not display in the interface, but has been created in the folder. This is the file that contains the dynamic value of the different variable simulated at the daily time step. We will use the embedded graphic display of JavaSTICS to discover it.

To display simualtions, please do as follows :

* Go into the tab menu “Model outputs > Dynamic graphics” or press the “graph” icon (last icon below the tabs menu)
* In the “Source file” section, press select and select Mod\_s+*yourUSMname*.sti, which should be Mod\_sUSM\_2008\_sol\_Bordia2\_N\_180\_F3.sti, and press “Open”
* You should now have access to a list of simulated variables. Please note that they are much more variable simulated by STICS, and those present in the list are the main. Please also note in this user interface, you can display up to 4 charts.
  + Clic on “lai(n)” and then press “Create chart”
  + Clic on “masec(n)”, press “ctrl”+clic “mafruit” and then press “Create chart”
  + Clic on “HR(1)”, press “ctrl”+clic “HR(2)” and then press “Create chart”
  + Clic on “AZnit(1)”, press “ctrl”+clic “AZnit(2)” and then press “Create chart”
  + Press “View”

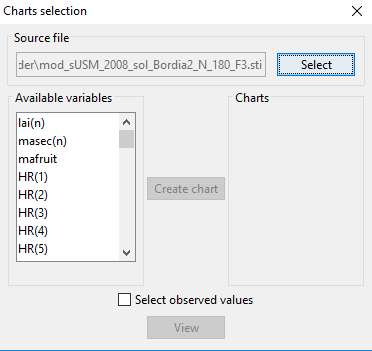
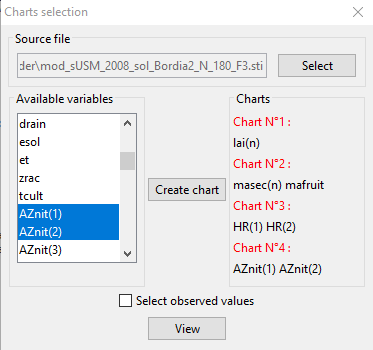
 

Figure 7: Before and after variable selection

* Take some time to explore the variables displayed and discuss results with teachers and/or your partner.
  + How do you understand the variables?
  + What do you think of masec(n) (total biomass) and mafruit (grain yield) variables ?
  + What about the dynamics of HR(x) (soil moisture) and AZnit(x) (N-NO3 soil content)? “x” represent the horizon; (1) is the upper layer above ploughing depth and (2) stands for the 20/30cm below the ploughing depth.

## Changing plant parameter values and running new simulations

### General consideration

I’m sure that most of you have now discovered that the simulated total biomass and grain yield were far too excessive.

Models can be used to guide fundamental research. In this case, we used the model to create and *ideotype*, which could be helped to guide breeding selection. An ideotype is an “ideal” plant phenotype/genotype. The model was in this case used to know which were the most interesting parameters, behind which correspond genetic characteristics, to be selected by breeders to increase yield under the pedo-climatic conditions of the Hesbaye area. Isn’t it wonderfull ?

Unfortunately, before giving you the files, we forgot to restore the parameters to realistic values. This section of the exercise will be devoted to restore realistic values to the parameters. But first, let’s present a summary of which parameter had been modified.

You might also be interested to know that the simulation of the functioning of the sole plant requires ~140 parameters itself.

Table 1: parameter values distinction between and ideotype and a realistic crop.

|  |
| --- |
| Parameter Definition Ideotype value Realistic value |
| efcroiveg Radiation use efficiency during vegetative cycle 4.4 4.2  efcroirepro Radiation use efficiency during reproductive cycle 4.6 4.2  nbgrmax Maximal number of grains 29000 28000  pgrainmaxi Maximal weight of a grain 0.05 0.0455  stdrpmat Degree-days of grain filling phase (reproductive phase) 800 790  vitircarbT Dynamic harvest index controlling 0.00070 0.00066  the allocation of biomass to the grain |

### Modifying the plant file to go from ideotype to realistic file

To modify the plant parameter file, please proceed as follows :

* Go into “MODEL INPUTS > GLOBAL PARAMETERS > PLANT AND GENOTYPE” (Figure 11)
* Select “WW\_Gbx\_plt.xml” and press open.
* Open the tree structure as follows (Fig 12) to access the parameters and modify their values as presented in table 1.
* Don’t forget to “SAVE” the changes
* Plot again the results and see how it changed the simulations values (Fig 13), especially on masec(n) and mafruit variables.

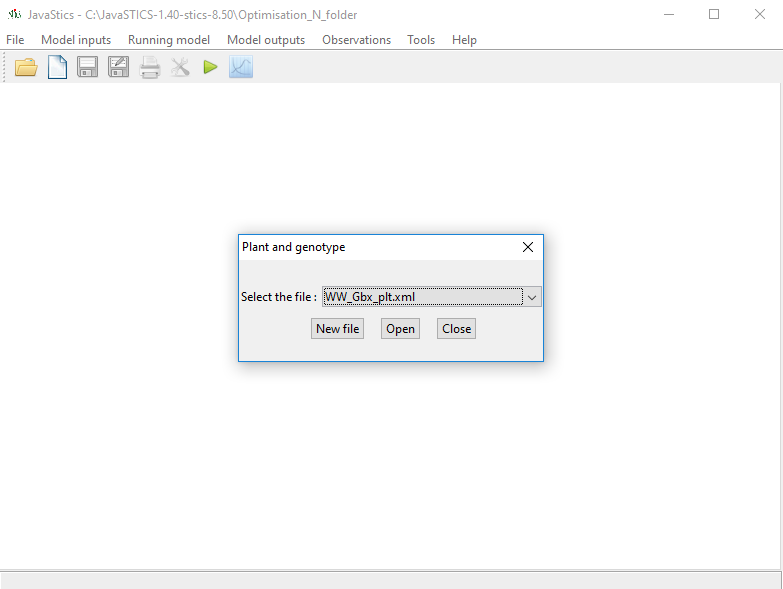


Figure 8: Opening the plant file

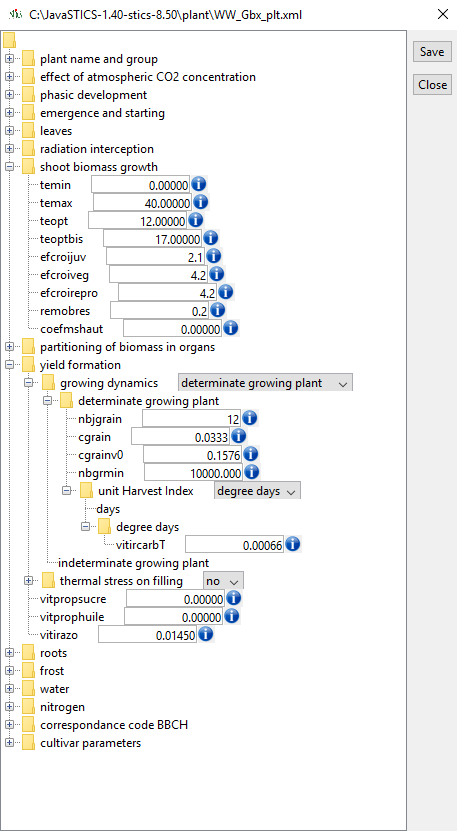
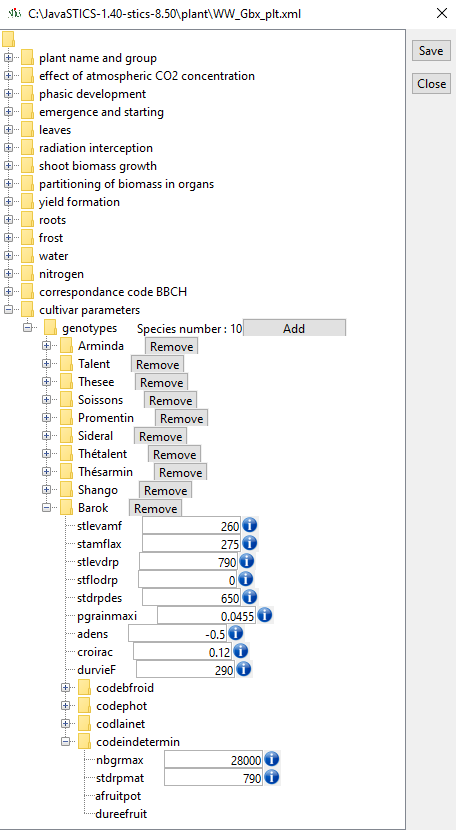
 

Figure 9: Plant parameter file –   
Tree structure to access efcroiveg, efcroirepro and vitircarbT values (left) and   
stdrpmat, nbgrmax and pgrainmaxi values (right).

### Understanding the results

You might have noticed, when analysing the tree structure, that:

* efcroiveg, efcroirepro and vitircarbT are considered as related to the sepcies, i.e. related to any wheat variety. They are supposed to be common across all wheat variety, but constant for wheat species. Indeed from a genetic point of view, they are considered as specific parameters and only vary slowly with time and selection. In particular :
  + efcroiveg and efcroirepro are the radiation use efficiency in vegetative and reproductive phases. They correspond to the plant ability to efficiently use the solar radiation and realize photosynthesis to capture CO2 and produce dry matter;
  + vitircarbT is a dynamic harvest index, which controls the dynamic allocation of biomass to the grain. It does not control the amount of biomass produced by the plant (this role is played by efcroixxx) but it represent the amount of dry matter that is allocated to the grain when in reproductive phase (the “sink” force). The remaining dry matter, i.e. the part that is not allocated to the grain, can be stored in reserve organs, or allocated to other organs (roots, stem, etc.)
* stdrpmat, nbgrmax and pgrainmaxi appears below the cultivar sub-section. Those parameters can vary, sometime deeply, between different cultivar within the same species (wheat in this case). Stdrpmat is typically a cultivar parameter as it reflects the characteristic related to the crop precocity/late maturity. Nbgrmax and pgrainmaxi are related to yield components, respectively to :
  + nbgrmax : the amount of grain that a crop will set up. It is expressed per unit area in this case, but there is a link with the amount of tiller produced and the amount of grain per ear, which are both cultivar-dependent
  + pgrainmaxi : the maximal weight of a grain, which will control the maximum amount of dry matter that the grain will be able to store, and is a cultivar-dependent characteristic.

The aerial dry matter now produced (masec(n)) and allocated to the grain (mafruit) is now realistic and lies in the range of what was observed in the field under these pedo-climatic conditions (Fig 11).

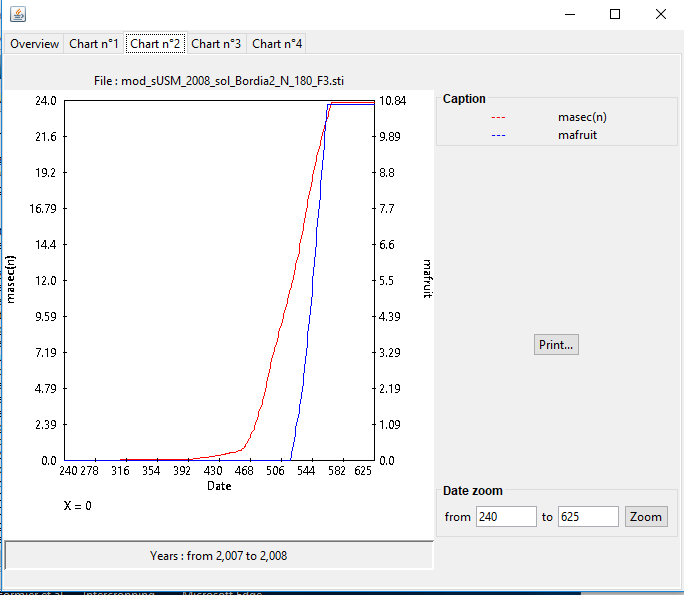


Figure 10: Plot of the *realistic* simulations of mafruit and masec(n)

## Creating a new management itinerary and the corresponding USM

The plant that has been grown received an optimum amount of nutrient. We will now see how it would have grown if we did not supplied any mineral N fertilizer and if the soil contained lower organic N amount (here the residues of the previous crop were fully returned to the soil).

### Creating a new management file

To create a new management file, please proceed as follows:

* Go into “MODEL INPUTS > LOCAL PARAMETERS > CROP MANAGEMENT”
* At this point, you must absolutely ***PRESS “NEW FILE”***. The model will create a new file based on the existing one.
* Change the name to “***TEC\_N0\_F3***” and press “OK”. It should successfully create the file.

For now, the new file is the exact image of the other one. Only the name changes. To modify this new management file, please proceed as follows:

* Go into “MODEL INPUTS > LOCAL PARAMETERS > CROP MANAGEMENT” (if you are not there anymore)
* At this point, you must ***SELECT*** the new file “***TEC\_N0\_F3\_tec.xml***” and then ***PRESS “Open”***.
* Proceed to the following modifications (Fig 12)
  + In the option “Supply of organic residues”, please reduce the amount of residues returned to the soil (qres) to 1.5tons/ha
  + In the option “fertilisation > mineral nitrogen inputs”, plese put “0” in the column “absolute\_value”, in front of each day (expressed in DOY) of supply.
  + Do not forget to “Save”
* (Optional) we invite you to explore the other options if you wish and understand/discover what the model is able to simulate. At this point, please do not modify anything or save any other changes than residues and N management.

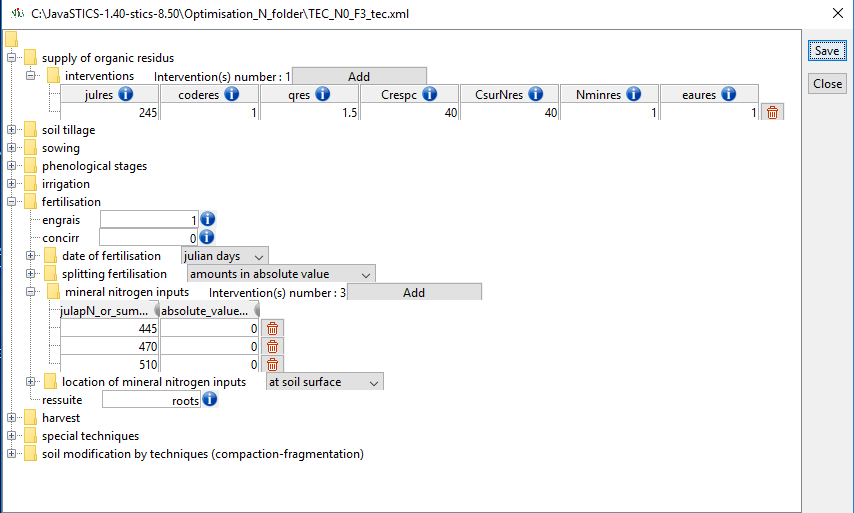


Figure 11: Changing management itinerary

### Creating a new USM

A new management parameter file will require to create a new USM. This will allow us to avoid overwriting the previous simulation file create and further intercompare the impact of different management. Please proceed as follows :

* Go into “RUNNING MODEL > CREATE AND RUN A SINGLE USM”
* At this point, we recommend to ***immediately*** save a copy by clicking on “***SAVE AS***”. Modify the name so that it has an explicit meaning to you. We recommend to name it “USM\_2008\_sol\_Bordia2\_N\_0\_F3”. Then press “OK”.
* As this point, as done for the the technical file, we only have created an image of the previous USM. Now is the right time to modify the technical management file.
  + Verify that you are in the correct USM (upper leftbox)
  + Select the technical management file where less residues are returned and no N fertilisation is provided.
* Do not forget to SAVE the changes by clicking on “SAVE”
* Now press “RUN”. The model should successfully run.

As we did previously, we will now look at the results of the new simulations:

* Go into the tab menu “Model outputs > Dynamic graphics” or press the “graph” icon (last icon below the tabs menu)
* In the “Source file” section, press select and select mod\_sUSM\_2008\_sol\_Bordia2\_N\_0\_F3.sti (or the name you gave to your USM, and press “Open”
* You should now have access to a list of simulated variables. This is the same list as previously, but behind there are new values. Display the same 4 charts as previously.
  + Clic on “lai(n)” and then press “Create chart”
  + Clic on “masec(n)”, press “ctrl”+clic “mafruit” and then press “Create chart”
  + Clic on “HR(1)”, press “ctrl”+clic “HR(2)” and then press “Create chart”
  + Clic on “AZnit(1)”, press “ctrl”+clic “AZnit(2)” and then press “Create chart”
  + Press “View”
* What do you think of the new simulations? how do you think less N has impacted :
  + LAI simulations
  + Aerial biomass and grain yield
  + N soil dynamic in the two first soil layers of the profile

***Bravo, you have successfully completed this section.***

***You can now enjoy modelling !***