Food and Agriculture Organization of the United Nations

Crop Module 1
Introduction to AquaCrop

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DAY 1: TABLE OF CONTENTS

Covered during the pre-training session

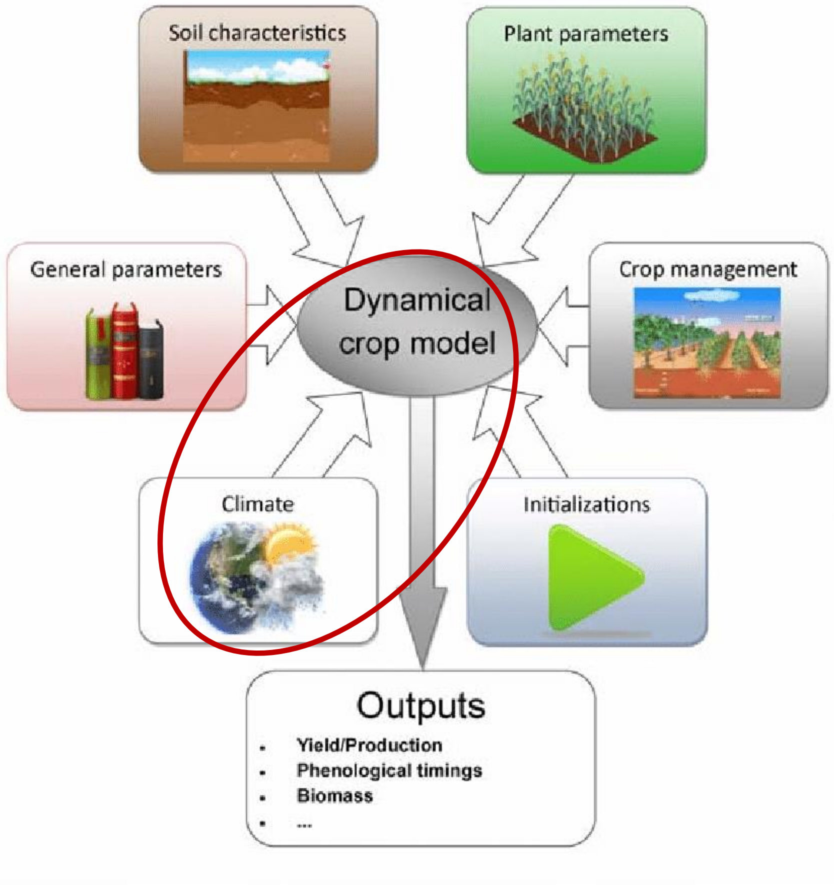
PRE-TRAINING SESSION

Crop models: what are they useful for?

Crop models are sets of mathematical equations that represent processes within a predefined plant system as well as the interactions between crops and its environment.

Crops models can contribute to agriculture in many ways:

- Understand crop responses to environmental changes;
- Compare attainable and actual yields;
- Identify constraints to crop production and water productivity;
- Develop irrigation schedules for maximizing production;
- Study the effect of climate change;
- Support decision-making on water allocations and water related policies;



Costa *et al.*, 2015

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Some of the most widely used crop models

Model name	Main features/advantages	Link
AquaCrop	Crop-water productivity	link
AEZ	Maximum potential yield	link
APSIM	Crops and agricultural inputs	link
EPIC	Focuses on soil erosion	link
DSSAT	Crop growth and development	link
CropSyst	Effect of management on productivity	link

Useful overview of crop models

AquaCrop compared to other crop models

- AquaCrop produces much finer outputs (for site-specific locations) than other models and, as a result, its spatial applications are narrower.
- AquaCrop does not consider the leaf area index (LAI) as done by many other crop simulation models (i.e., GAEZ, DSSAT and CropSyst)
- Uses a relatively low number of parameters and mostly-intuitive input variables that can be determined by simple methods.
- AquaCrop simulates one crop at the time and cannot run multiple crops for comparative economic assessments as oppose to GAEZ.
- AquaCrop considers abiotic/biotic stresses (living and non-living factors), while other models do not (WOFOST)
- AquaCrop does not take into account other reducing factors such as pests and diseases

Limitations of crop models

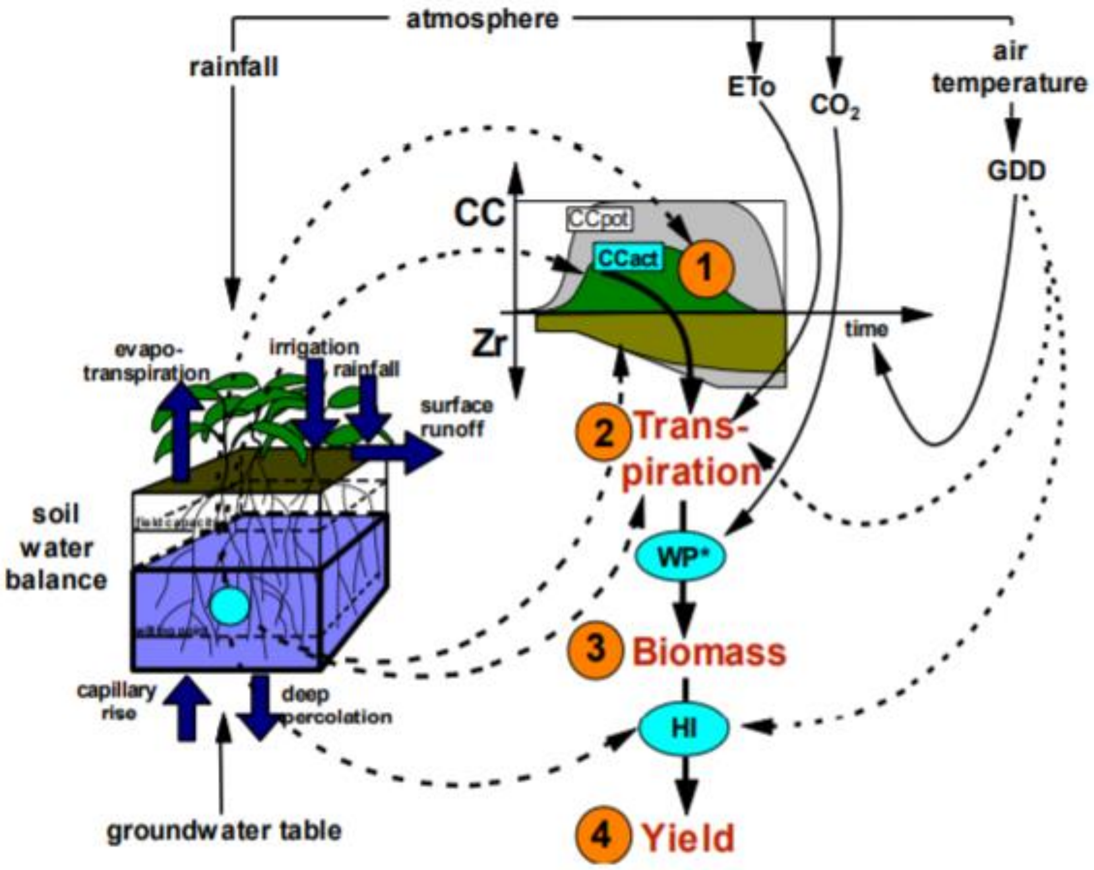
Every model has its strengths and weaknesses and, therefore, the selection process is a critical step determined by the robustness of the model, as well as on the applications, context and objective of the impact assessment.

A potential threat in crop modelling is that users are not always familiar with the intended use and limitations of each tool and, consequently, are not necessarily aware of the uncertainties associated with their outputs

- A major limitation of crop growth models is the lack of spatial information of the actual conditions of each field or region.
- Many crop-growth models require a significant amount of input data, sometimes difficult to retrieve.
- Many crop-water productivity models lack comprehensive fertilizer management and pests and diseases modules.

AQUACROP MODEL

AquaCrop: introduction



AquaCrop simulates crop yield in different steps:

1) crop development
2) crop transpiration
3) biomass production
4) yield formation

Evapotranspiration: location, air temperature, humidity and solar radiation…

Penman Monteith equation:

$$\lambda ET = \frac{\Delta(R_n - G) + \rho_a c_p \frac{(e_s - e_a)}{r_a}}{\Delta + \gamma\left(1 + \frac{r_s}{r_a}\right)}$$

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AquaCrop interface

Graphical User interface

Plug-in or Standalone

LIST	File folder
OUTP	File folder
PARAM	File folder
SIMUL	File folder
aquacrop	Application
AUTHORS.md	MD File
LICENSE	File

Data used for this simulation

Climate module: AquaCrop default climatic files for Córdoba (south Spain) for the year 1981.

Crop module: AquaCrop default crop files (**daily values**) for tomato grown in Córdoba and transplanted on 1st May.

Management module:

- ➢ Irrigation sub-module: create our own irrigation files.
- ➢ Field sub-module: AquaCrop default field files (moderate soil fertility).

Soil module:

- ➢ Soil profile: AquaCrop default soil files (sandy-loam).
- ➢ Groundwater sub-module: AquaCrop default groundwater files (constant water at 2m depth).

The core of the model

DATA	02/05/2018 10:20	Carpeta de archivos	
IMPORT	02/05/2018 10:20	Carpeta de archivos	
OBS	02/05/2018 10:20	Carpeta de archivos	
OUTP	02/05/2018 10:20	Carpeta de archivos	
SIMUL	02/05/2018 10:20	Carpeta de archivos	
_DEISREG.ISR	02/05/2018 10:29	Archivo ISR	1 KB
_ISREG32.DLL	23/04/1997 1:16	Extensión de la ap...	40 KB
AquaCrop	02/05/2018 9:35	Aplicación	12.867 KB
AquaCrop	20/12/2006 9:15	Icono	2 KB
DelsL1.isu	02/05/2018 10:29	Archivo ISU	10 KB

Step 1: open the AquaCrop folder in your desktop

Step 2: launch AquaCrop

PaddyRiceGDD.CRO	17/04/2017 16:42	Archivo CRO	7 KB
Patancheru.CLI	29/01/2009 12:12	Archivo CLI	1 KB
Patancheru.ETo	29/01/2009 12:12	Archivo ETO	3 KB
Patancheru.PLU	29/01/2009 12:12	Archivo PLU	2 KB
Patancheru.TMP	29/01/2009 12:12	Archivo TMP	4 KB
ModerateSF.MAN	17/04/2017 11:15	Archivo MAN	1 KB
Sand.SOL	17/04/2017 10:02	Archivo SOL	1 KB
RCP8-5.CO2	12/07/2015 14:12	Archivo CO2	3 KB
TR2a.IRR	31/12/2009 10:38	Archivo IRR	1 KB
WPSandLoam.SW0	24/12/2011 7:14	Archivo SW0	1 KB

Many of these files (ETO, PLU, TMP) are automatically created by AquaCrop when preparing the climatic files.

CLIMATE MODULE

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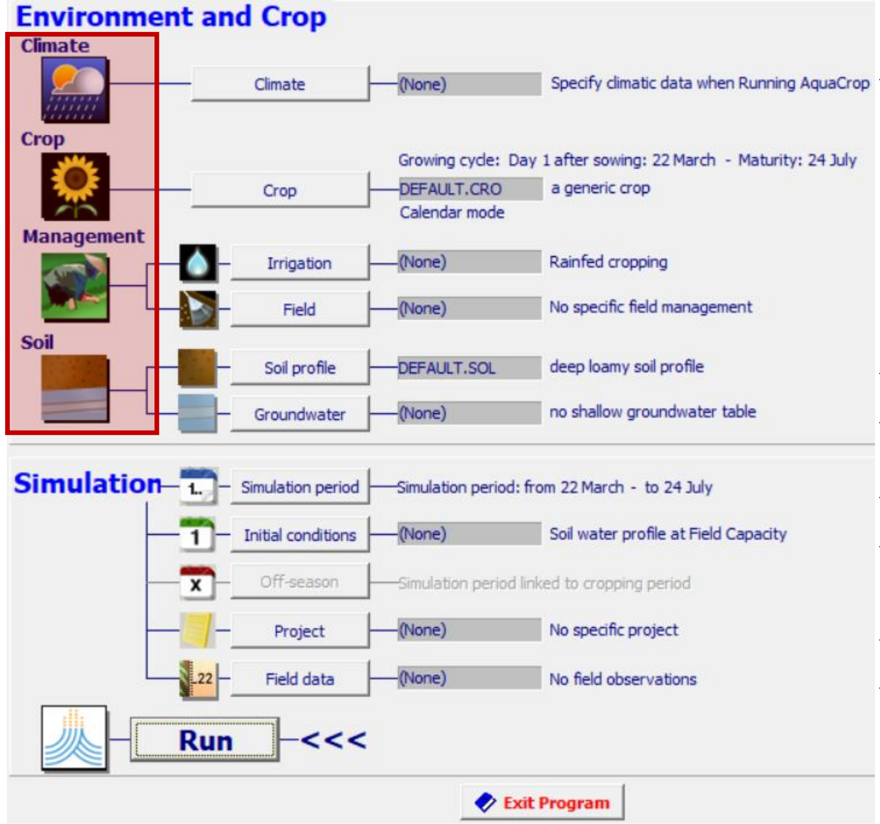
AquaCrop: the interface

Step 1: open AquaCrop, select the language and click on **start**



← Climate data collected in the field and or from gridded/point geospatial climate datasets.

← Observed crop characteristics

← Irrigation method, application depth & time etc.

← Soil fertility & practices affecting soil-water balance

← Soil profile characteristics (texture, FC, PWP, SAT)

← Water depth below soil surface and soil salinity

← Simulations coinciding with the growing cycle of the crop

← Soil water content at the date of sowing

← Aggregation of the above files into one project file

← Observations from the field (CC, biomass and SWC)

CC: Canopy Cover; FC: Field Capacity; PWP: Permanent Wilting Point; SWC: Soil Water Content; SAT: Saturation

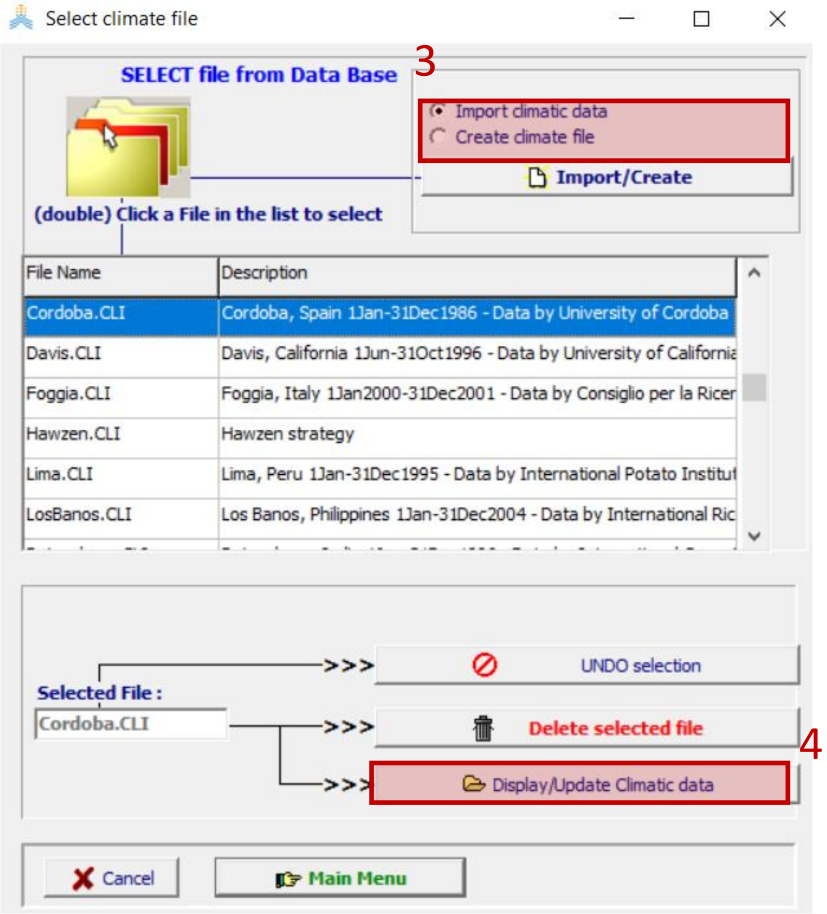
Climate module: selecting a climatic file

Steps 1-2: click on the **climate** module and then click on **select/create climate file**

Remember! We are importing default climatic files from AquaCrop, we are not creating them…

Step 3: click once (but not twice!) on the climatic file of **Córdoba, Spain**

If you click twice on Córdoba, AquaCrop will bring you directly into the main interface



Step 4: click on **display/update climatic data**

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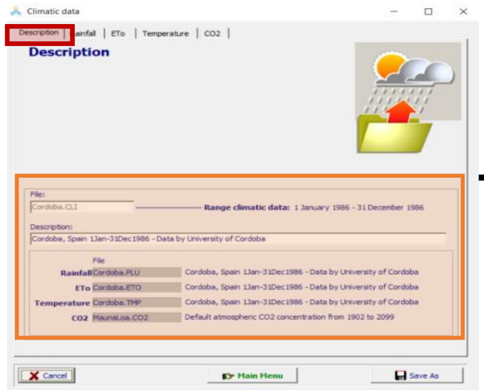
Climate module: climate data

1

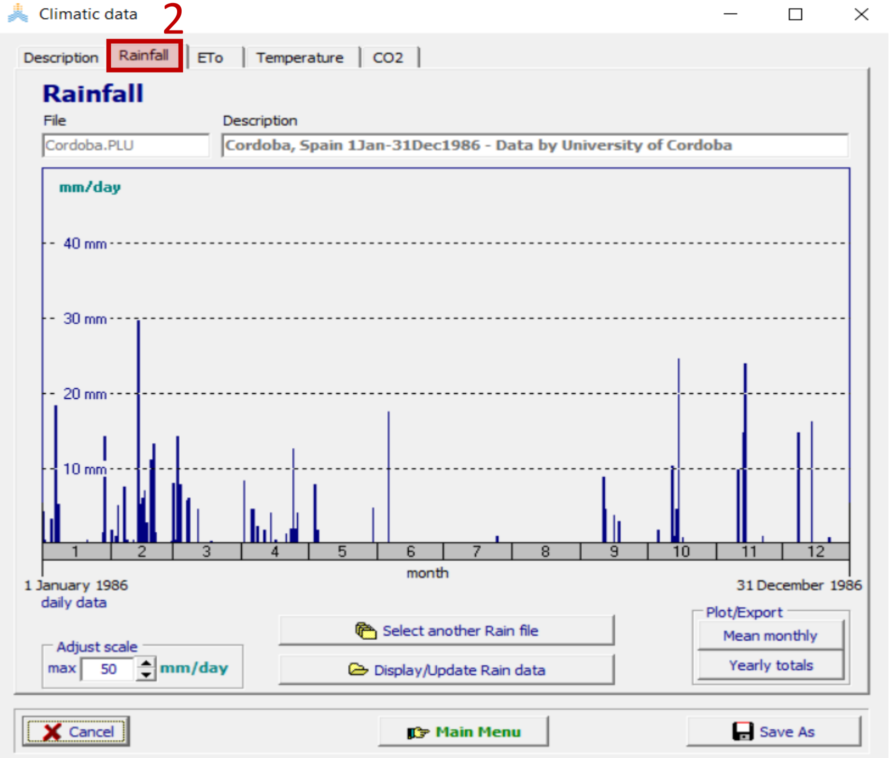


Step 1: click on **description**

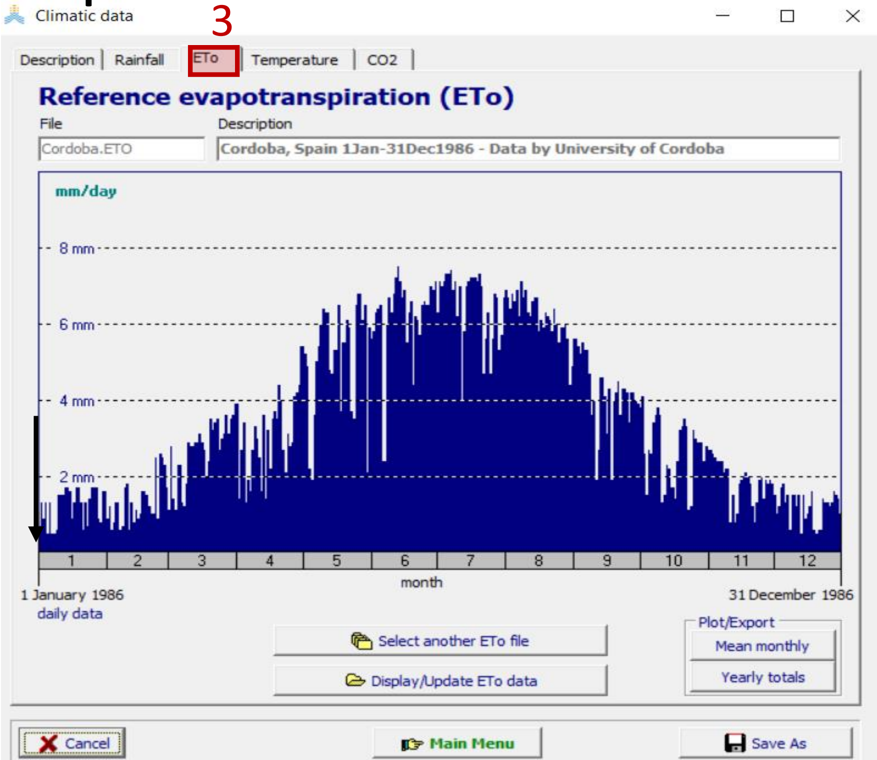
Here you will find all the files within the selected climatic folder. Each of these files includes its respective extension: PLU, ETO, TMP, CO2…

We will be running simulations for the summer of 1986 in Córdoba!

Step 2: click on **rainfall**



Step 3: click on **ETo**



You can display the data on daily, monthly, or yearly basis

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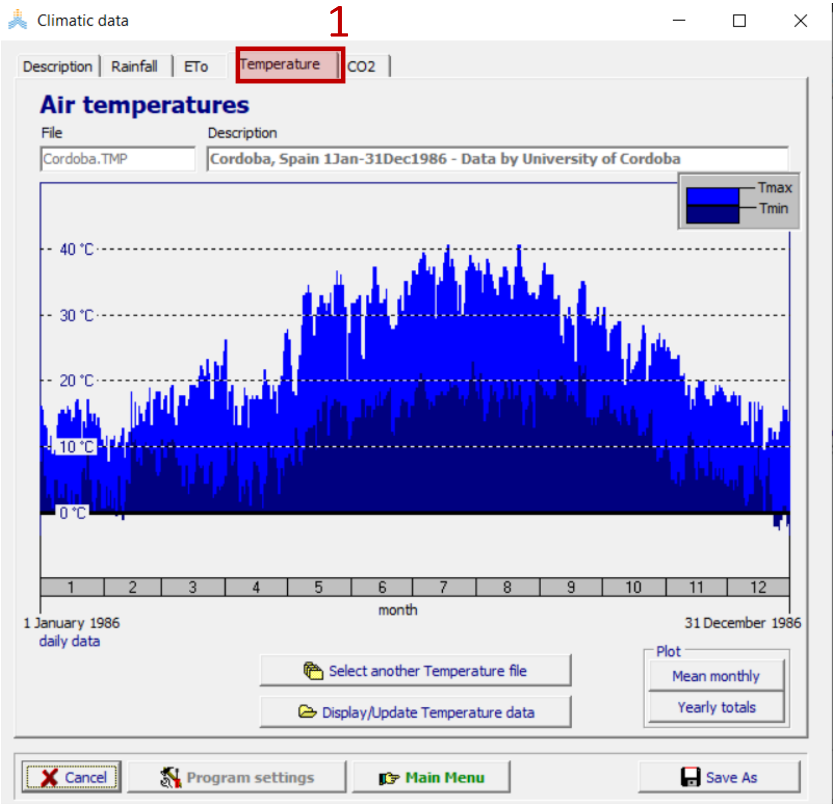
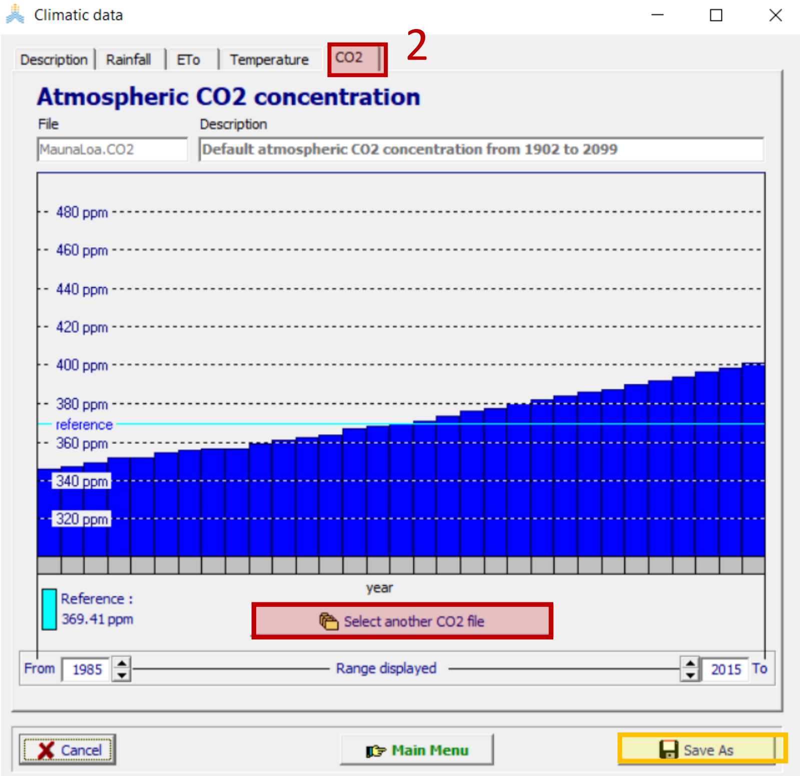
Climate module: climate data

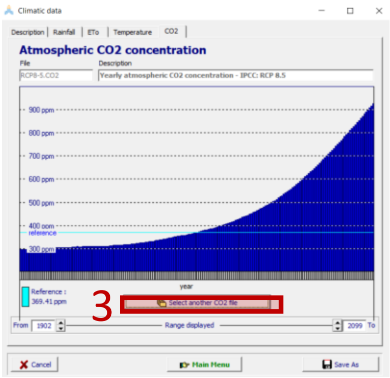
Step 1: click on **temperature**



Step 2: click on **CO_2**



SSPs are now available on AquaCrop!



File Name	Description
RCP4-5.CO2	Yearly atmospheric CO2 concentration - IPCC: RCP 4.5
RCP6-0.CO2	Yearly atmospheric CO2 concentration - IPCC:RCP 6.0
RCP8-5.CO2	Yearly atmospheric CO2 concentration - IPCC: RCP 8.5
SSP1_1.9.CO2	Atmospheric CO2 concentration from 1902 to 2099 - Scenarion SSF
SSP1_2.6.CO2	Atmospheric CO2 concentration from 1902 to 2099 - Scenarion SSF
SSP2_4.5.CO2	Atmospheric CO2 concentration from 1902 to 2099 - Scenarion SSF
SSP3_7.0.CO2	Atmospheric CO2 concentration from 1902 to 2099 - Scenarion SSF
SSP5_8.5.CO2	Atmospheric CO2 concentration from 1902 to 2099 - Scenarion SSF

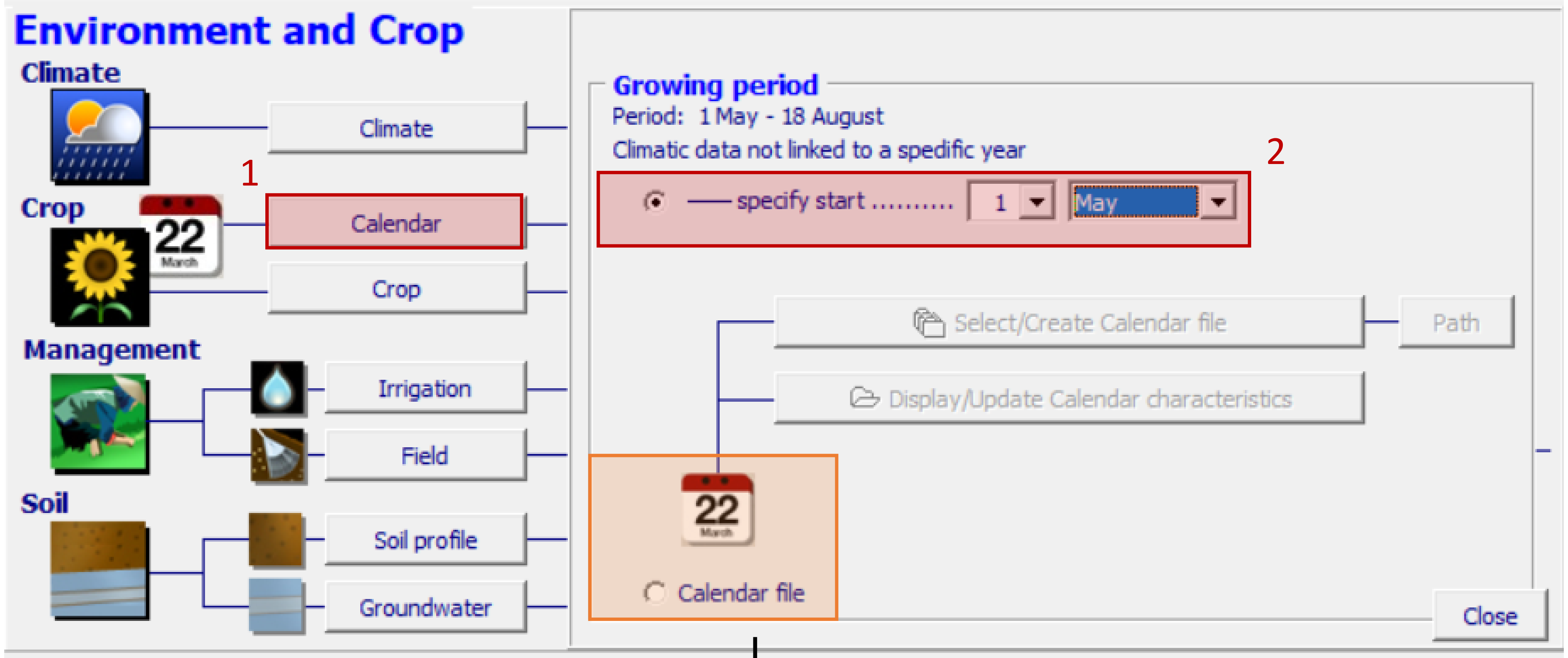
Step 3: test another **CO_2** file

CROP MODULE

Crop module: calendar information

Steps 1-2: click on **calendar** and select a **sowing date (1st of May)**

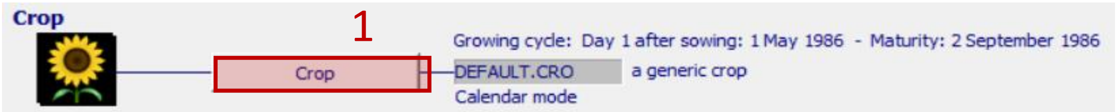
The sowing date needs to be within the timeframe of the climatic file!

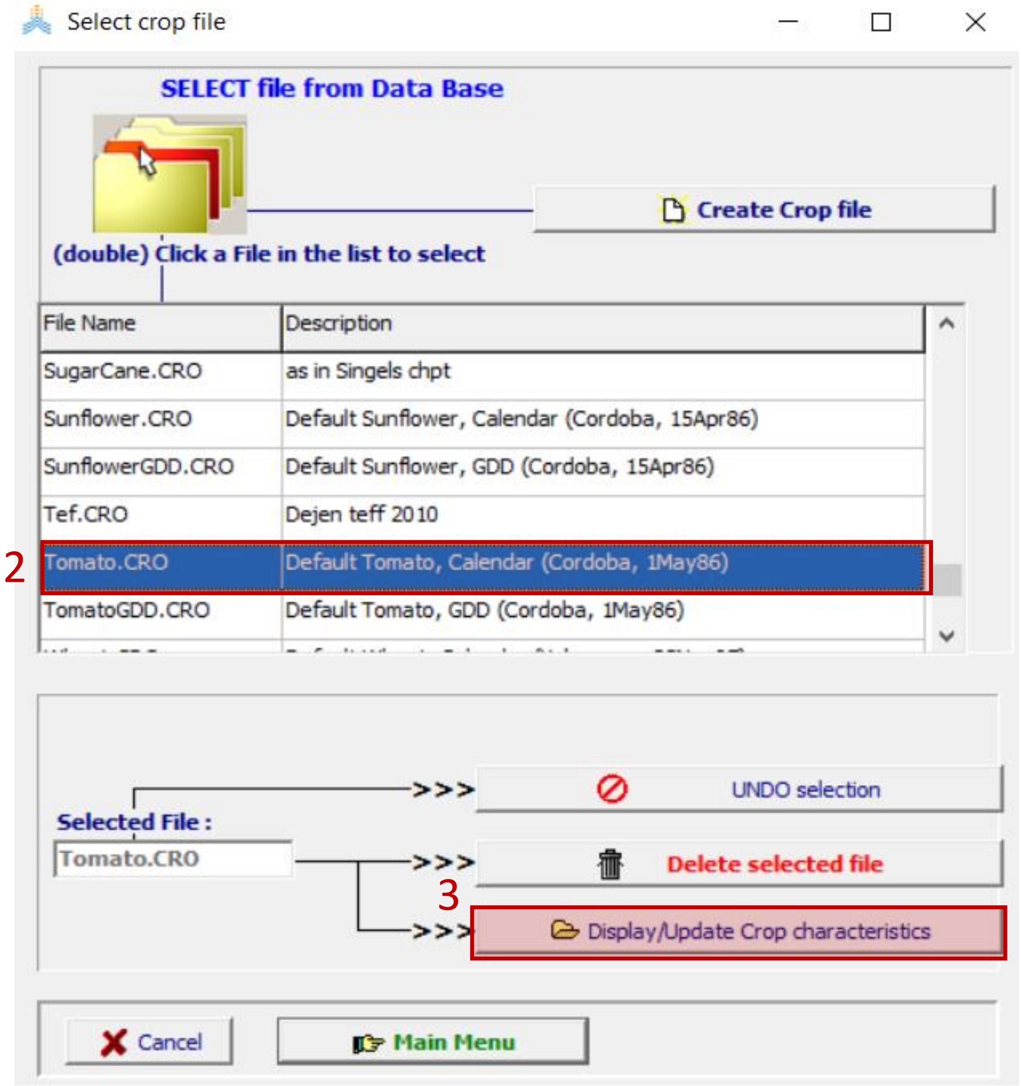


You can also create your own calendar file (for advanced users!)

Crop module: crop information

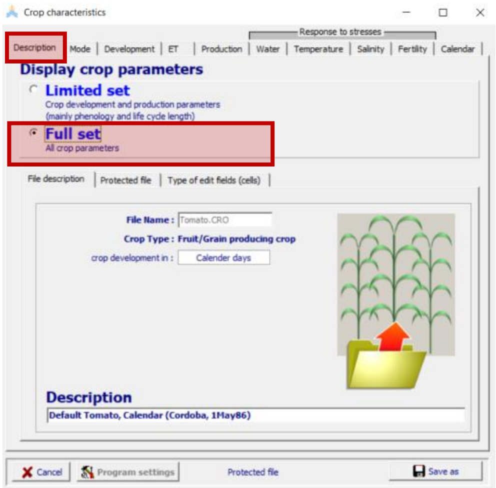
Steps 1-2: click on **crop** and select **default tomato days**





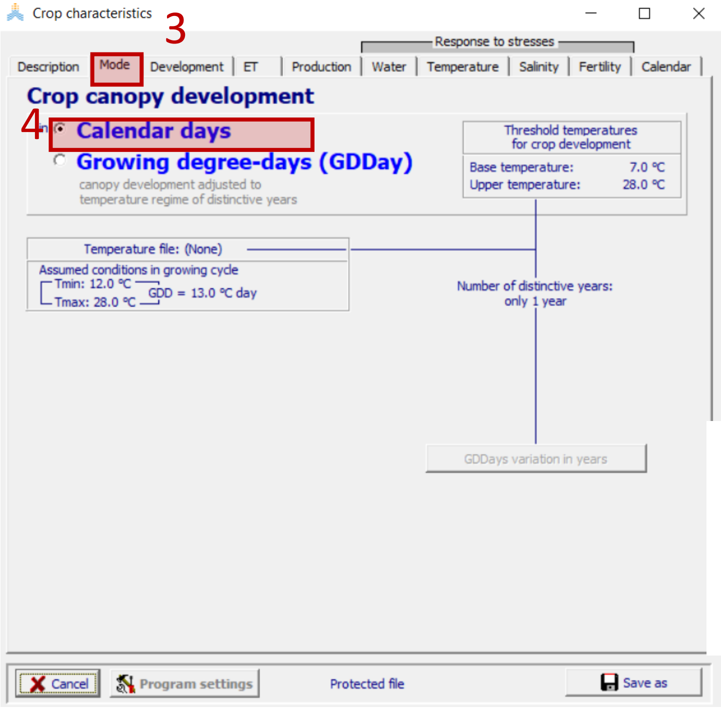
Step 3: click on **Display/Update Crop characteristics**

Crop module: crop information



Steps 1-2: click on **description** and **full set**

While **limited set** does not include crop's responses to stresses (water, temperature, salinity, fertility), **full set** does.



Steps 3-4: click on **mode** and select **calendar days**

The second option is to select GDD (cumulative heat units throughout the growing cycle) (for advanced users!)

$$GDD = \left[\frac{(\text{Max Temp} + \text{Min Temp})}{2}\right] - \text{Base Temp}$$

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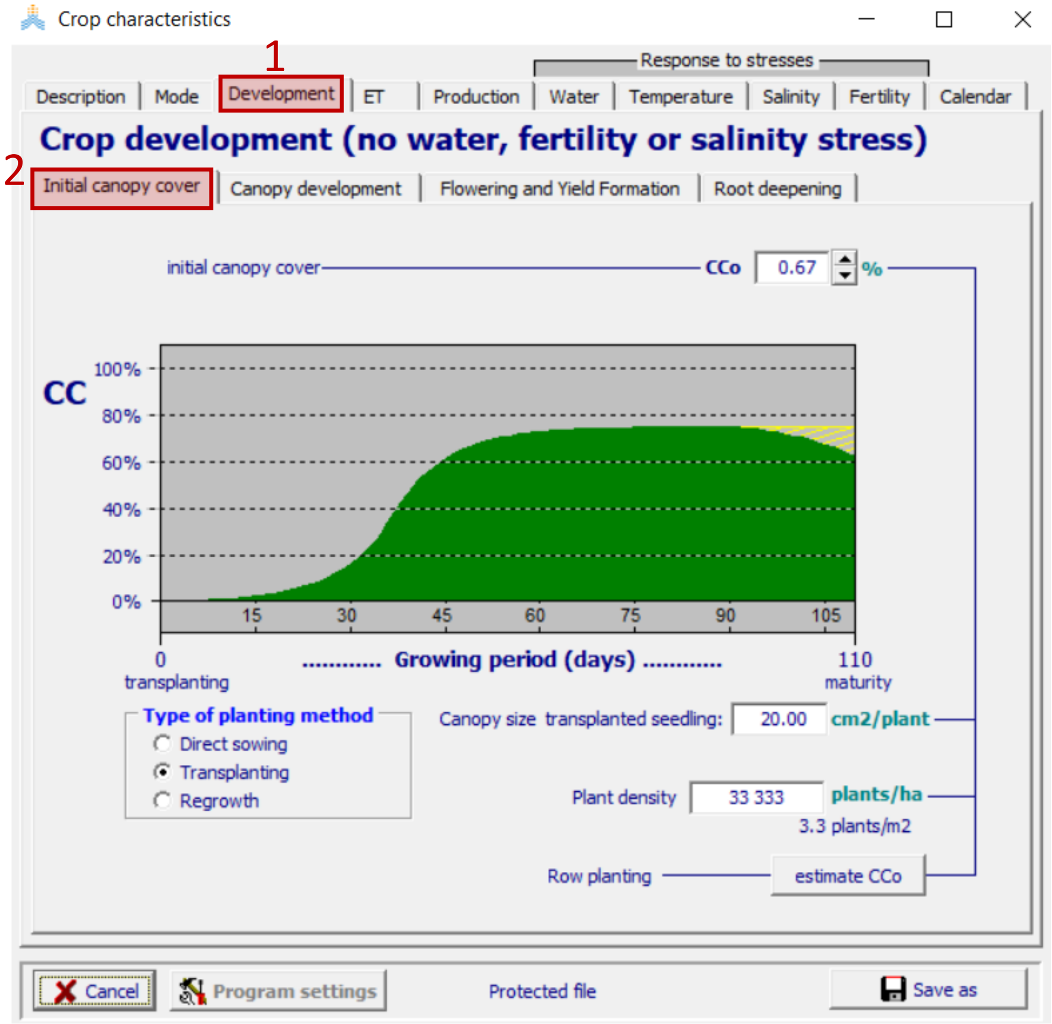
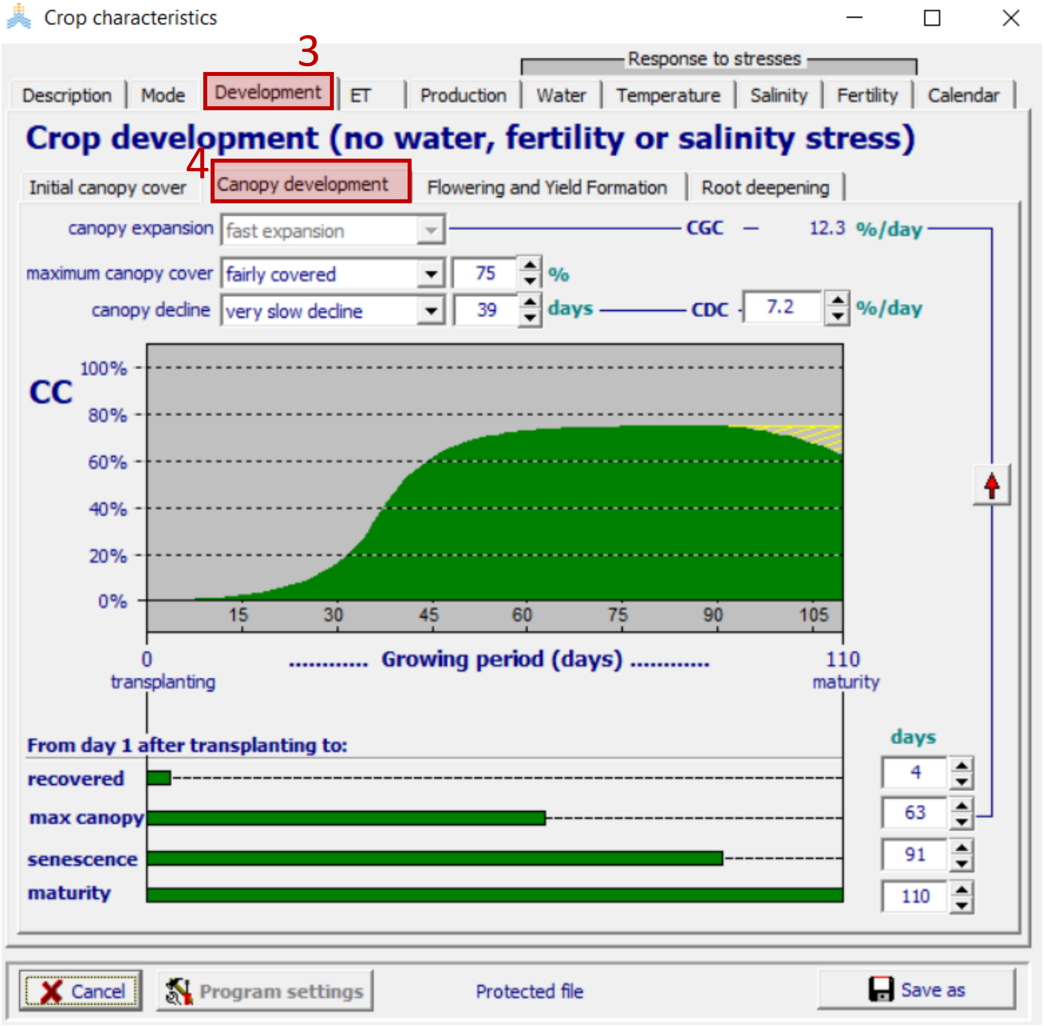
Crop module: crop development

Steps 1-2: click on **development** and then **initial canopy cover**

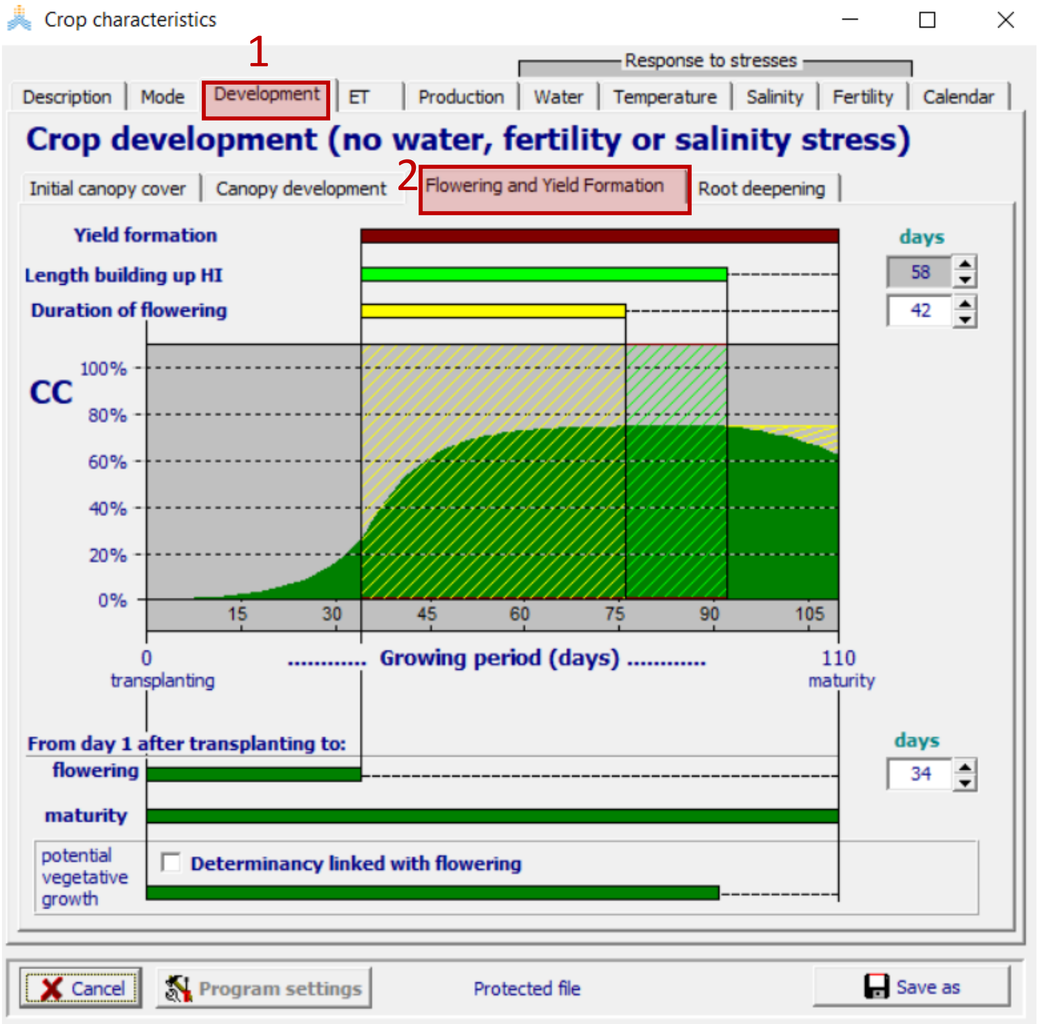


Steps 3-4: click on **development** and then **canopy development**

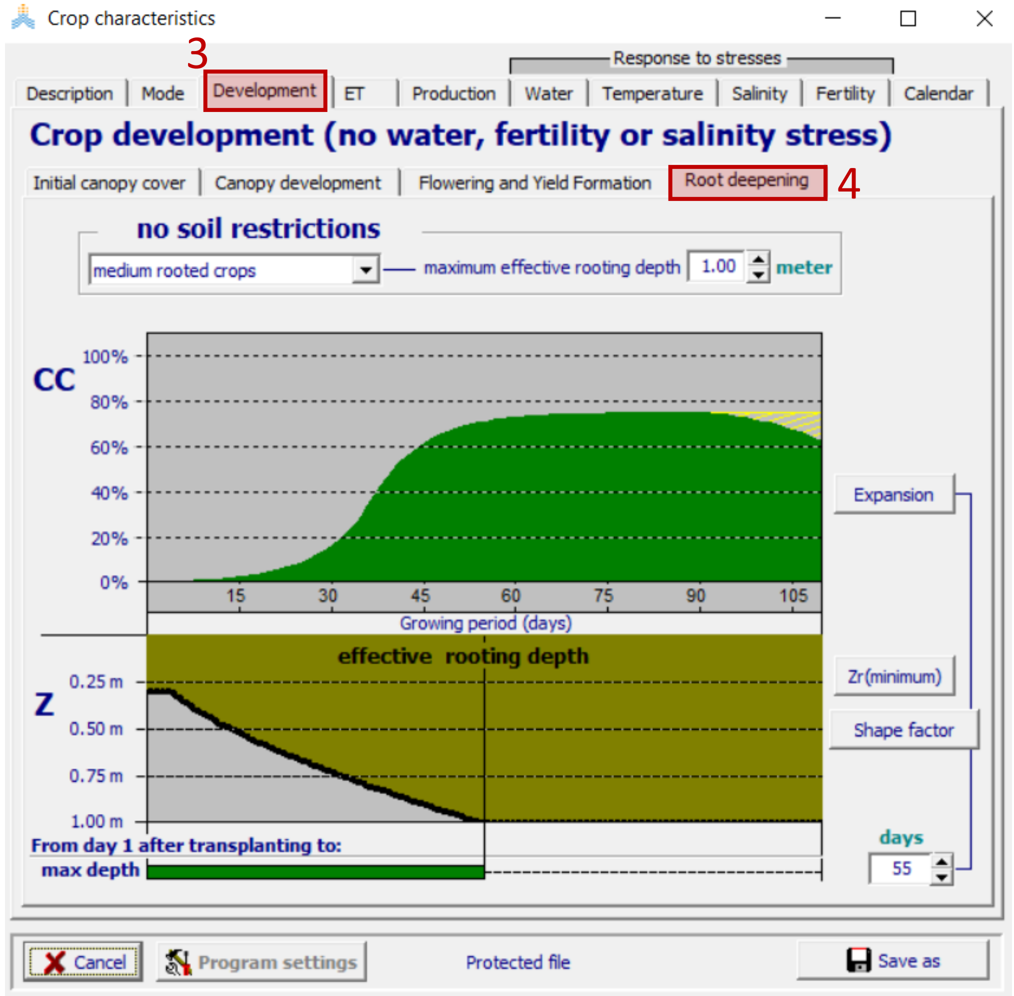


Crop module: crop development

Steps 1-2: click on **development** and then **flowering & yield formation**



Steps 3-4: click on **development** and then **root deepening**



Crop module: crop evapotranspiration

Crop transpiration (Tr) is calculated by multiplying the evaporating power of the atmosphere with the crop coefficient (KcTr) and by considering water stresses (Ks) and temperature stress (KsTr) throughout the growing cycle:

Tr = Ks * KsTr * (KcTr,x CC*) * Eto

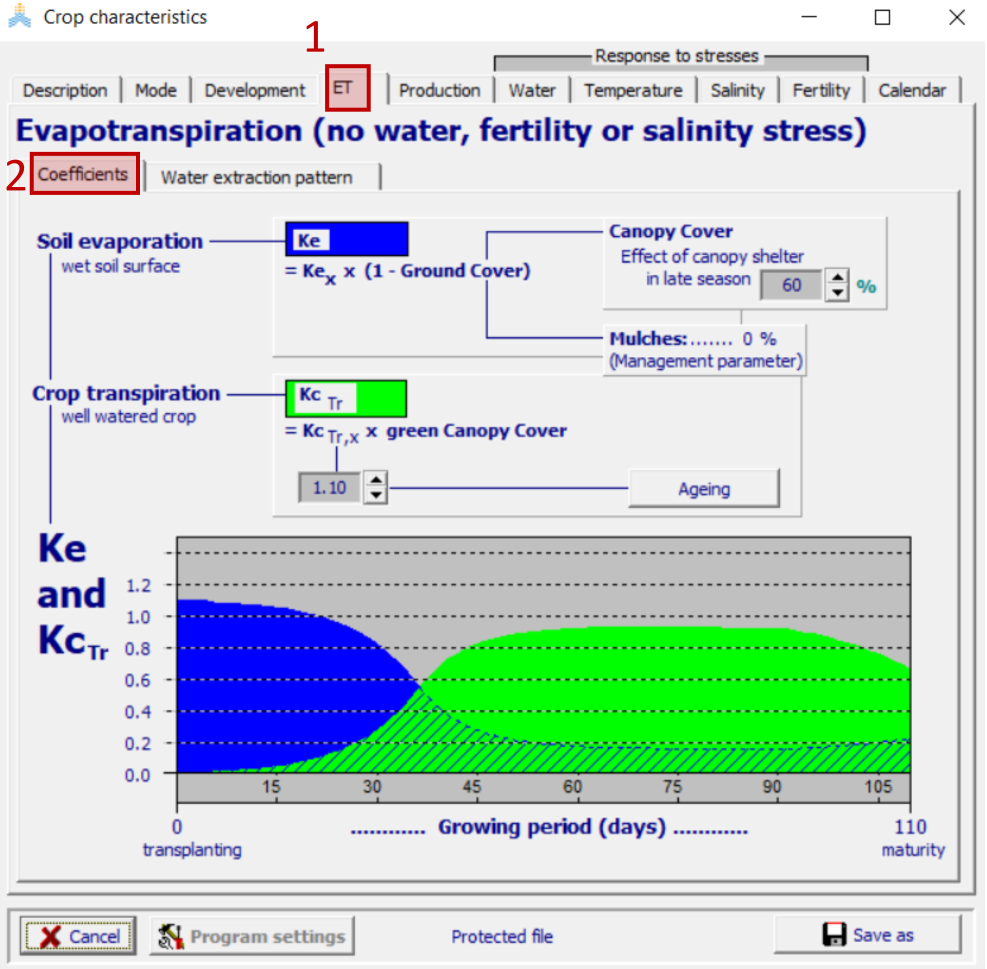
where the evaporating power (ETo) is expressed by the reference grass evapotranspiration as determined by the FAO Penman-Monteith equation. The crop transpiration coefficient (KcTr = KcTr,x CC*) is proportional to the fractional canopy cover (CC) and, as such, continuously adjusted to the simulated canopy development.

Penman-Monteith equation

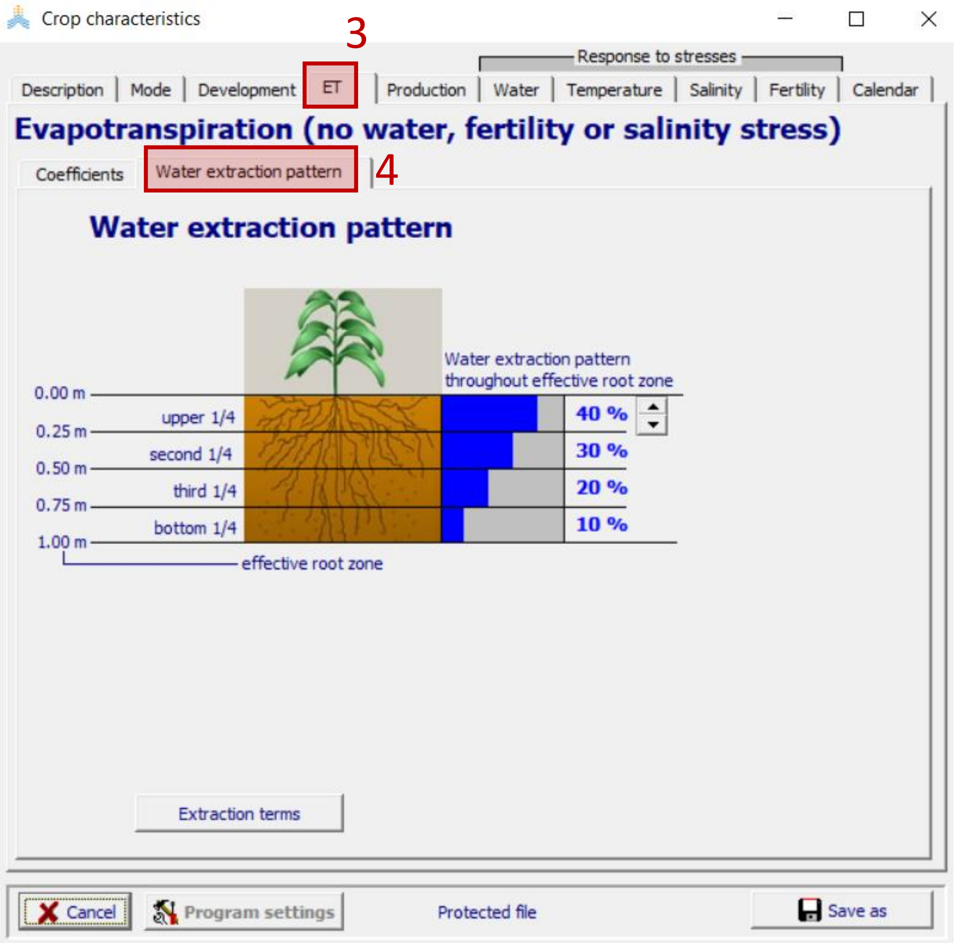
$$\lambda ET = \frac{\Delta (R_n - G) + \rho_a c_p \frac{(e_s - e_a)}{r_a}}{\Delta + \gamma \left(1 + \frac{r_s}{r_a}\right)}$$

Crop module: crop evapotranspiration

Steps 1-2: click on **ET** and then click on **coefficients**

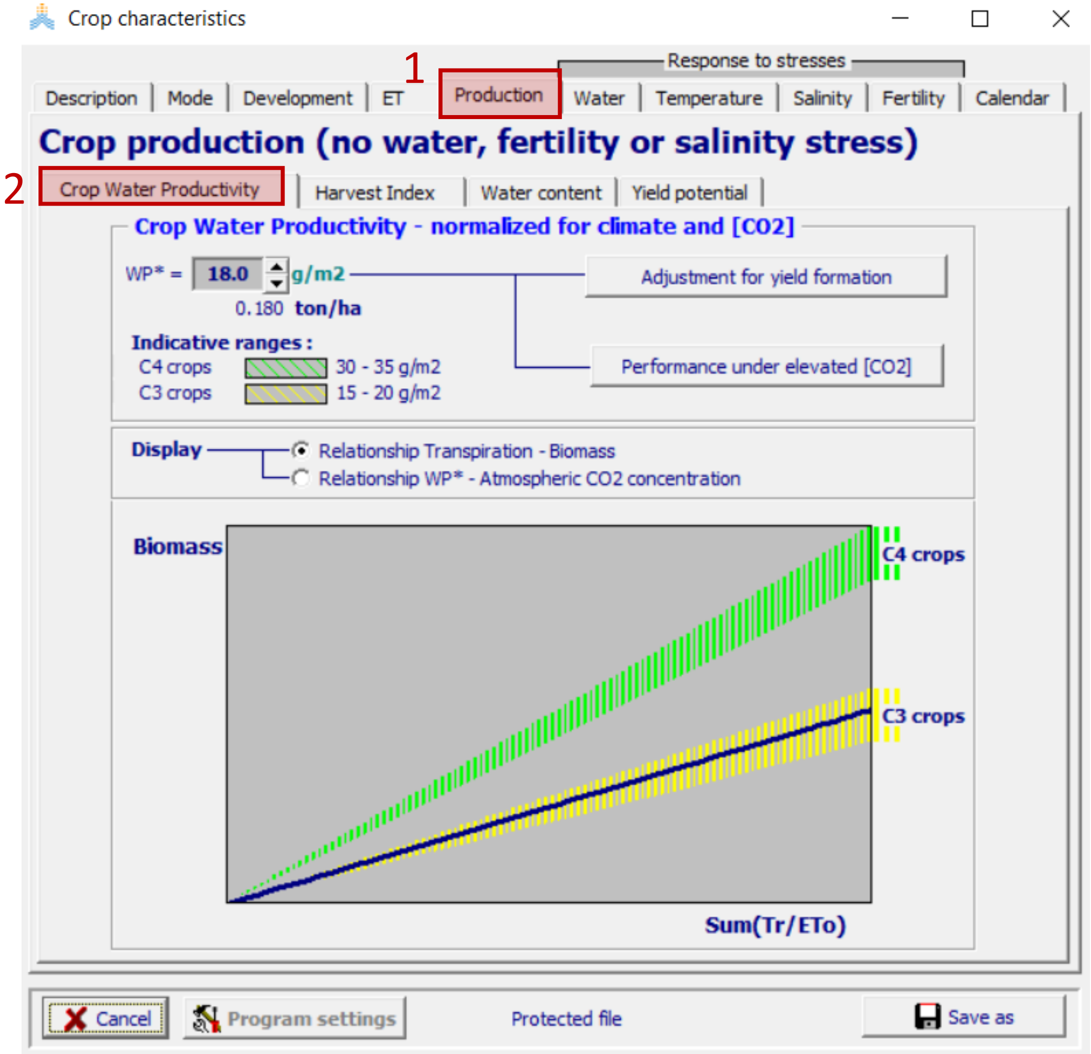


Steps 3-4: click on **ET** and then click on **water extraction pattern**

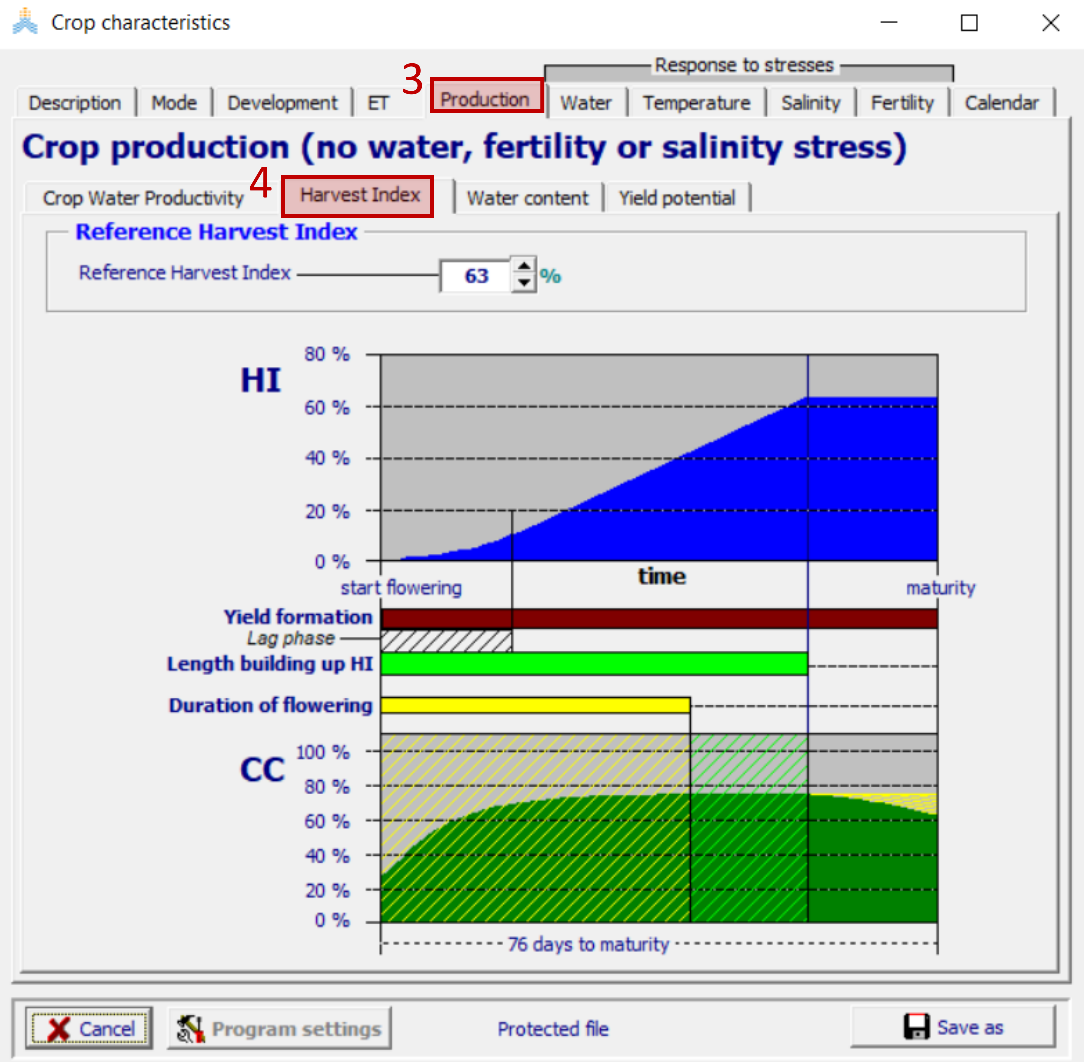


Crop module: crop production

Steps 1-2: click on **production** and then **crop water productivity**

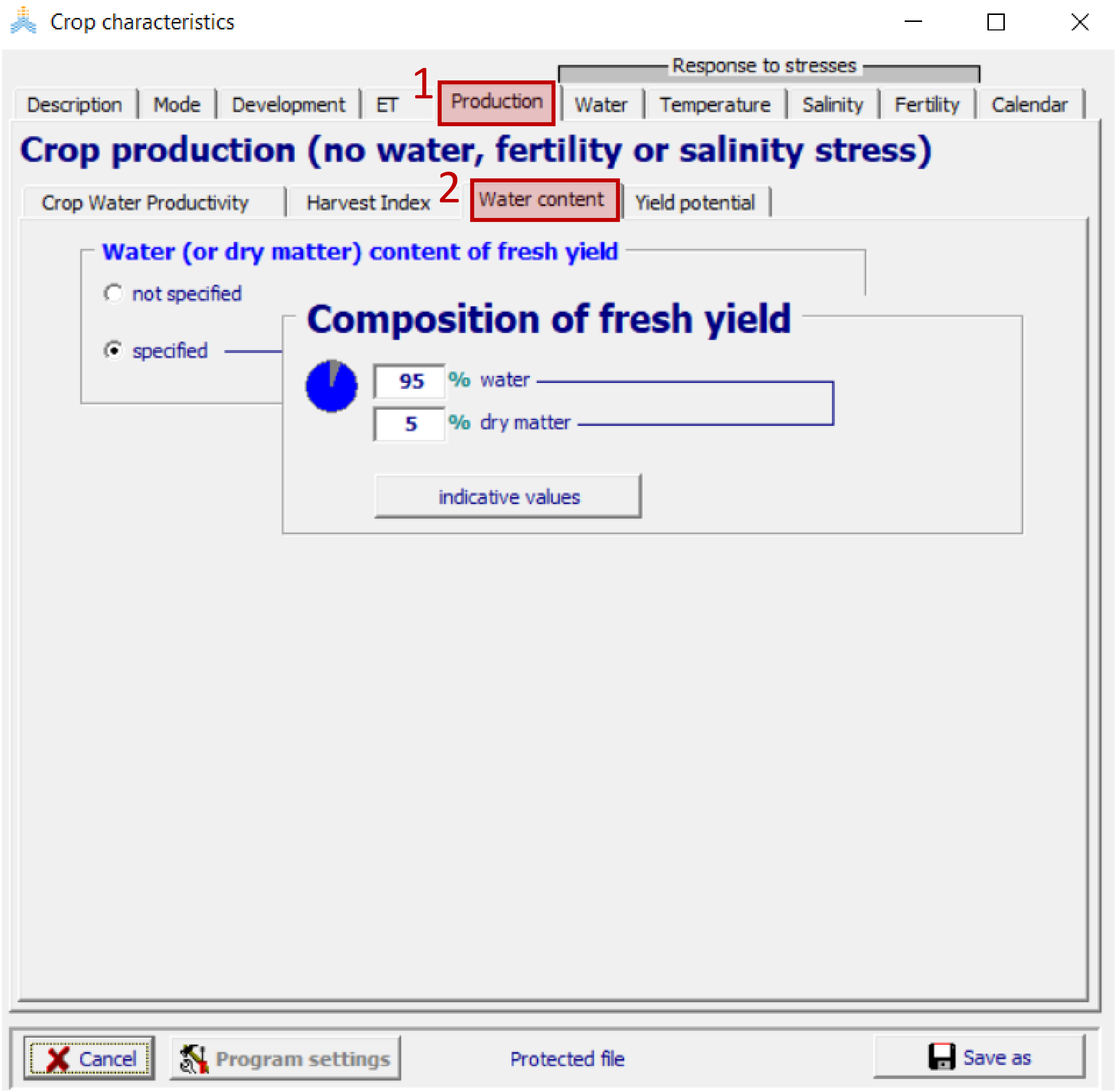


Steps 3-4: click on **production** and then **harvest index**

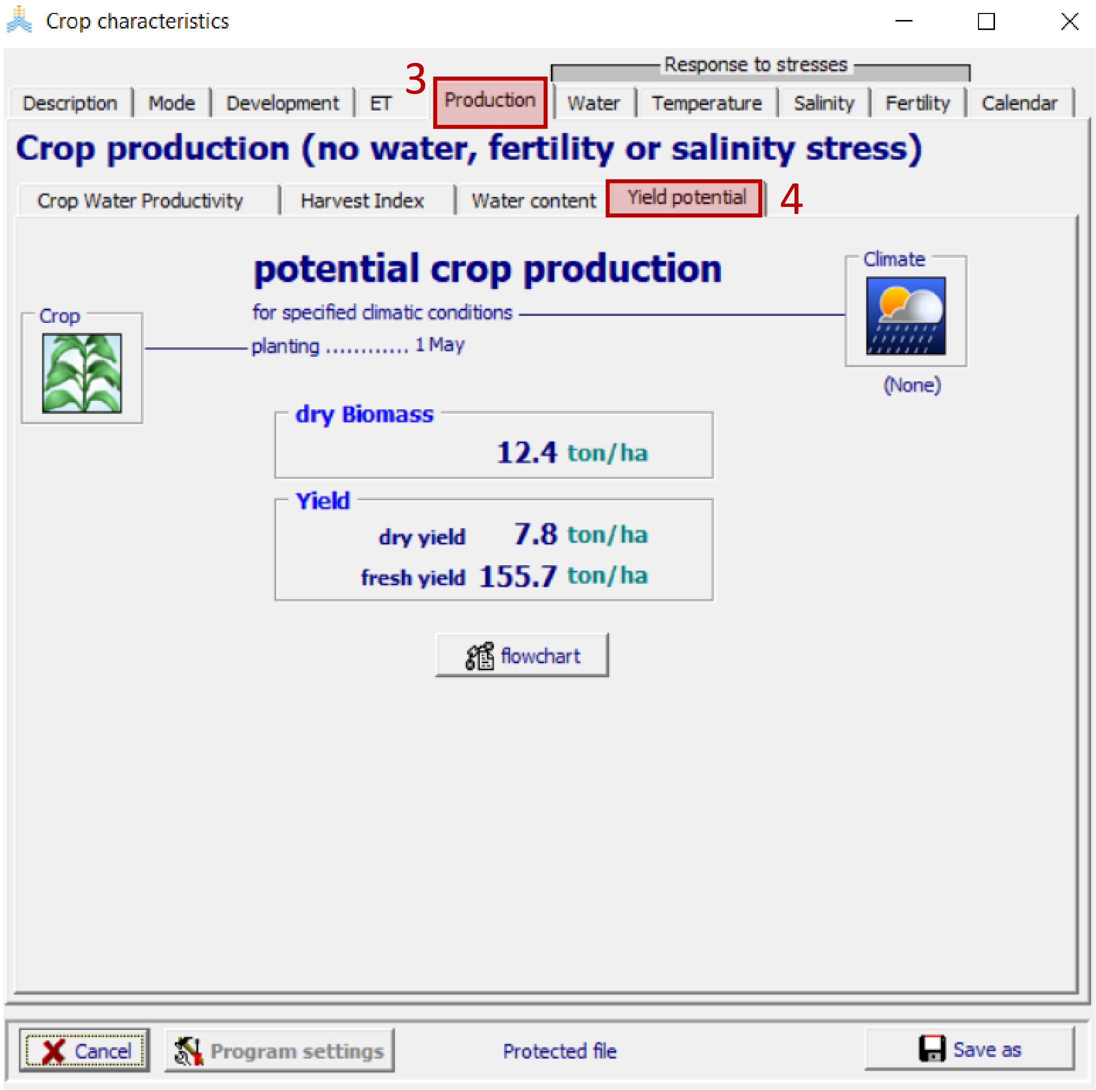


Crop module: crop production

Steps 1-2: click on **production** and then **water content**



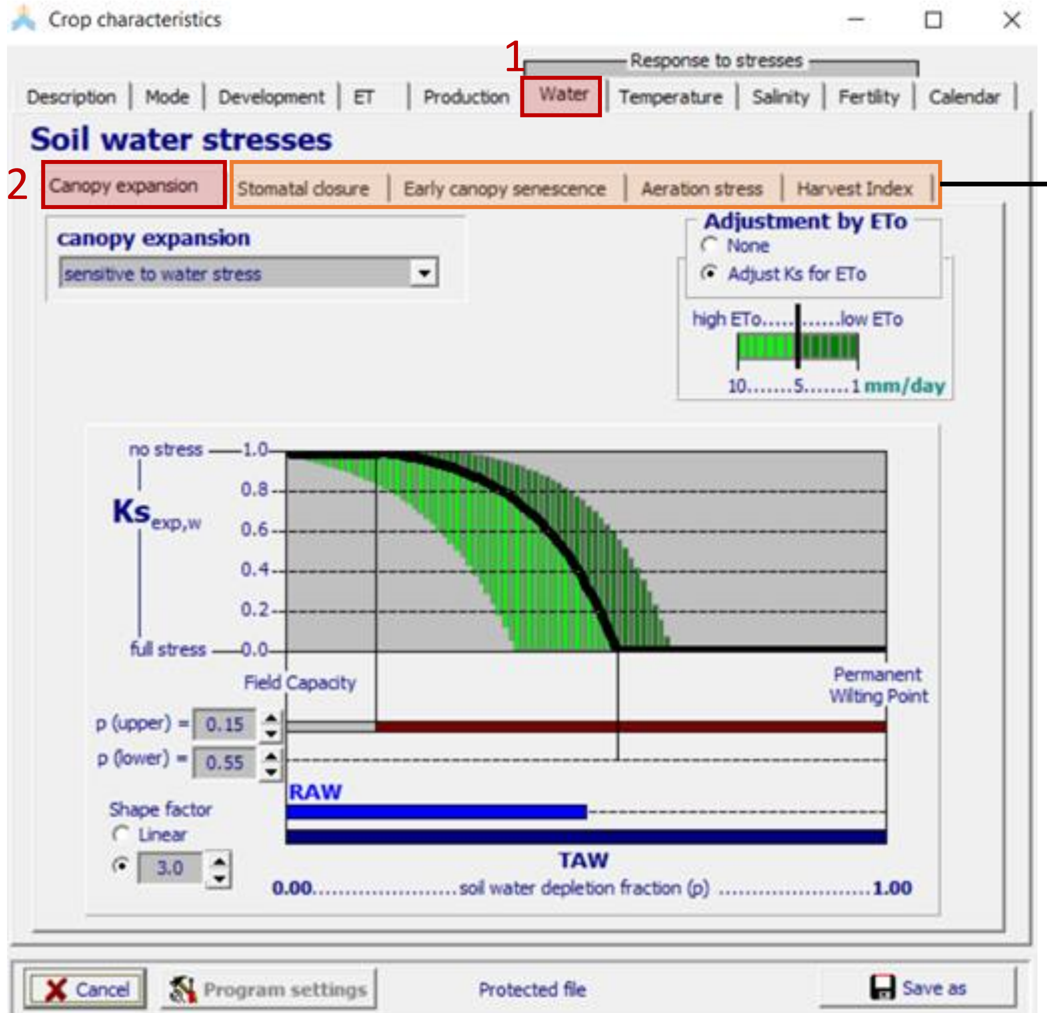
Steps 3-4: click on **production** and then **yield potential**



Crop module: soil-water stress

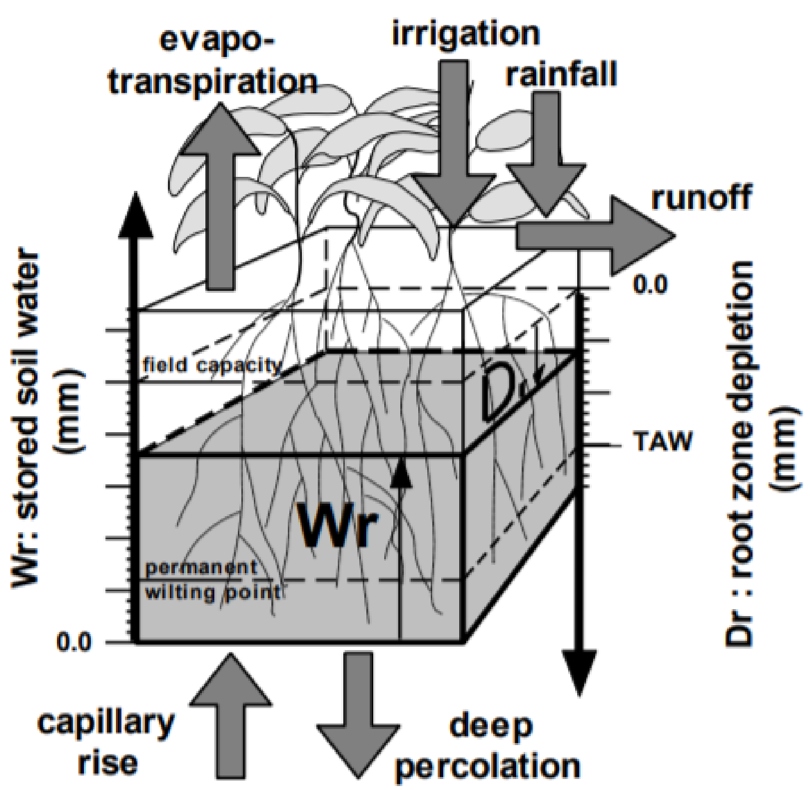
Soil water stress: start to affect a particular process when the stored soil water in the root zone drops below an upper threshold level (FC and PWP)

Steps 1-2: click on **water** and **canopy expansion**



For advanced users!

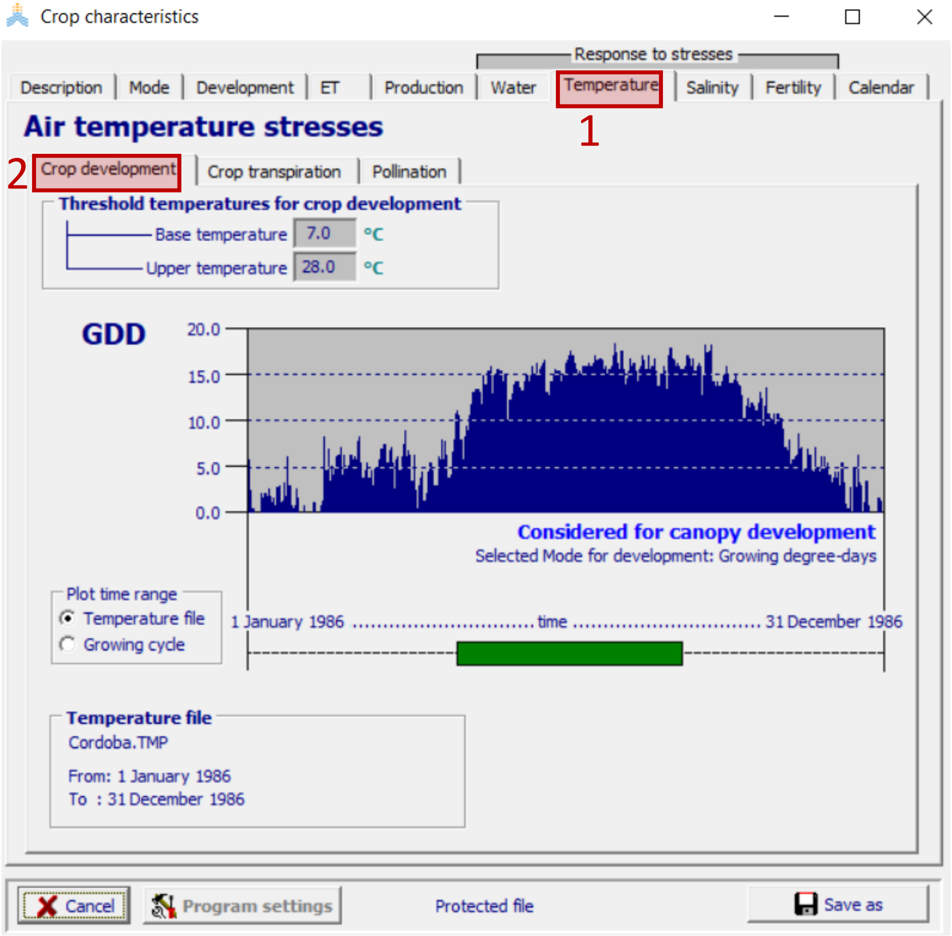
Soil-water balance



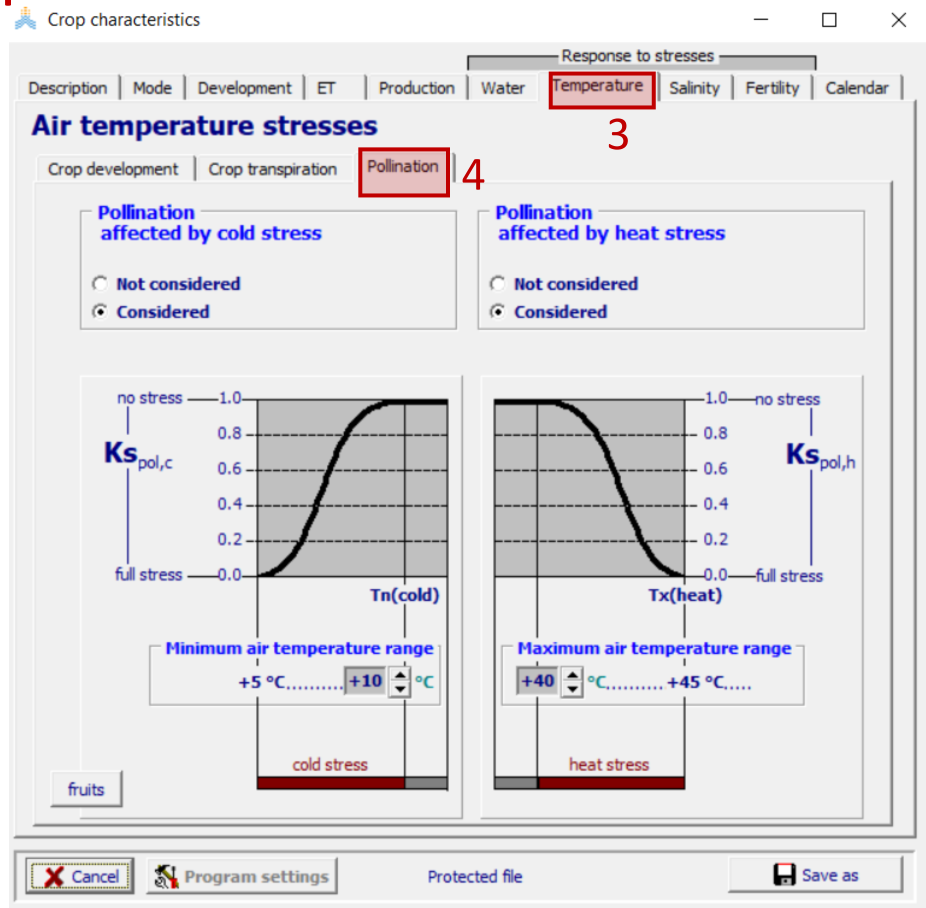
Crop module: temperature stress

Temperature stress: cold temperature stress reduces crop transpiration. Hot and cold temperature stresses inhibit pollination and reduce the harvest index (HI)

Steps 1-2: click on **temperature** and then click on **crop development**



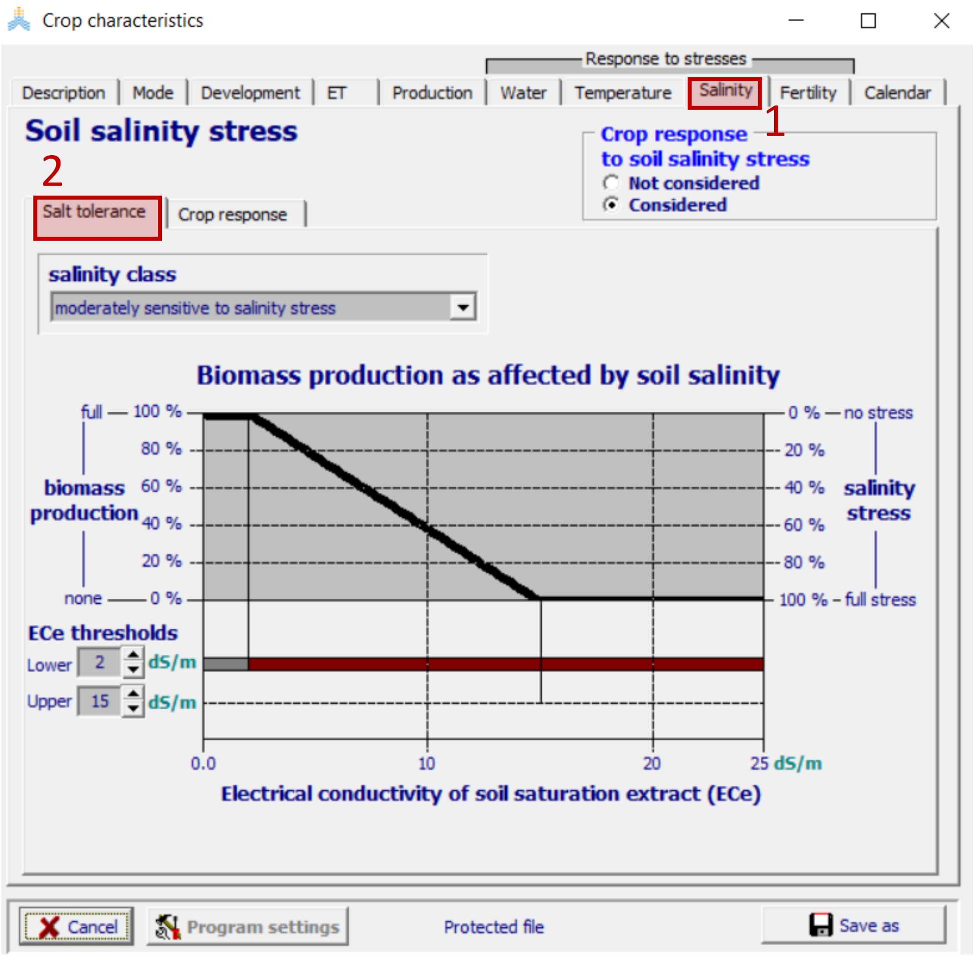
Steps 3-4: click on **temperature** and then **pollination**



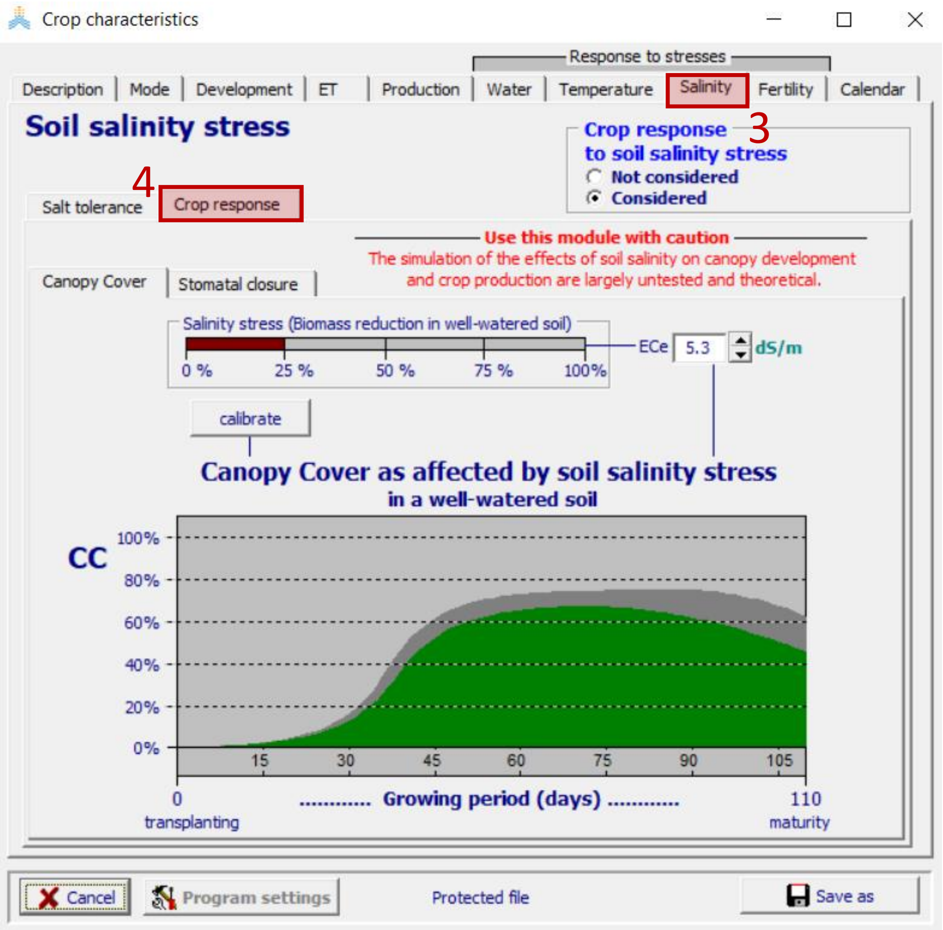
Crop module: salinity stress

Salinity stress: since soil salinity reduces the availability of the water in the root zone reservoir, the presence of dissolved salts increases the effect of soil water stress.

Steps 1-2: click on **salinity** and then click on **salt tolerance**

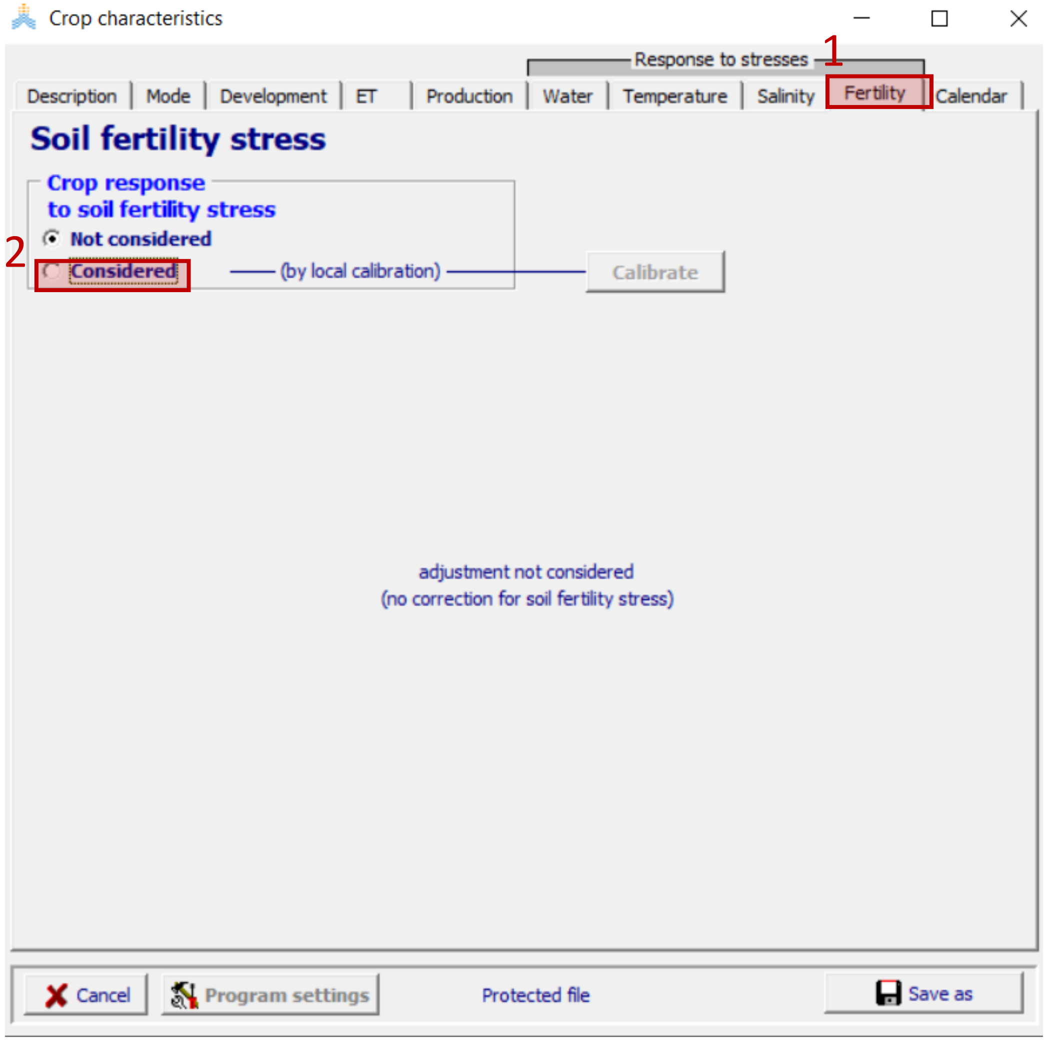


Steps 3-4: click on **salinity** and then click on **crop response**

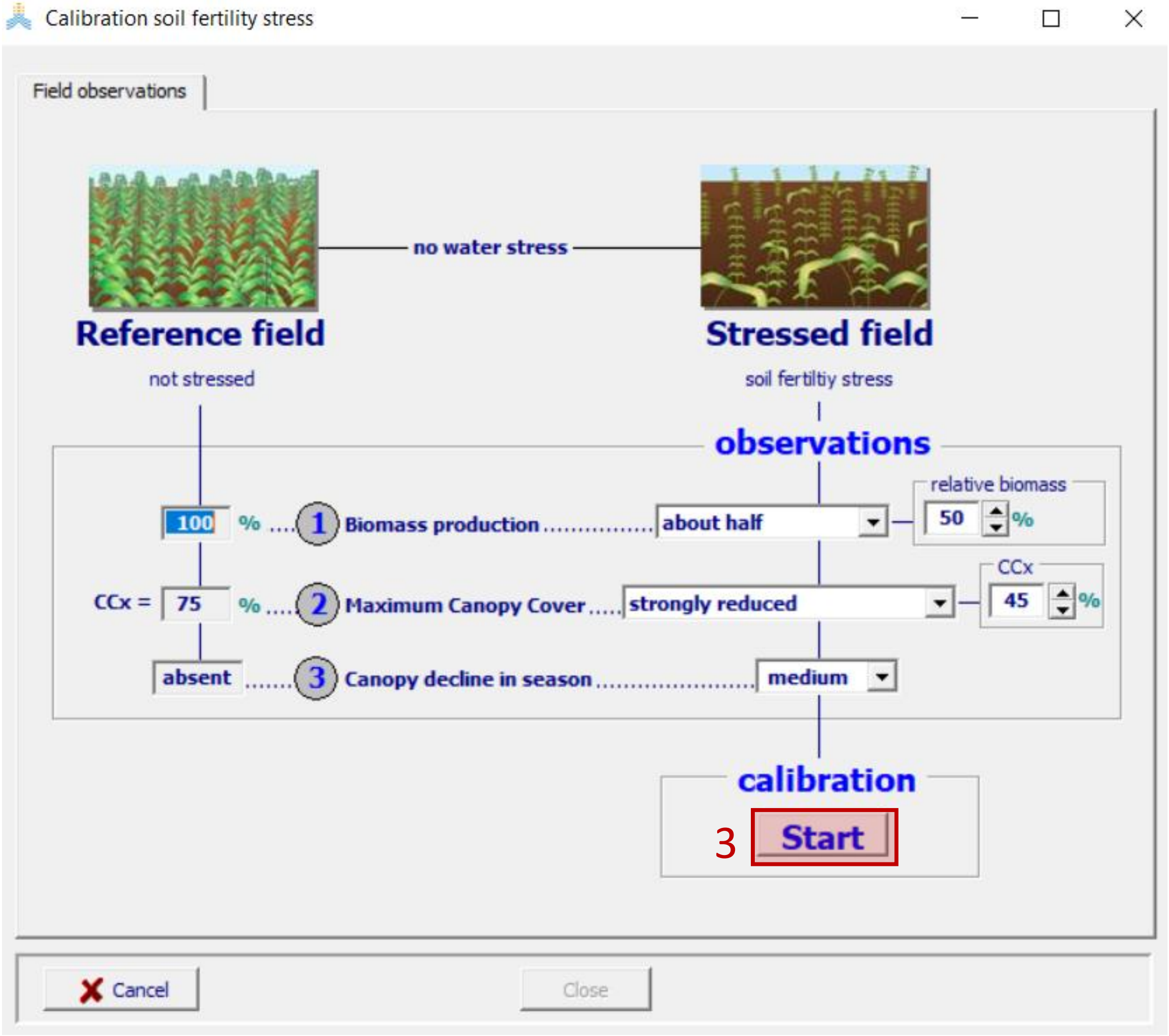


Crop module: soil fertility stress

Steps 1-2: click on **fertility** and then on **considered**

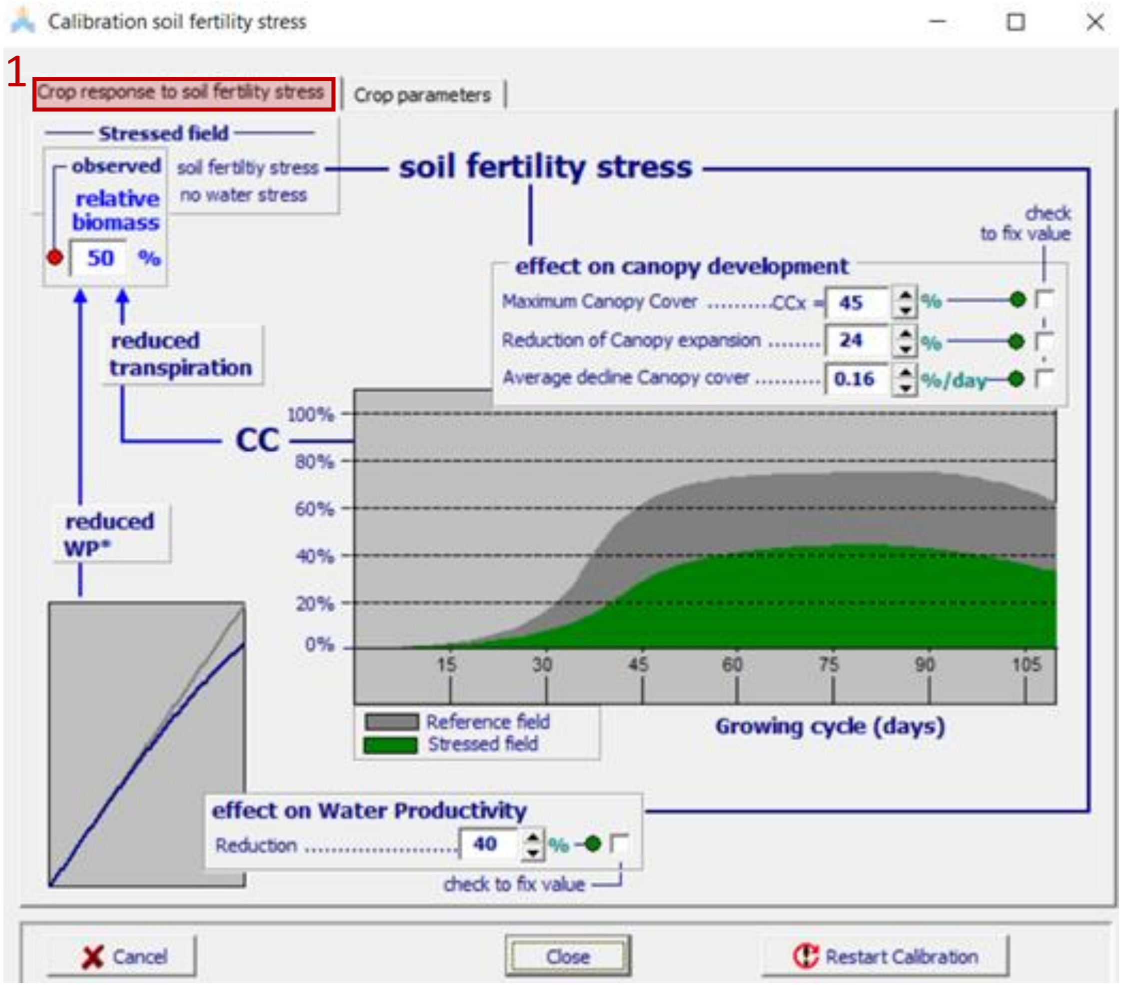


Step 3: click on **Start**

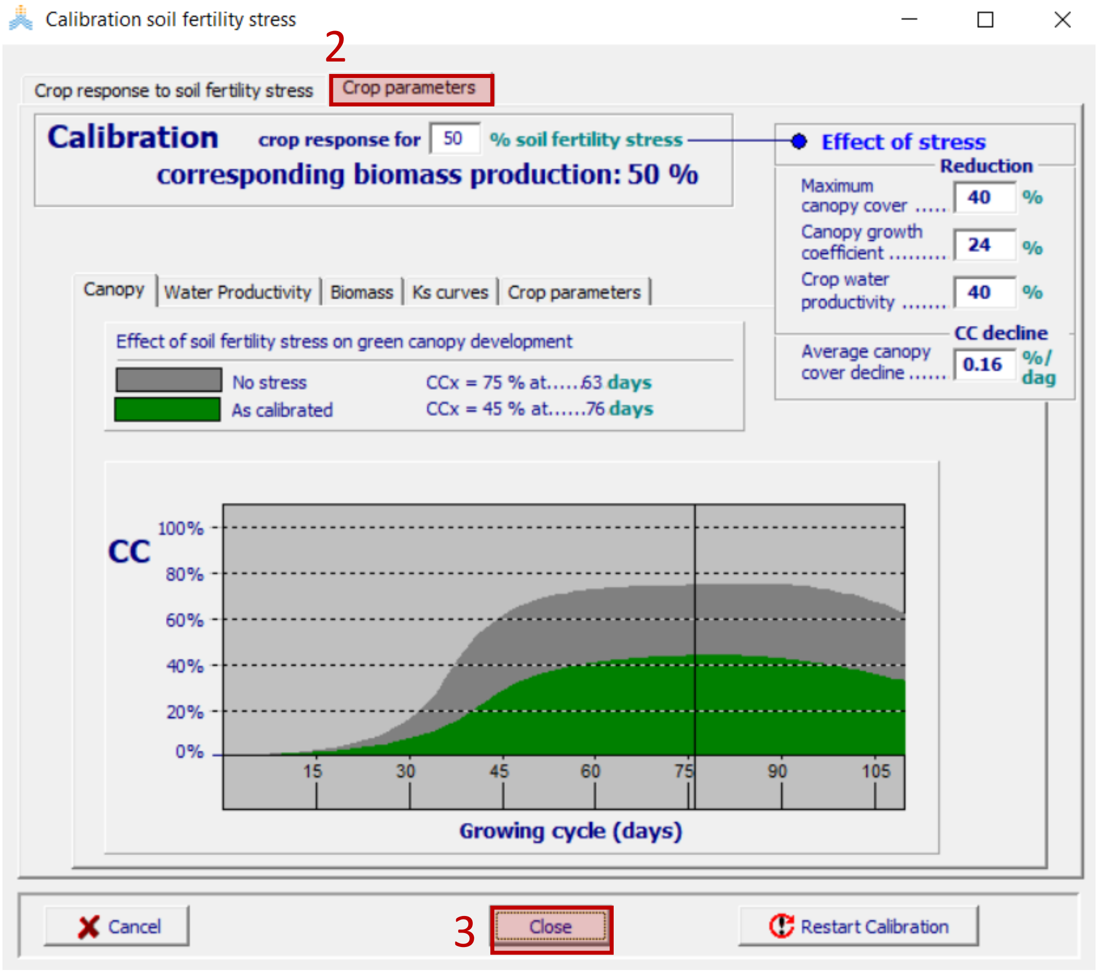


Crop module: soil fertility stress

Step 1: click on **crop response to soil fertility stress**



Steps 2-3: click on **crop parameters** and then **close**



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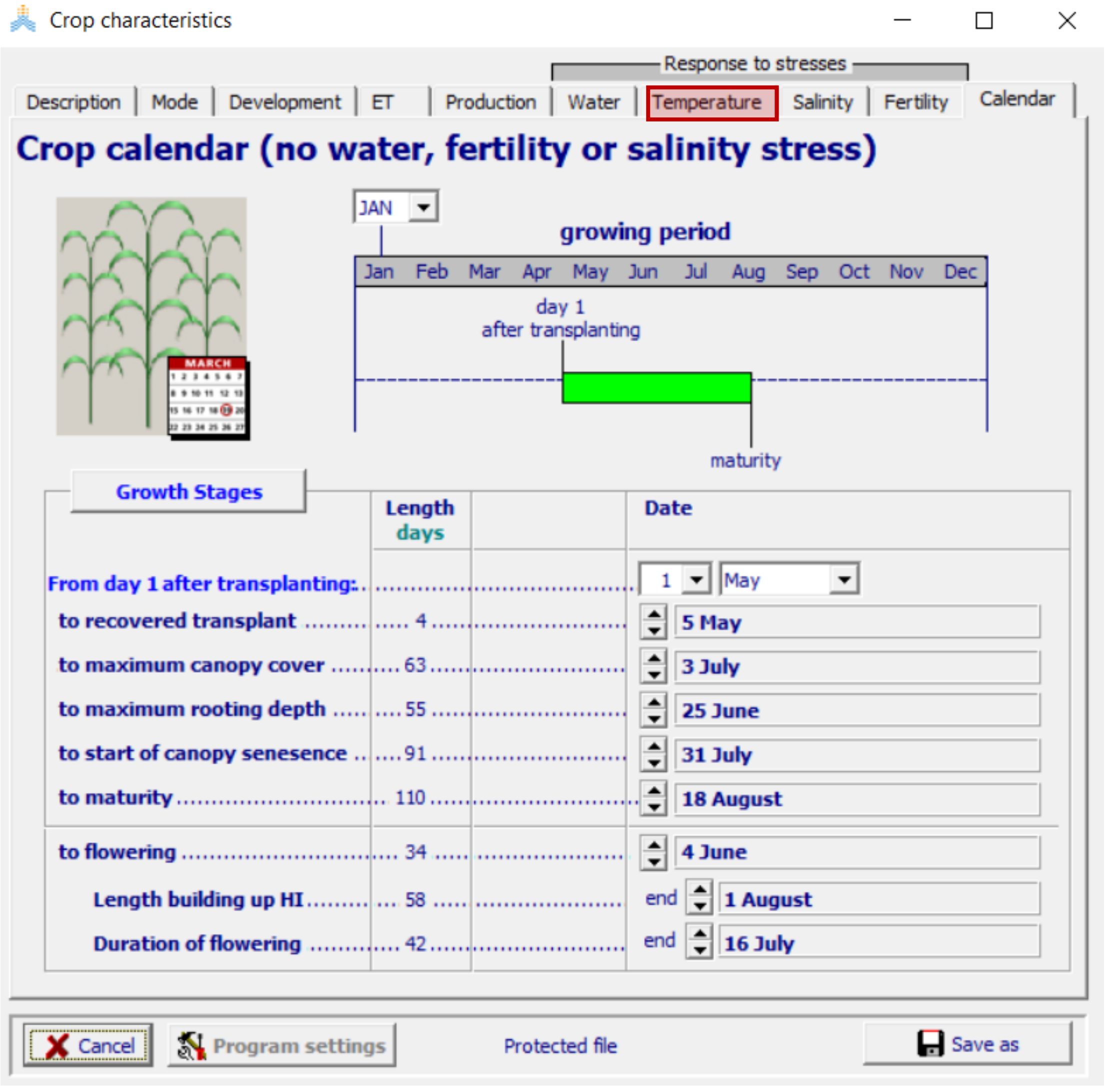
Crop module: calendar information

Step 1: click on **calendar**



Summary of all the phenological phases based on the selected transplanting date

MANAGEMENT MODULE

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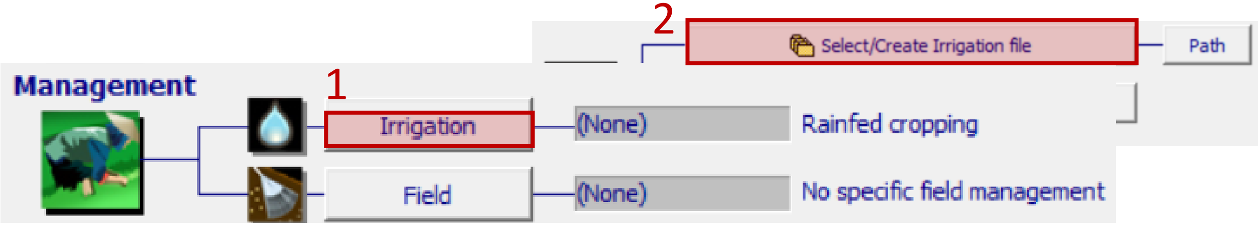
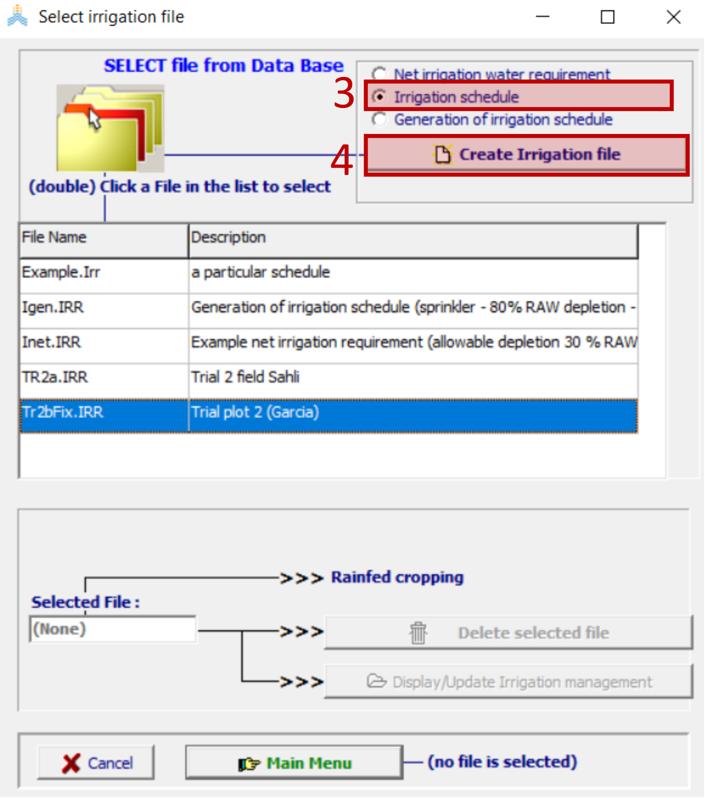
Management module: irrigation

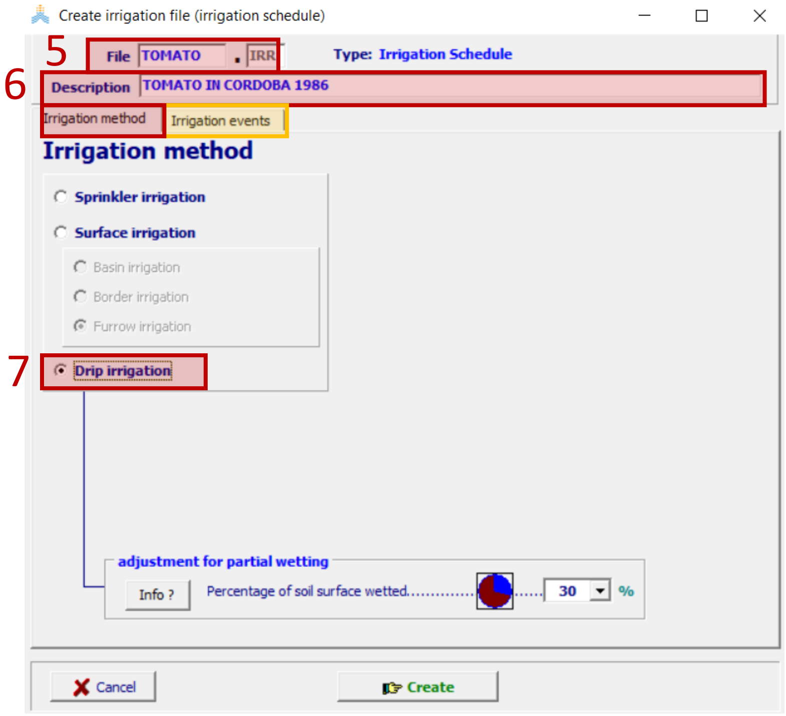
Steps 1-2: click on **irrigation** and then **select/create irrigation file**



Steps 3-4: click on **irrigation** schedule and then **create irrigation file**

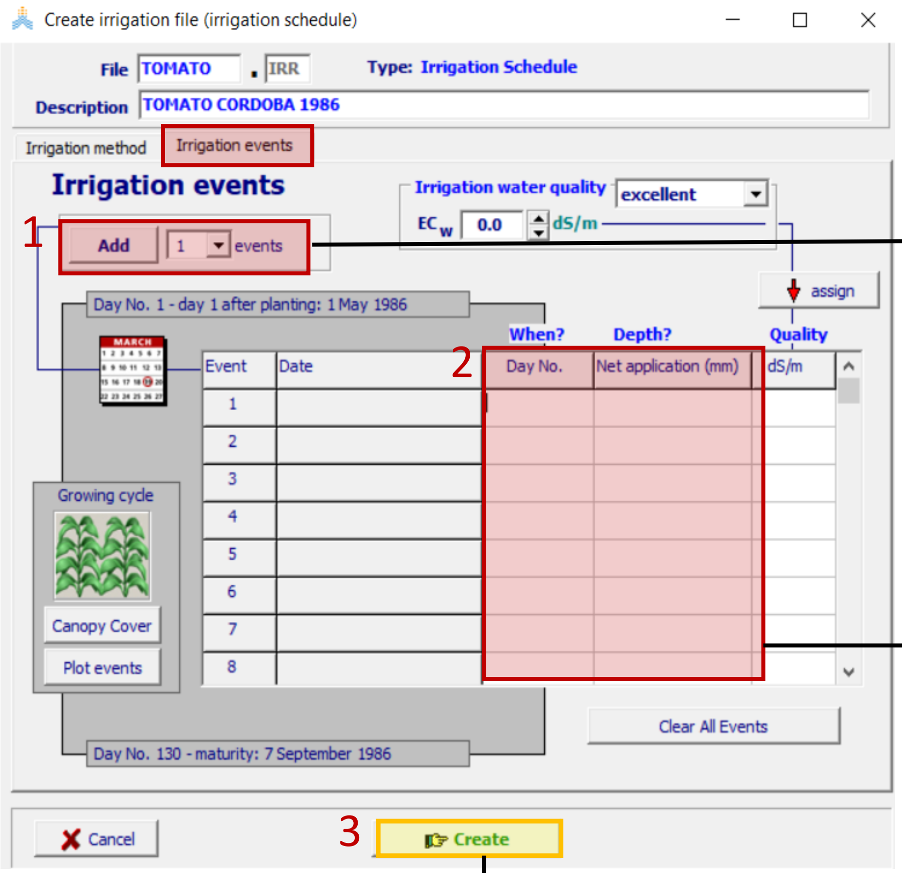


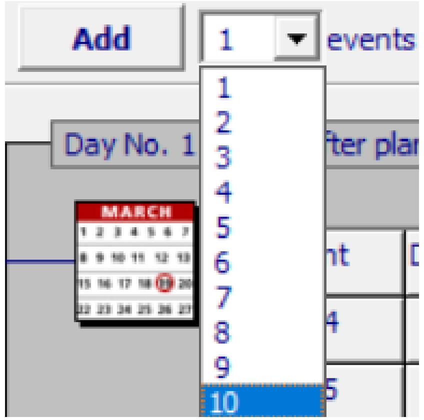
Steps 5-7: name your file "**tomato**" and provide a description "**tomato in Córdoba 1986**" and select the irrigation method, in our case, **drip irrigation**. Then click on **irrigation events**



Management module: irrigation

Step 1: click on **add events** and add **10.** **REPEAT STEP 1** to have a total of 20 irrigation events





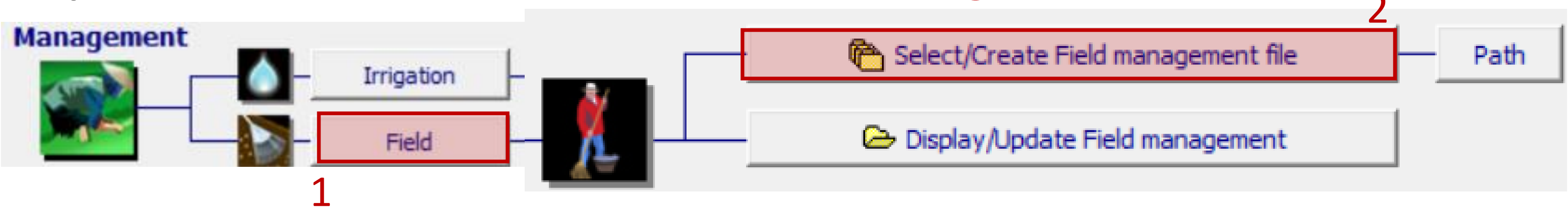
Step 2: type the frequency of irrigation (**5** days) and the net application of water (**10** mm). In total, you should have 20 irrigation events each with 10mm (total net application during the growing cycle: **200mm**)

Event	Date	Day No.	Net application (mm)	dS/m
1	5 May 1986	5	10	0.0
2	10 May 1986	10	10	0.0
3	15 May 1986	15	10	0.0
4	20 May 1986	20	10	0.0
5	25 May 1986	25	10	0.0
6	30 May 1986	30	10	0.0
7	4 June 1986	35	10	0.0
8	9 June 1986	40	10	0.0

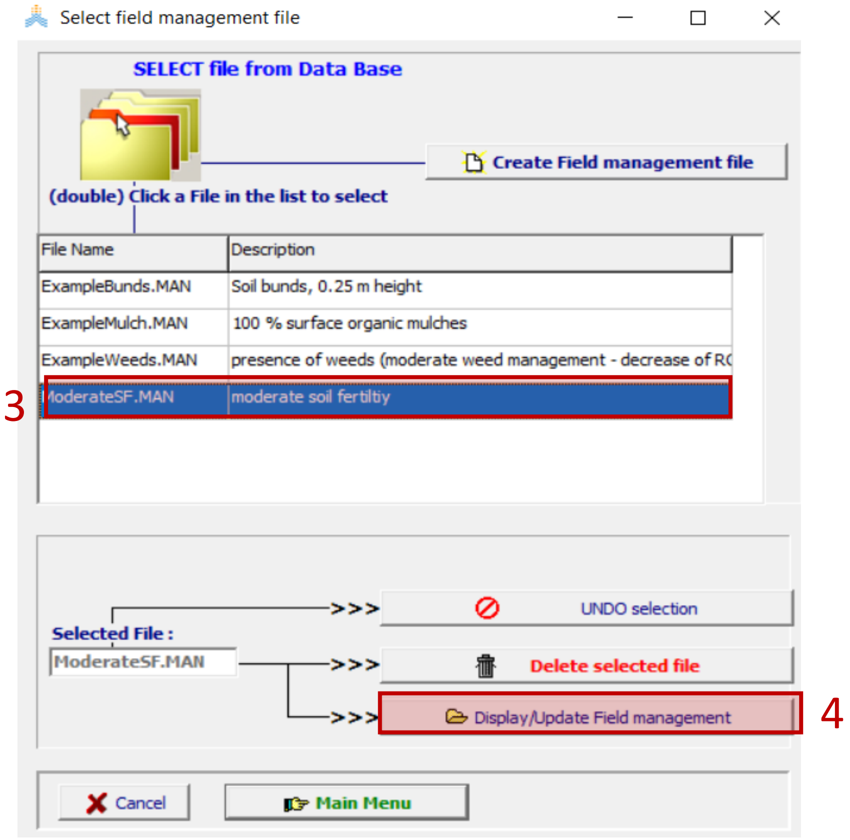
Step 3: click on **create**. AquaCrop should have created the irrigation file with the frequency and the irrigation amount specified!

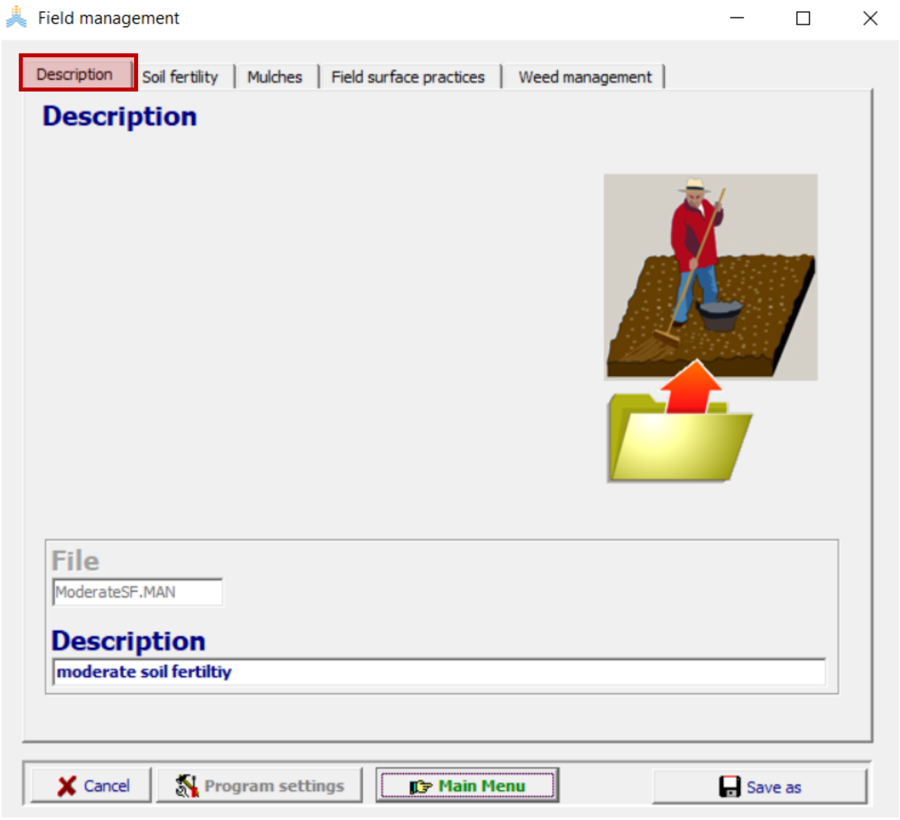
Management module: field management

Steps 1-2: click on **field** and **select/create field management file**



Steps 3-4: click once on **moderate soil fertility** and **display/update field management**

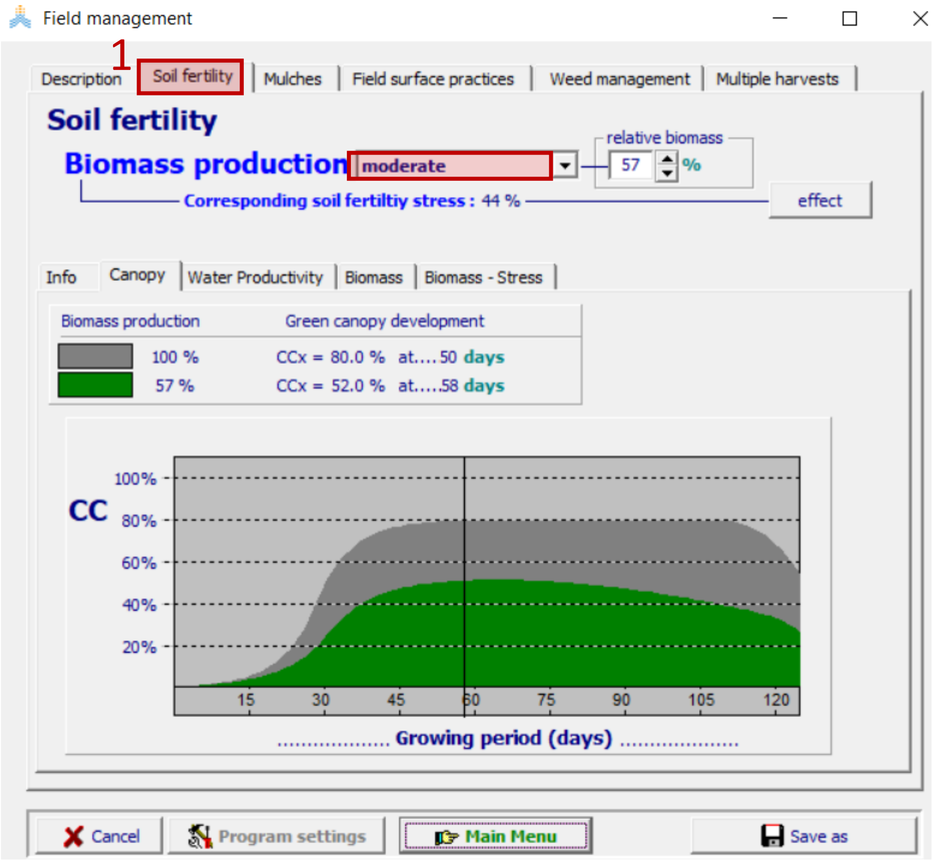




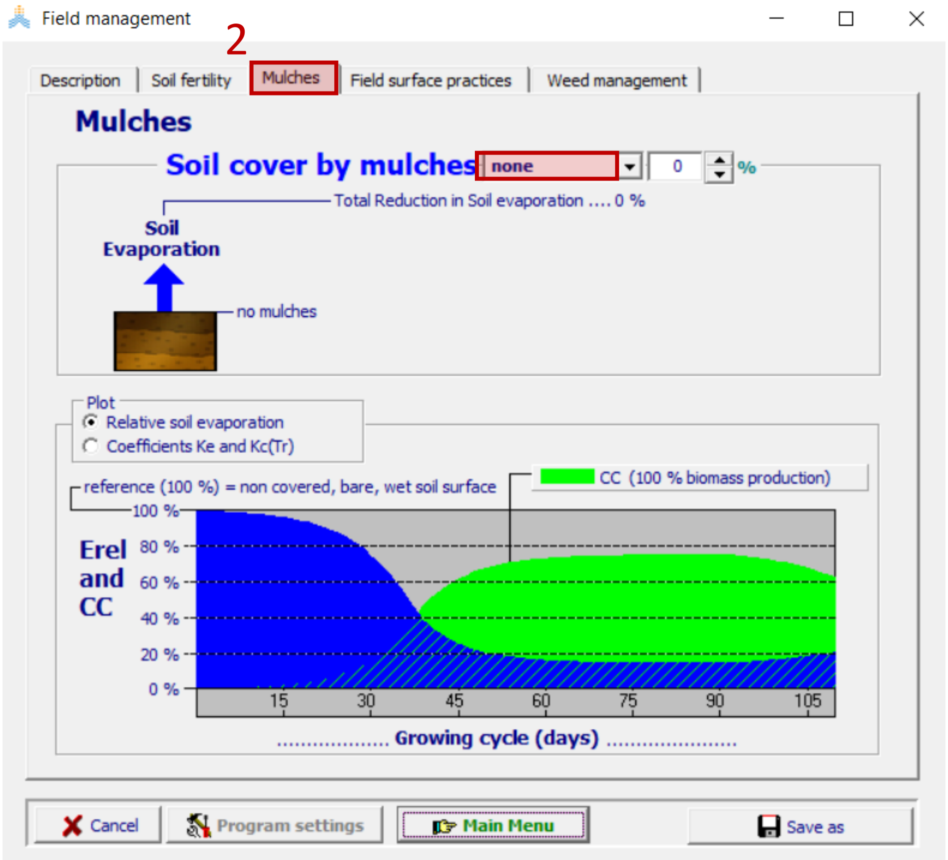
Management module: field management

Field management practices are choices of soil fertility levels, weed management, and practices that affect the soil water balance such as mulching to reduce soil evaporation, soil bunds to store water in the field, and tillage practices such as soil ridging or contours reducing run-off of rainwater.

Step 1: click on **soil fertility**

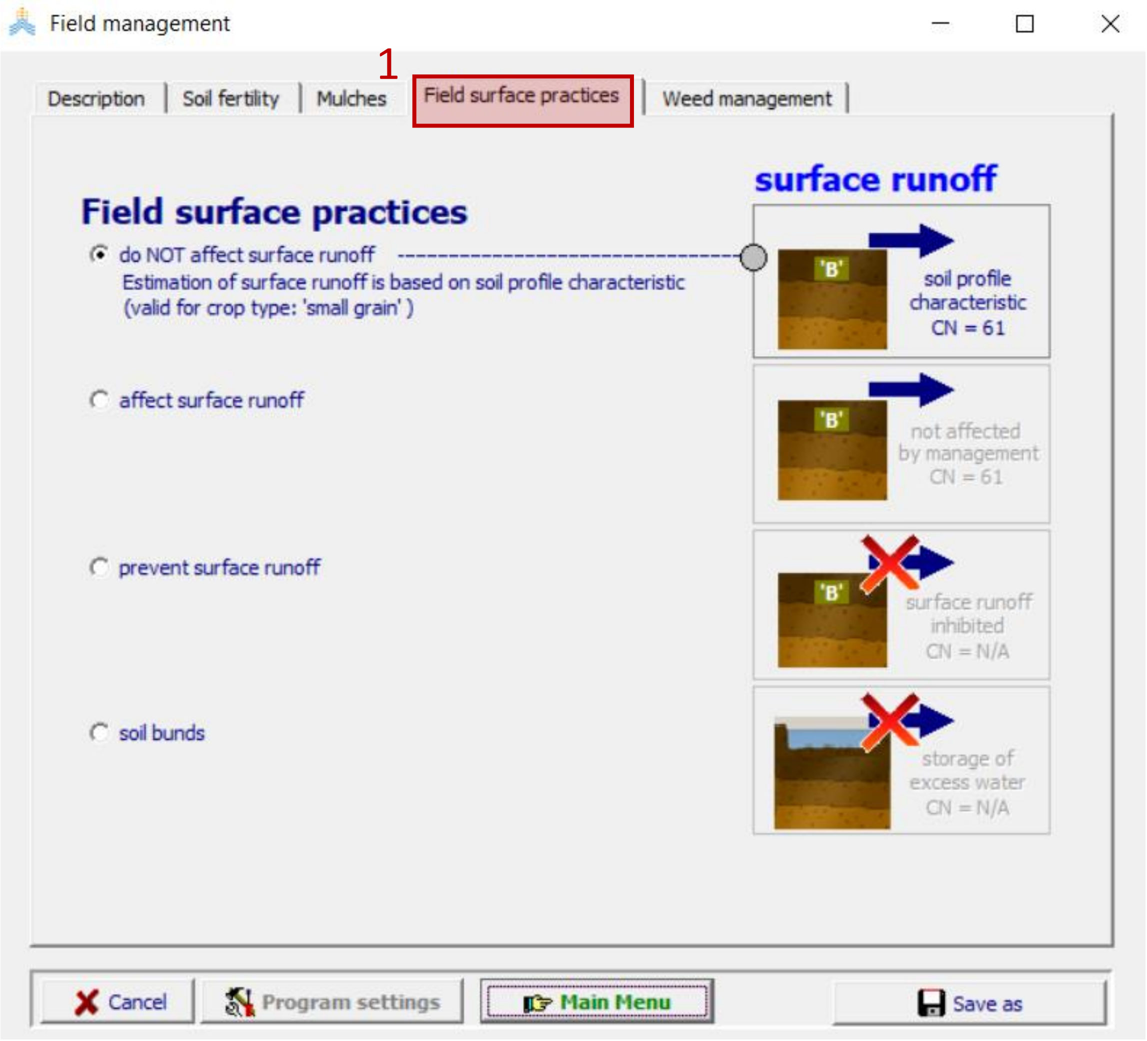


Step 2: click on **mulches**

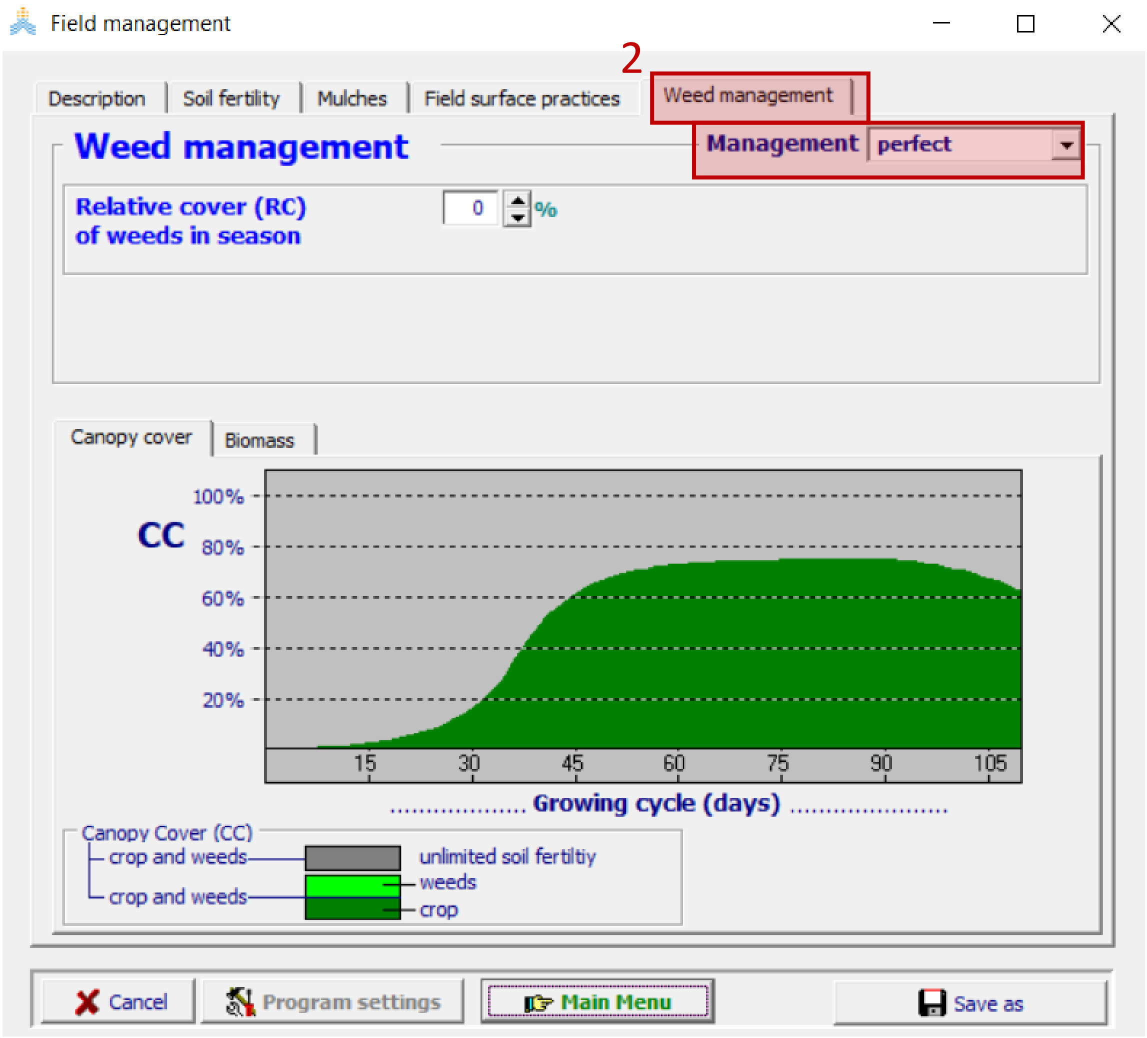


Management module: field management

Step 1: click on **field surface practices**



Step 2: click on **weed management**



SOIL MODULE

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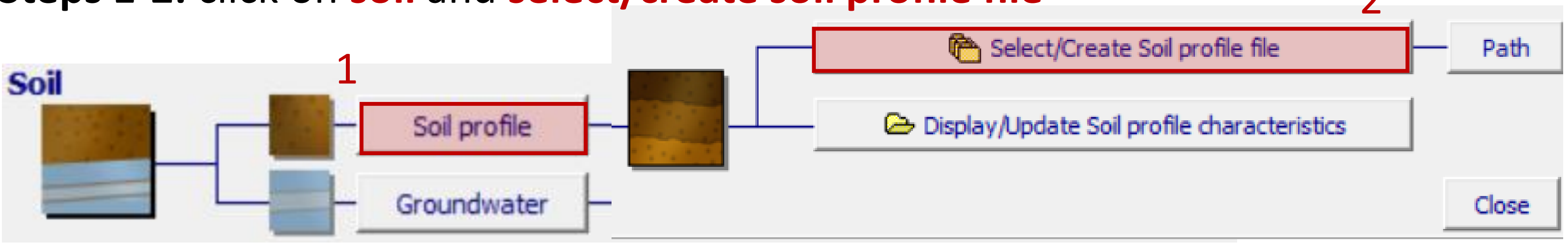
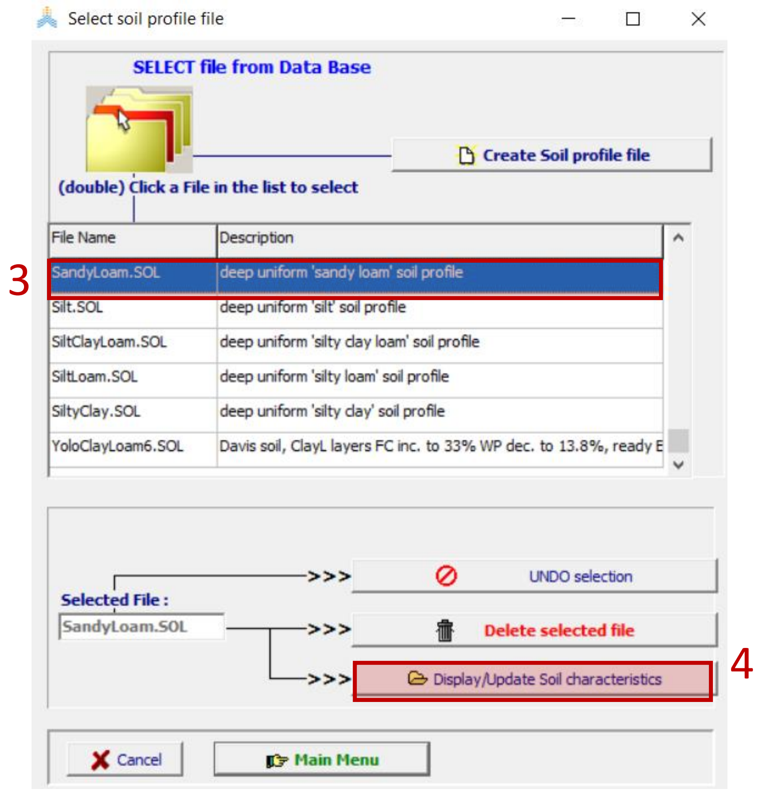
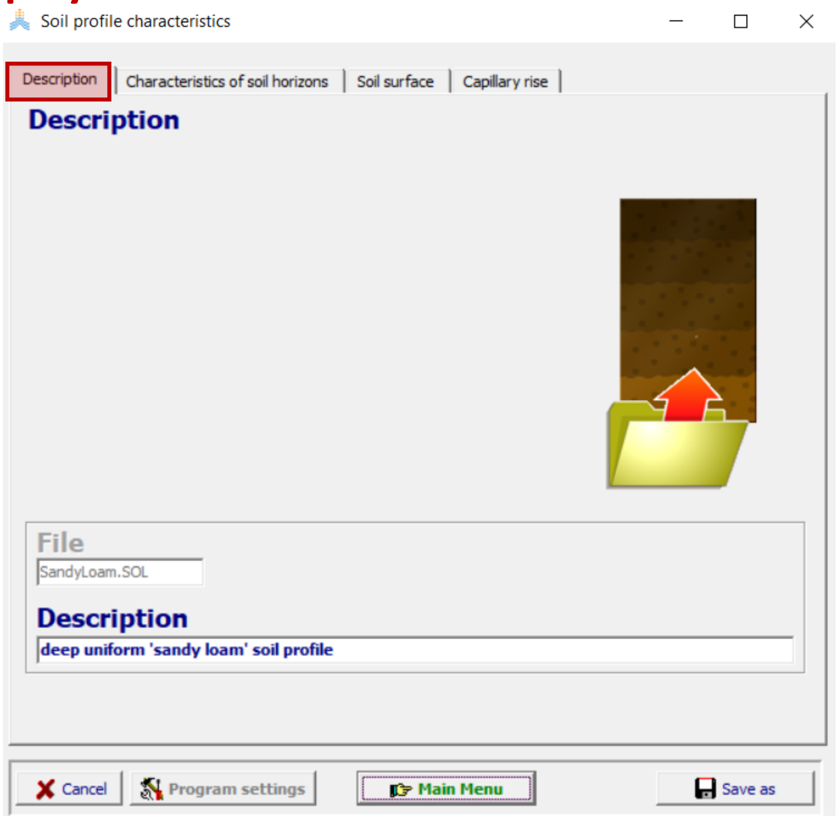
Soil module: soil profile & texture classes

Steps 1-2: click on **soil** and **select/create soil profile file**



Steps 3-4: click once on **sandy-loam** and then click on **display soil characteristics**

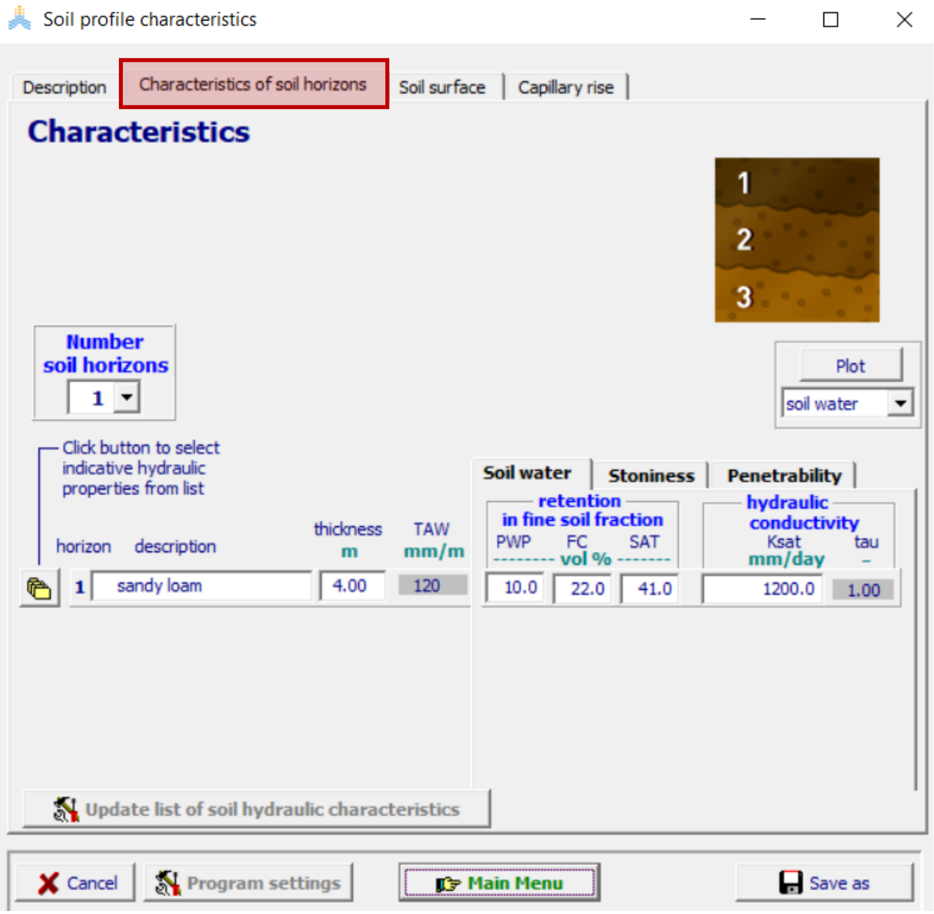




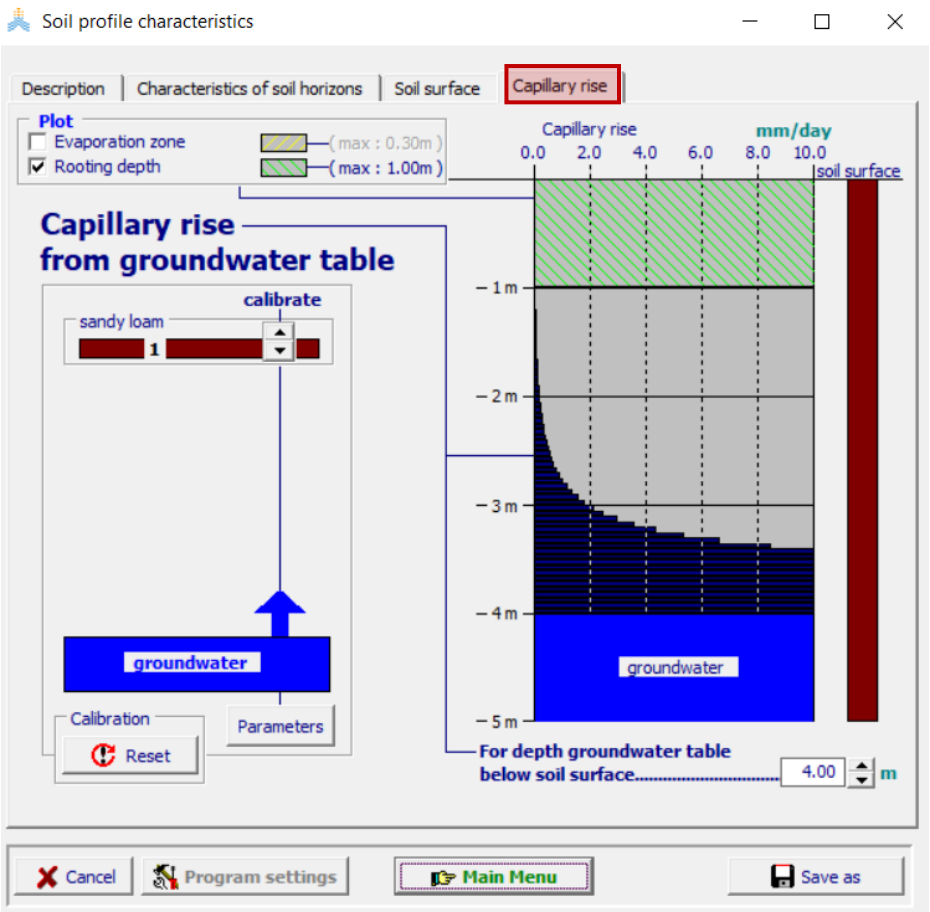
Soil module: soil profile & texture classes

The soil profile can be composed of up to five different horizons of variable depth, each with their own physical characteristics. The characteristics are the water retention in the fine soil fraction at saturation (SAT), field capacity (FC), and at permanent wilting point (PWP), and the hydraulic conductivity of the soil at saturation (Ksat).

Step 1: click on **characteristics of soil horizons**

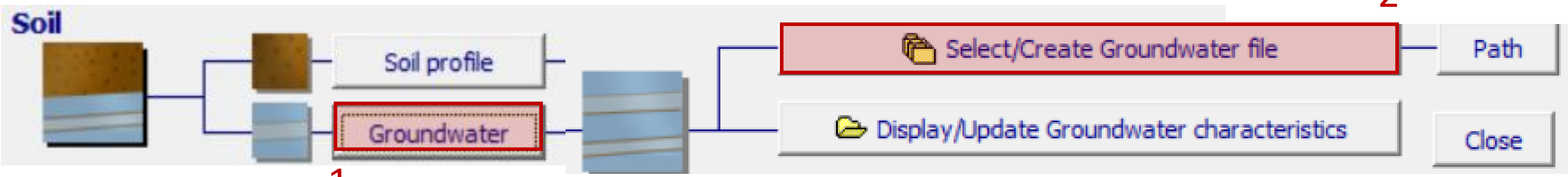


Step 2: click on **capillary rise**

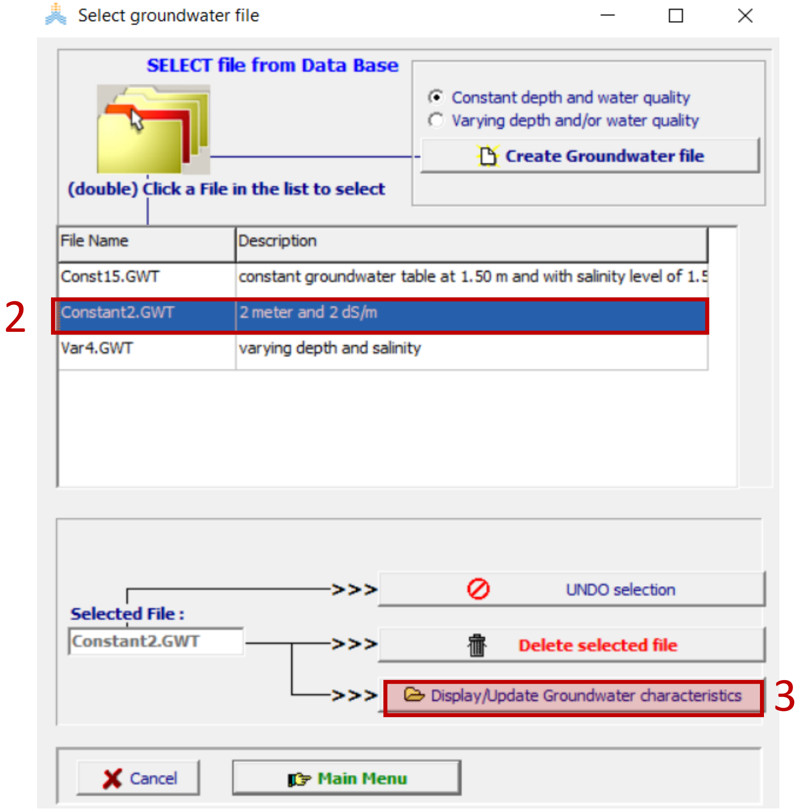


Soil module: groundwater

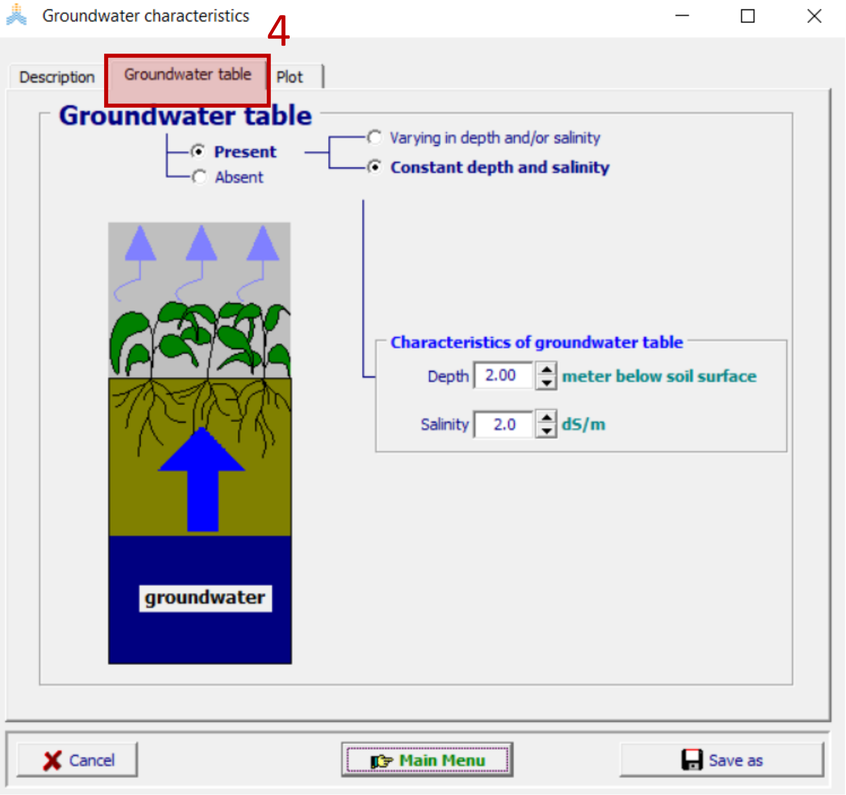
Step 1: click on **soil** and **groundwater**, then **select/create groundwater file**



Steps 2-3: click once on **Constant 2** and then click **display**



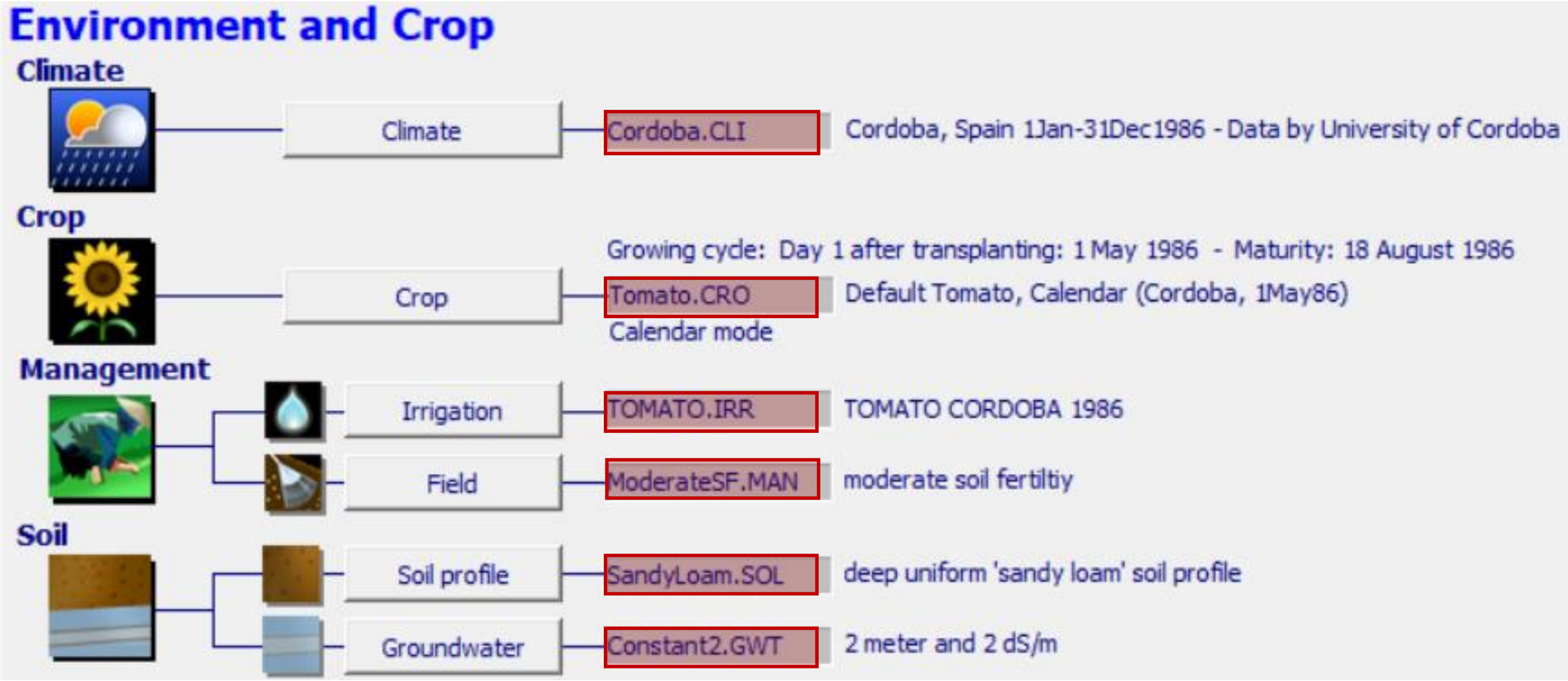
Step 4: click on **Groundwater table**



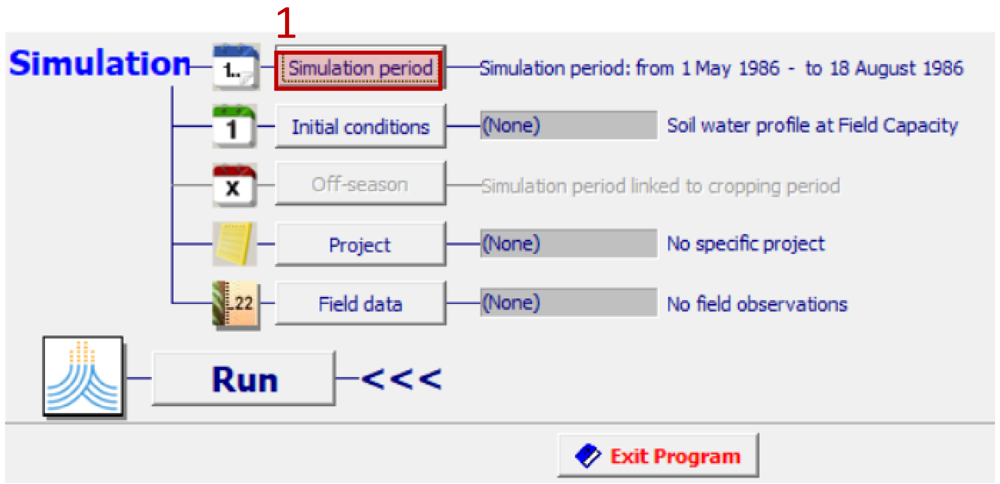
SIMULATION

Summary of input files

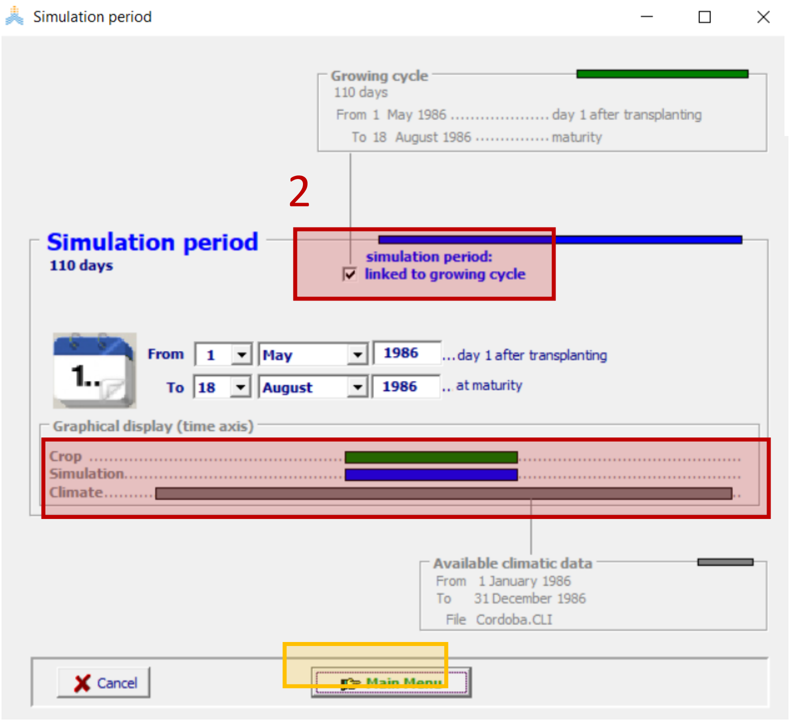
Below you will find a summary of selected files to run the simulations, including climate file **(Cordoba)**, crop file **(tomato)**, irrigation schedule **(tomato)**, field management **(moderate)**, soil profile **(sandy-loam)**, and groundwater **(constant)**



Simulation period

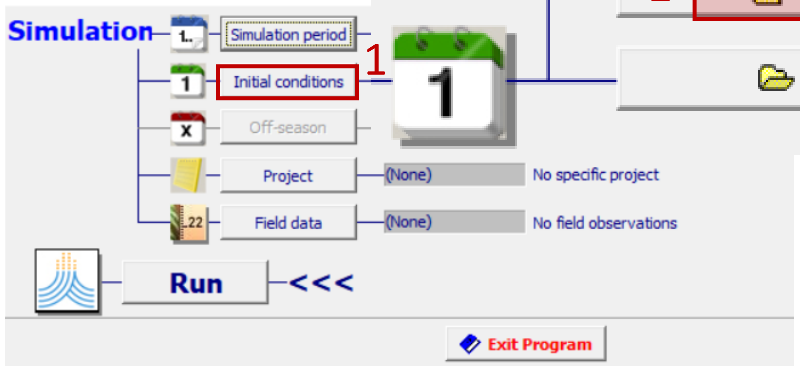


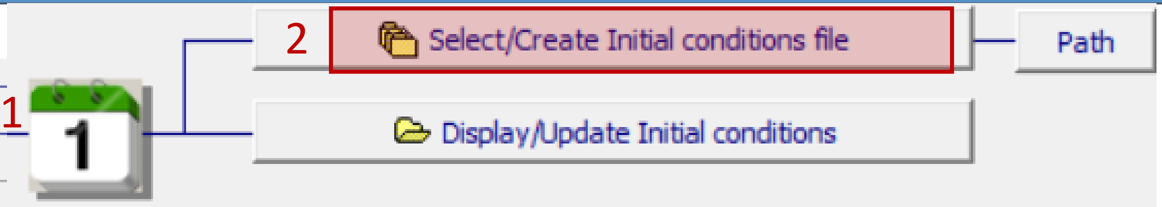
Step 1: click on **simulation period**



Step 2: double-check that the **simulation period** coincides or its within the timeframe of the climatic file

Initial conditions

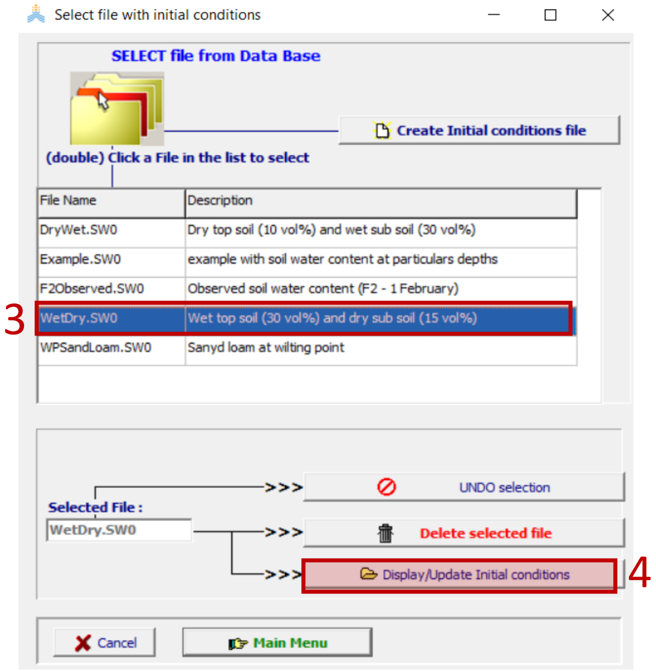


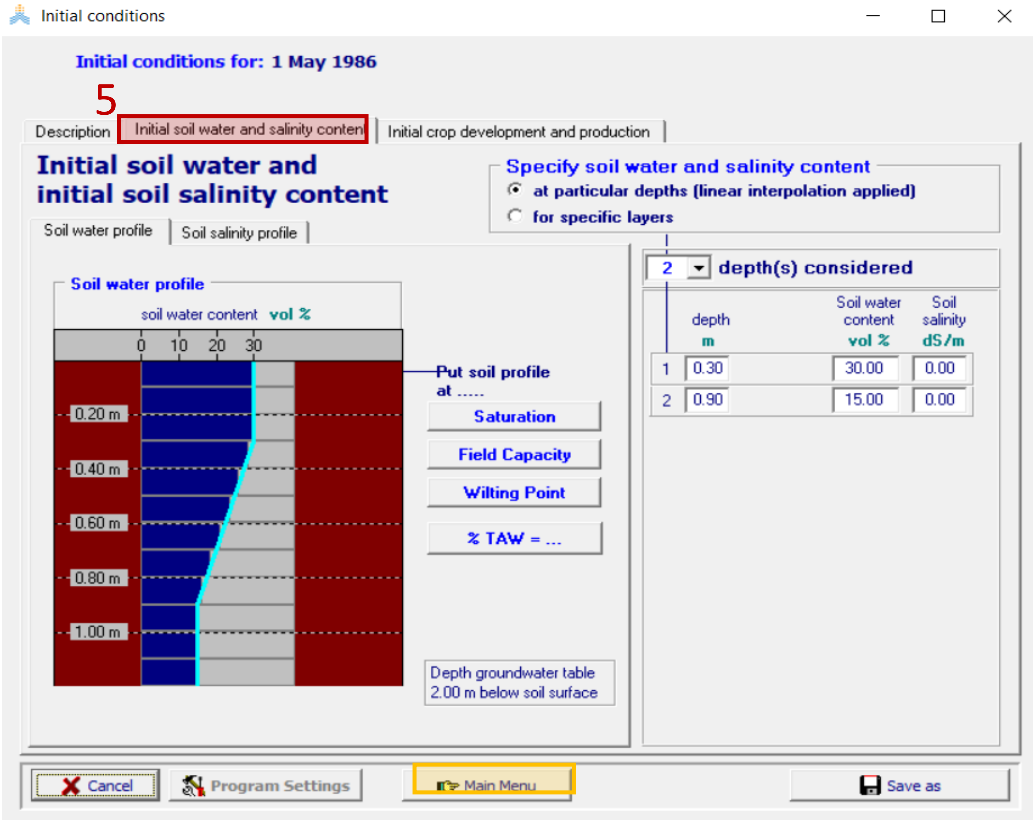


Steps 1-2: click on **initial conditions** and then **select/create initial conditions file**

Step 5: click on **initial soil water and salinity content**

Steps 3-4: click once on **wet/dry** and click on **display/update initial conditions**





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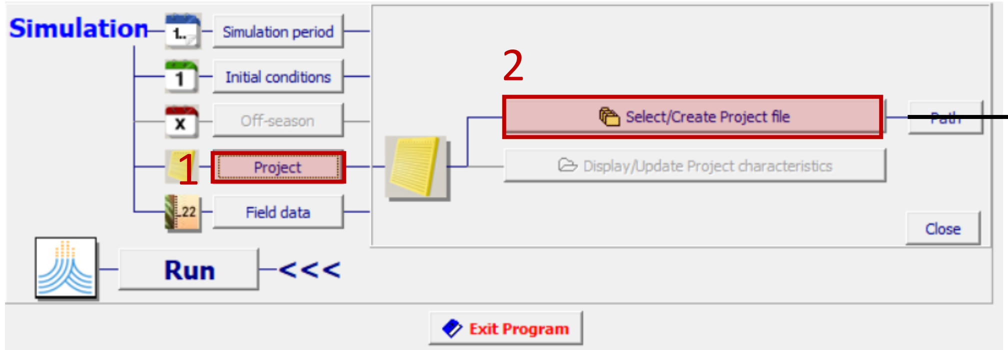
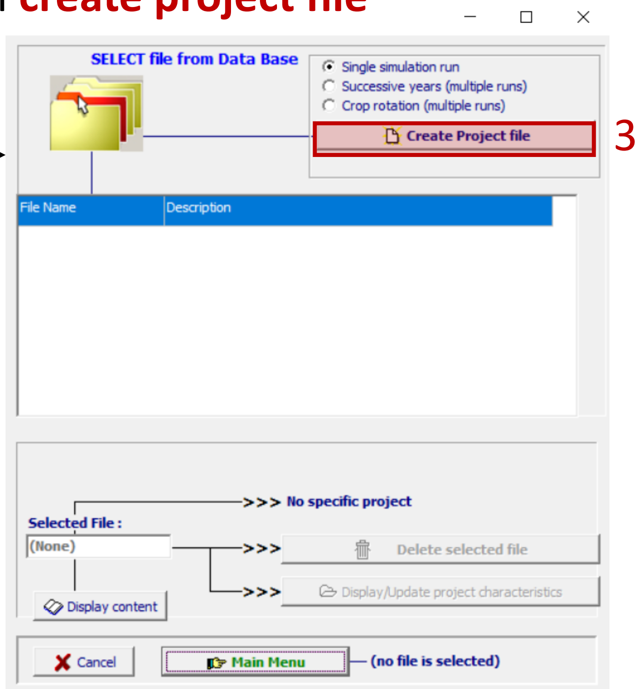
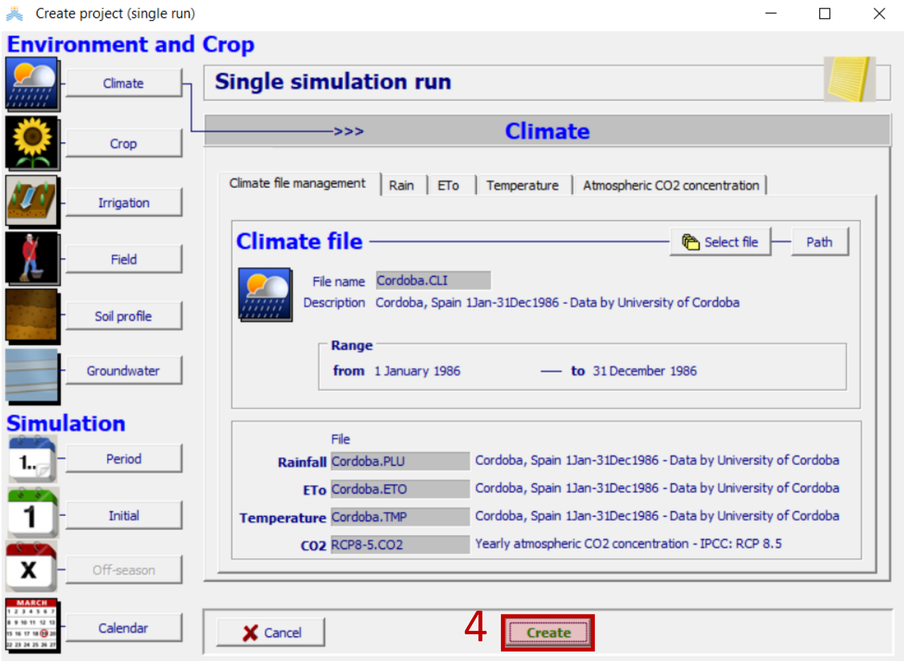
Create project file

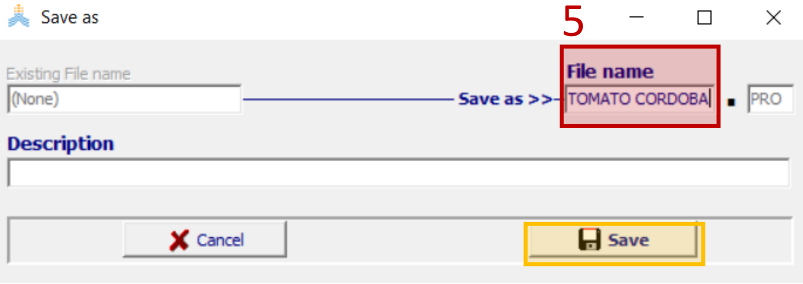
Steps 1-3: click on **project**, then **select/create project file** and click on **create project file**



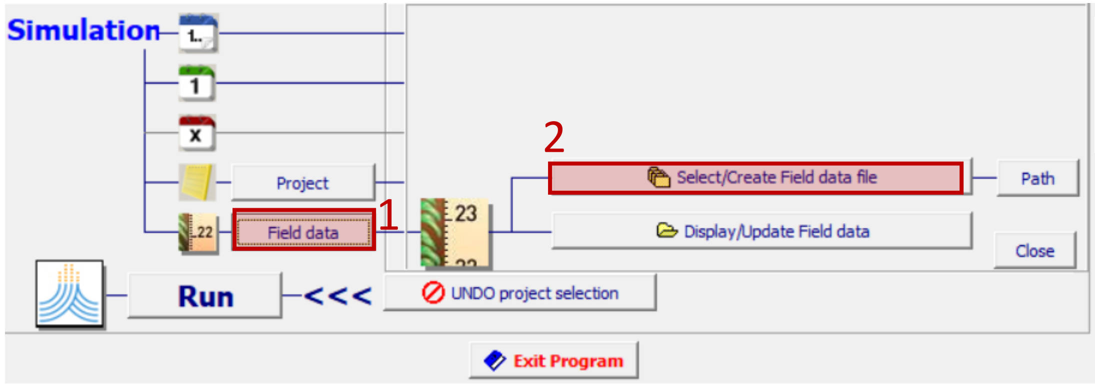


Step 4: click on **create**, name the file as "**tomato Cordoba**" and **save** the file





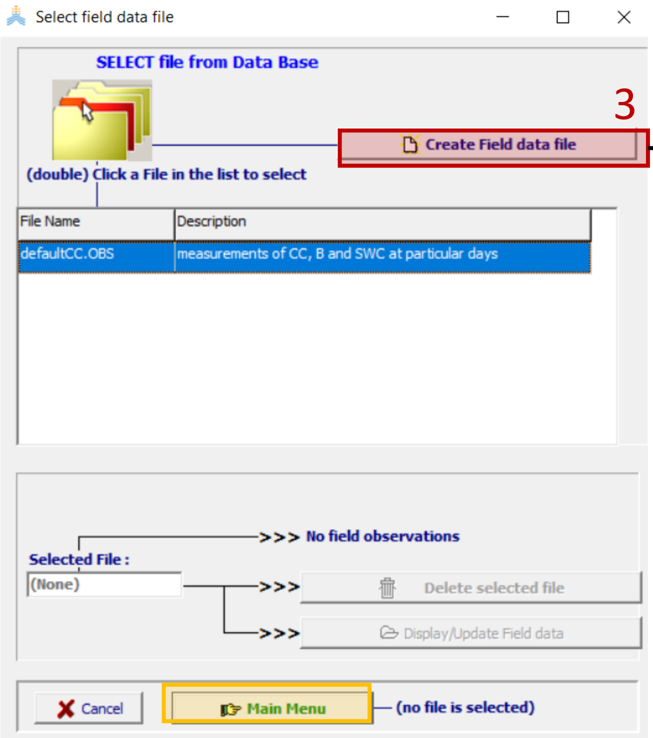
Field data: CC, biomass and SWC observations

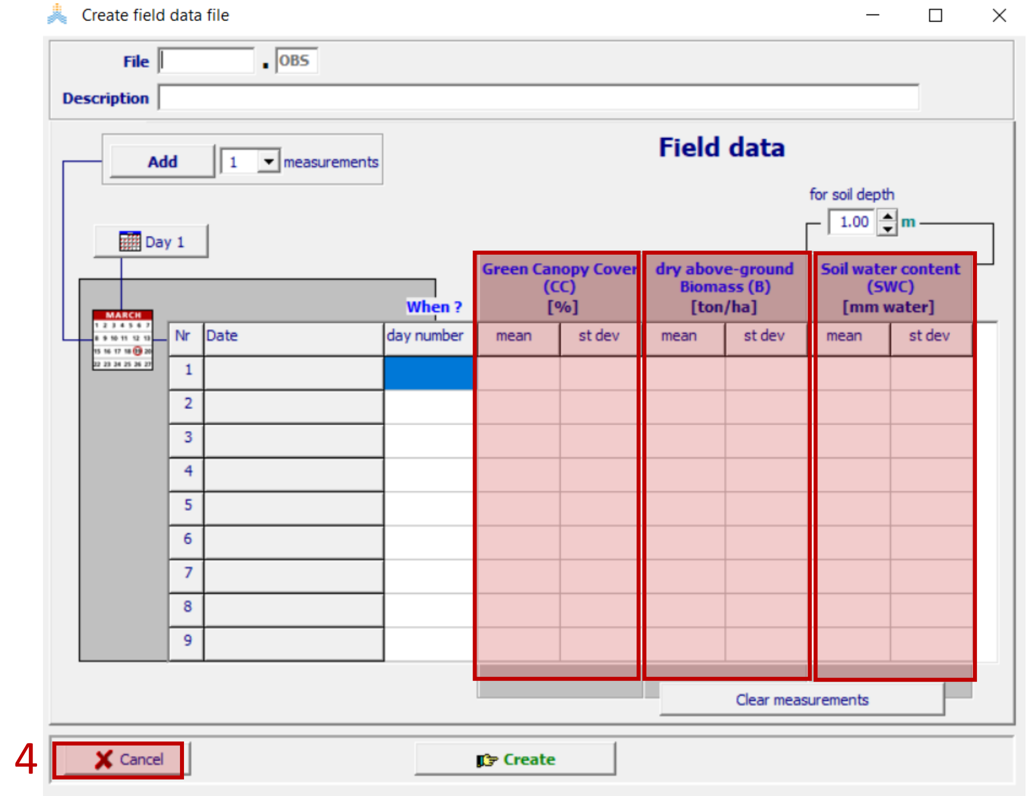


Steps 1-2: click on **field data**, then **select/create project file**

You can introduce field observations (CC, biomass and SWC) to better calibrate the model

Steps 3-4: click on **create field data file**, but then click on **cancel**





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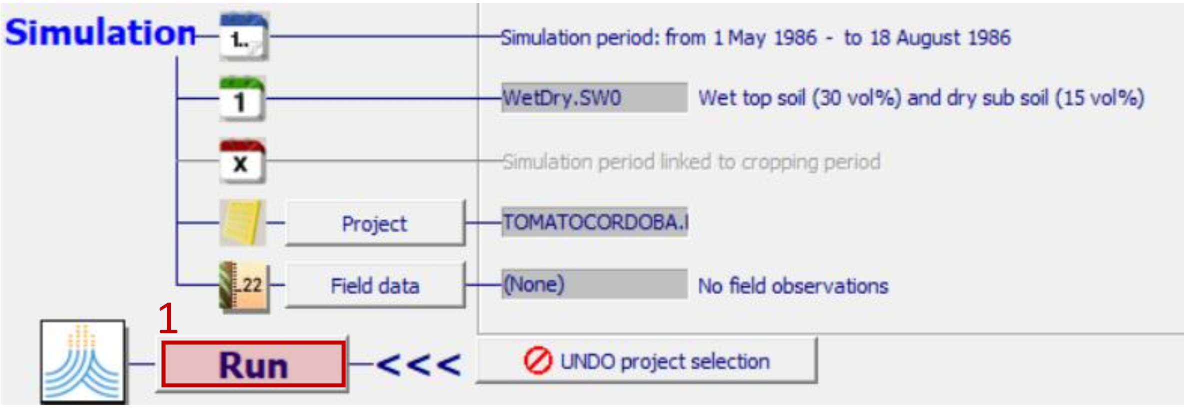
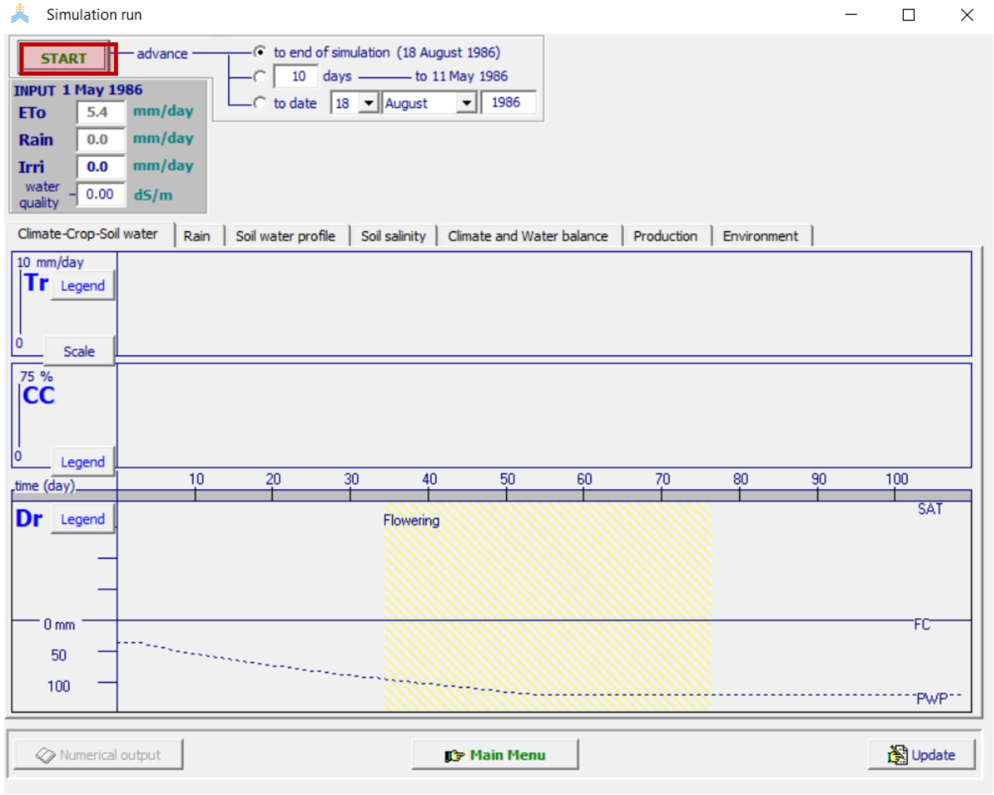
Run the simulations



Step 1: click on **Run**

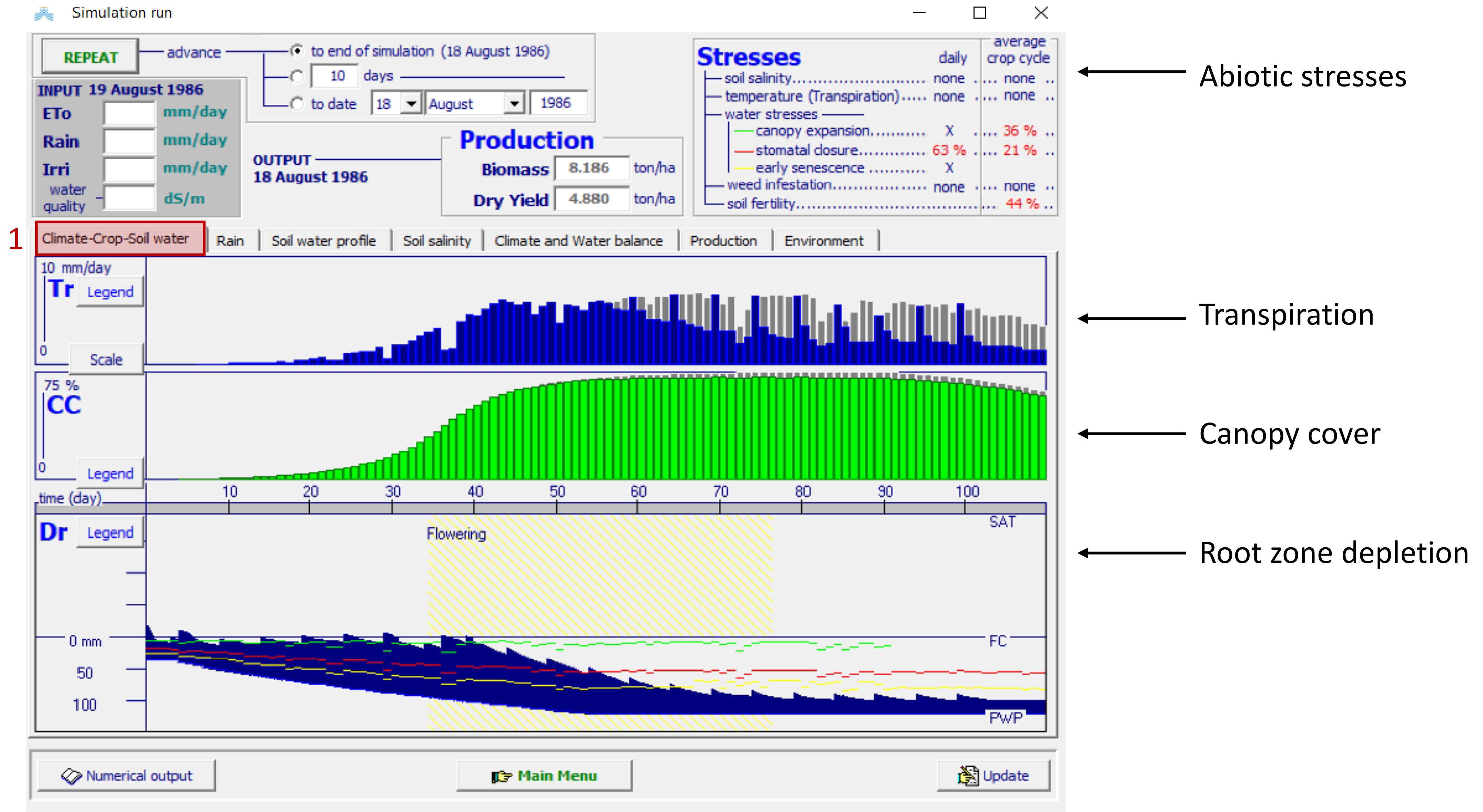
2



Step 2: click on **START**

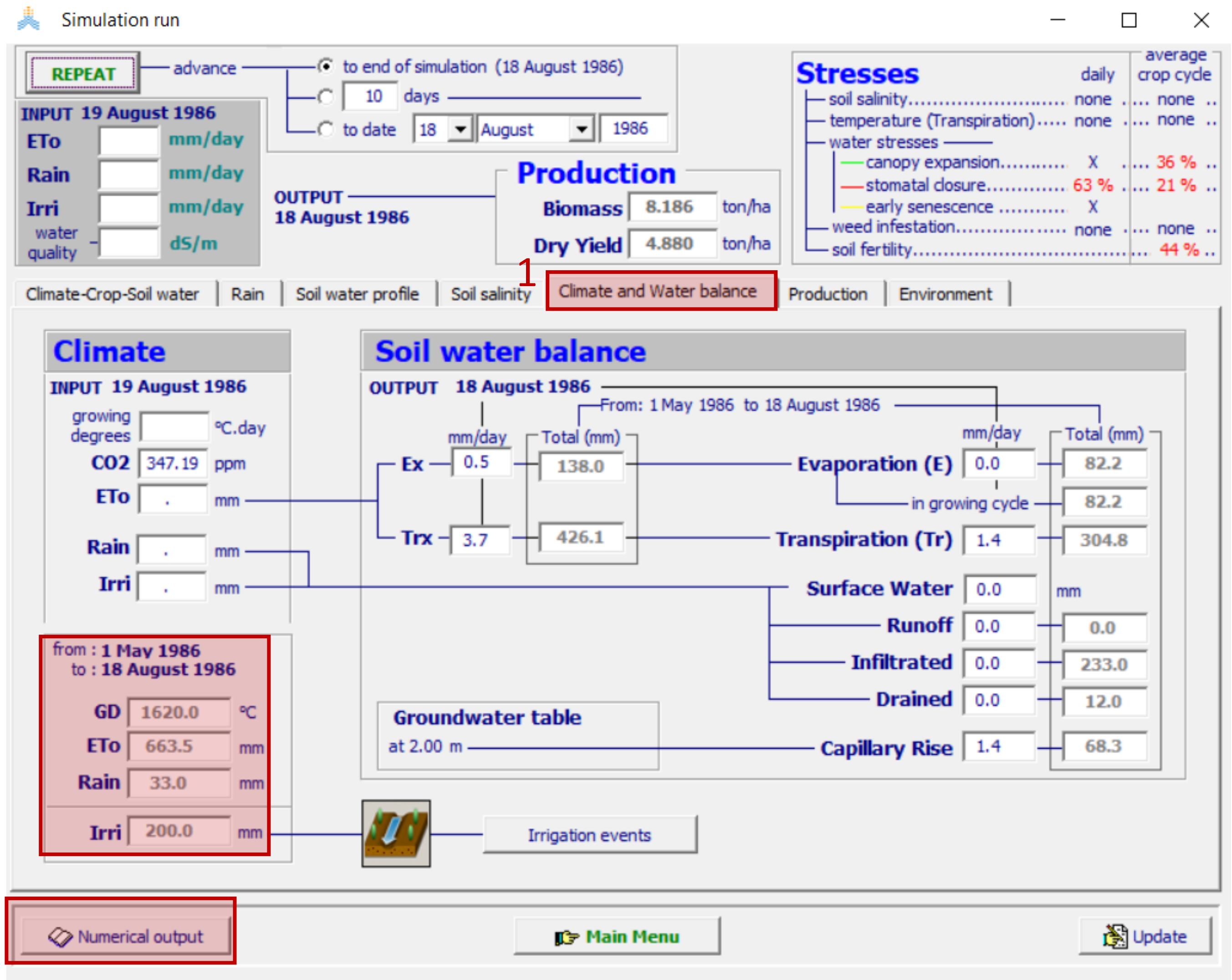
Simulation outputs: production & stresses

Step 1: click on **climate-crop-soil water**



Simulation outputs: climate and water balance

Step 1: click on **Climate and Water Balance**

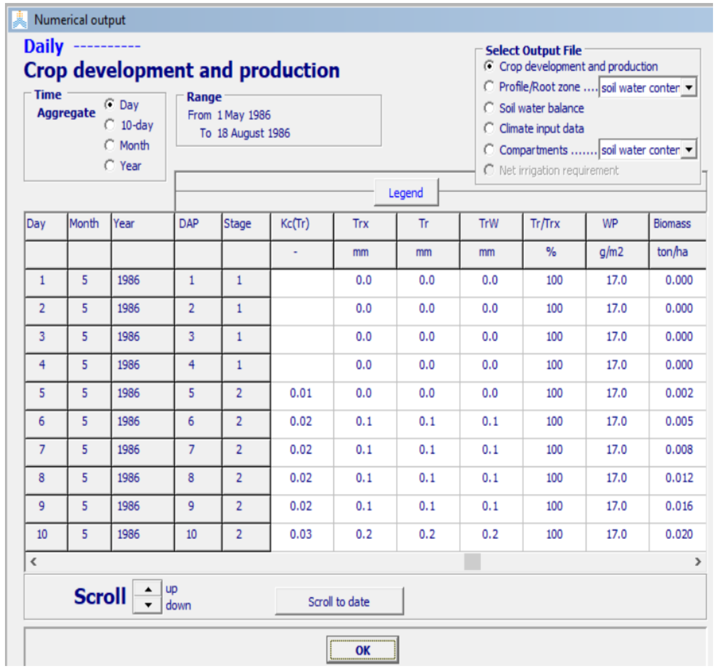


Simulation outputs: crop development & production

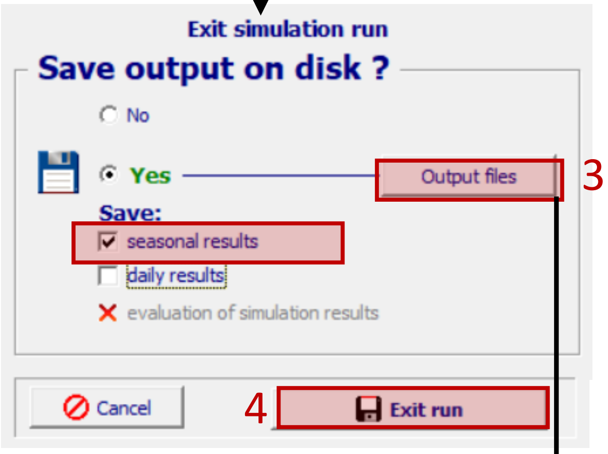
Step 1: click on **Numerical output**

1

2

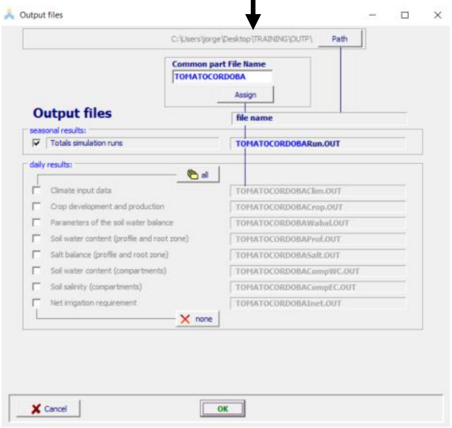


Step 2: click on **Main Menu,** click on **Yes** and save **seasonal results**



Step 3: click on **Output files** and verify the output file. Name the file **"FIRST SIMULATION"**

Step 4: click on **Exit run**



Take away messages

- Crop models are essential tools for improving field management and, thus, key for climate change adaptation.
- Crop models are a simplified representation of the reality.
- The higher the inputs the better the outputs. However, it is more time consuming and a higher processing power is required.
- AquaCrop calculates crop ET in four steps: (i) crop development, (ii) crop transpiration, (iii) biomass production, and (iv) yield formation.
- AquaCrop is divided into 4 modules of input requirements: climate, crop, management and soil

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Useful documents

- AquaCrop training handbook: link
- Reference manual version 7:
  - Chapter 1: link
  - Chapter 2: link
  - Chapter 3: link
  - Chapter 4: link
  - Chapter 5: link
  - Annexes: link
- 43 YouTube tutorials on how to use the model: link
- The AquaCrop model – 10 years of enhancing crop water productivity: link