



**Food and Agriculture
Organization of the
United Nations**



FAO Follow-up AquaCrop training

May 30, 2023

Jorge Alvar-Beltrán – Riccardo Soldan – Andrea Setti

FAO Climate Risk Team (OCB)



Workshop's agenda

30th May 2023 (4 h)

Content	Panelists
-Welcoming remarks	Ala Druta
-Introduction to AquaCrop Model (15 min) -Creation of Project files (1 h) -AquaCrop Plugin (30min)	Jorge Alvar Andrea Setti Riccardo Soldan
COFFEE BREAK (15 min)	
-AquaCrop Plotter: results' visualization and interpretation (1 h) -Q&A session (30min) -Parametrization of AquaCrop	Jorge Alvar Andrea Setti Riccardo Soldan



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Introduction to AquaCrop

May 30, 2023



Content

- Practical applications of crop models
- AquaCrop compared to other models
- How do crop models work?
- AquaCrop: user interface



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:

- understanding crop responses to environmental changes;
- comparing attainable and actual yields;
- identifying constraints to crop production and water productivity;
- developing irrigation schedules for maximizing production;
- studying the effect of climate change and promote agricultural transformation;
- supporting decision-making on water allocations and water related policies;

OCB applications of AquaCrop in Cambodia

The impacts of climate change on rice yields and crop water productivity are assessed over the Northern Tonle Sap Basin in Cambodia by applying the AquaCrop model over the century under two RCPs.

Short (95 days), medium (125 days) and long (155 days) cycle varieties are tested during the wet and dry seasons.

An assessment of different sowing dates and irrigation strategies (fixed and net irrigation during the dry season) elucidated the variation in response to changing environmental conditions.

Assess the impact of climate change on the yields and crop water productivity of tomato, pak choi and yard-long bean cultivated year-round under different irrigated conditions (drip, furrow and net irrigation) in Siem Reap, Cambodia.



CLIMATE CHANGE

Modelling climate change impacts on wet and dry season rice in Cambodia

Jorge Alvar-Beltrán¹  | Riccardo Soldan¹ | Proyuth Ly² | Vang Seng³ | Khema Srung³ | Rodrigo Manzanas⁴  | Gianluca Franceschini¹ | Ana Heureux¹



Contents lists available at ScienceDirect

Agricultural and Forest Meteorology

journal homepage: www.elsevier.com/locate/agrformet

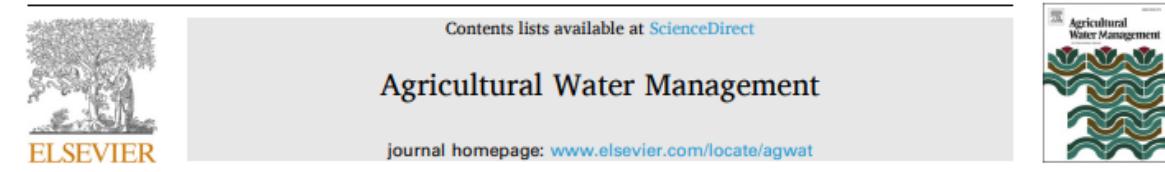


Climate change impacts on irrigated crops in Cambodia

Jorge Alvar-Beltrán^{a,*}, Riccardo Soldan^a, Proyuth Ly^b, Vang Seng^c, Khema Srung^c, Rodrigo Manzanas^d, Gianluca Franceschini^a, Ana Heureux^a

OCB applications of AquaCrop in Pakistan

This study assesses the impacts of two climate change scenarios (RCPs 4.5 and 8.5) on soil evaporation and transpiration rates, crop water productivity, wheat and sugarcane yields over the 21st century under two irrigation schedules (less/more frequent irrigation and higher/lower volume) in six locations along the Sindh and Punjab provinces.



Assessing the impact of climate change on wheat and sugarcane with the AquaCrop model along the Indus River Basin, Pakistan

J. Alvar-Beltrán ^{a,*}, A. Heureux ^a, R. Soldan ^b, R. Manzanas ^c, B. Khan ^a, A. Dalla Marta ^d



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

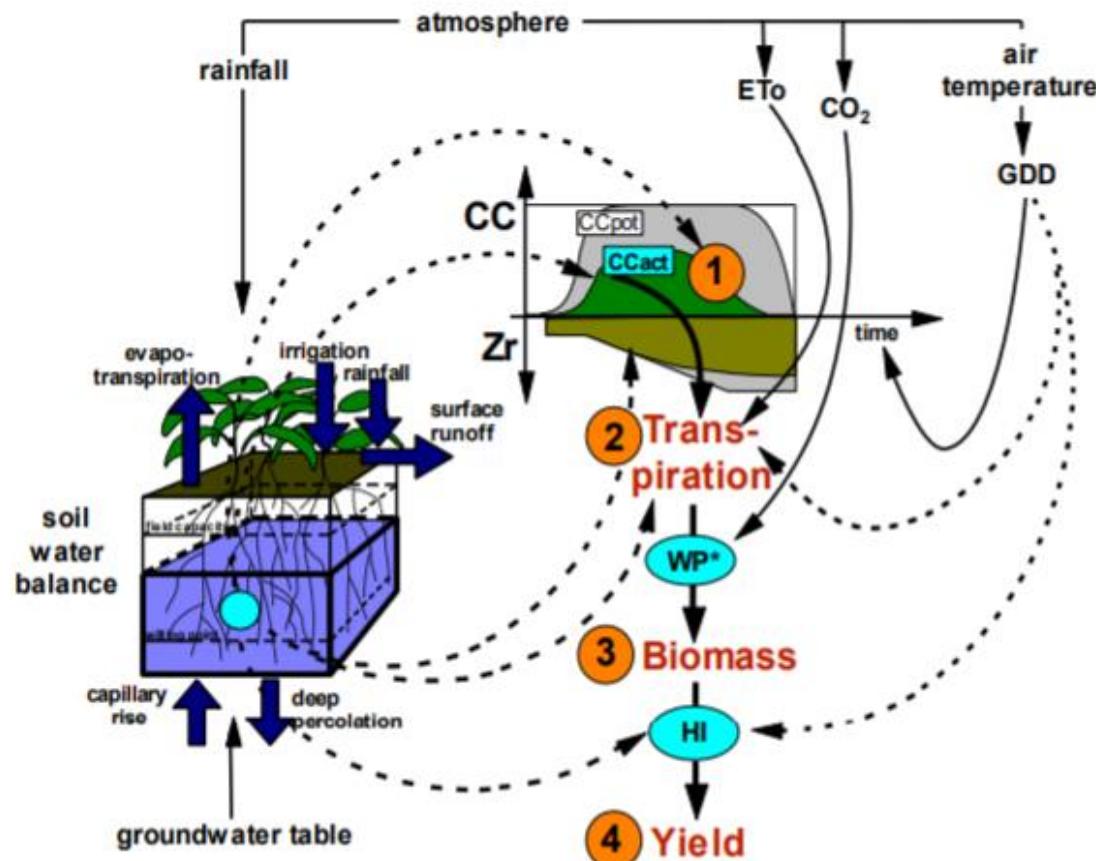
Useful overview of [crop models](#)



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 (GAEZ).
- AquaCrop considers abiotic/biotic stresses (temperature & weeds), while other models do not (WOFOST)
- AquaCrop does not take into account other reducing factors such as pests and diseases

AquaCrop: introduction



AquaCrop simulates crop yield in different steps:

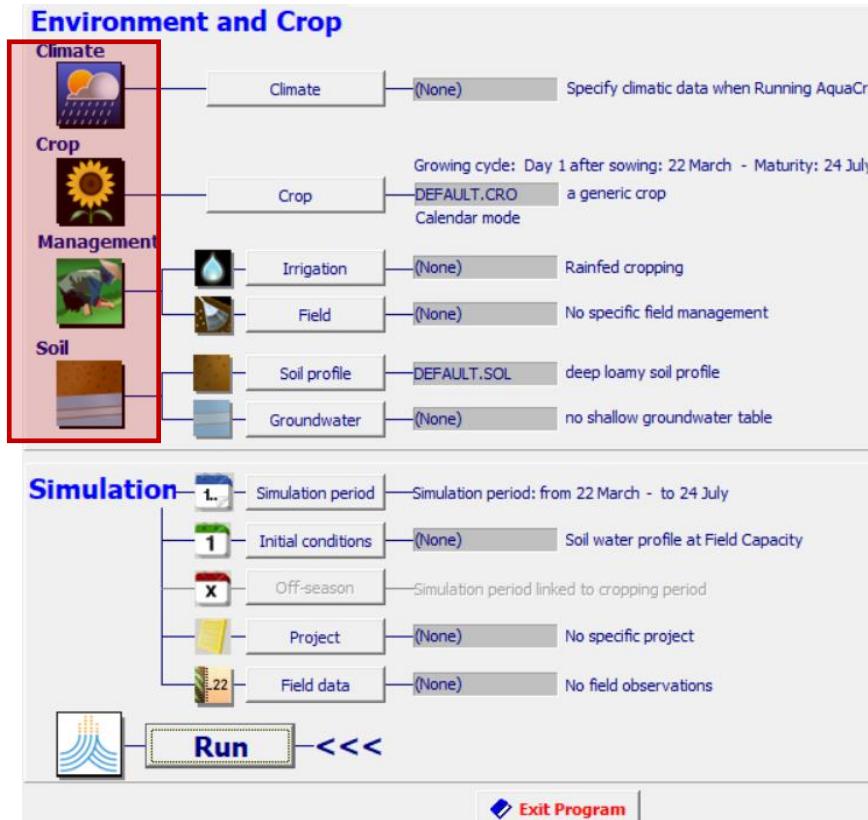
- 1) crop development
- 2) crop transpiration
- 3) biomass production
- 4) yield formation

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

Penman Monteith equation:

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

AquaCrop: the interface



← Weather 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)



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](#)



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Tutorial: how to make project files

May 30, 2023



Objective

Objective: run AquaCrop to see the effect of future climate projection on rainfed maize yields under two emission scenarios (RCPs) in two locations of Moldova (North – Soroca and South - Cahul).

- GCM: MOHC
- RCPs: 2.6 and 8.5
- Crop: Maize
- Locations: Soroca – Cahul

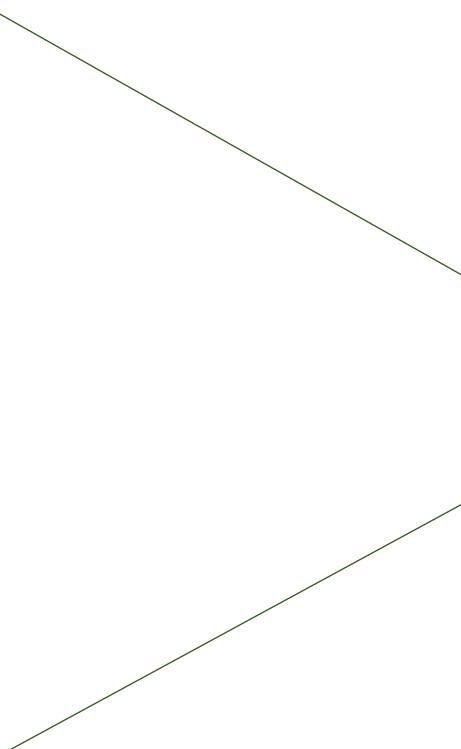
Project File (.PRM) structure

Experimental design

Locations	North (Soroca)
	South (Cahul)
GCM	MOHC
RCPs	2.6
	8.5
Management	Optimal
Crop	Maize

4 Project files

Time series: 119 years -> 1/01/1981 – 31/12/2099



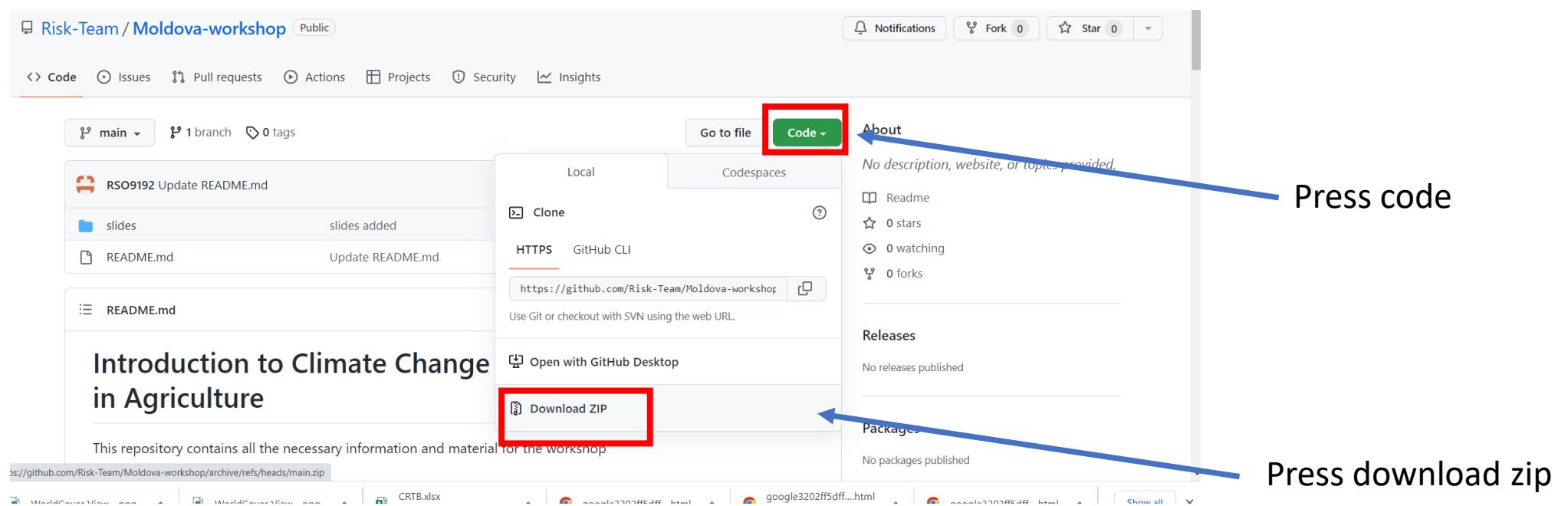
Maize_Short_Cahul_10May_Optimal_26_MOHC

Maize_Short_Cahul_10May_Optimal_85_MOHC

Maize_Short_Soroca_10May_Optimal_26_MOHC

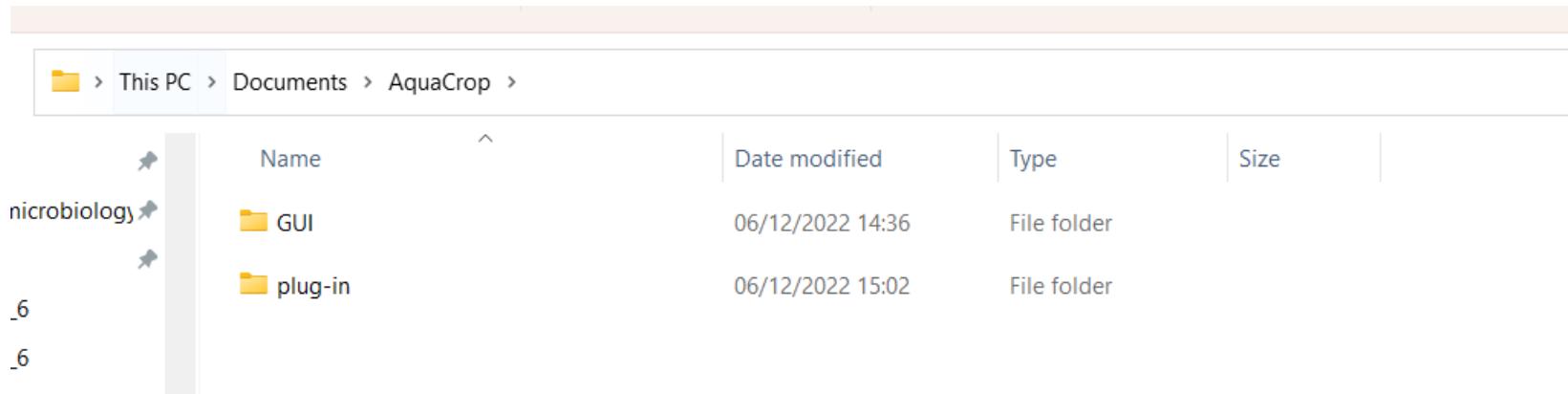
Maize_Short_Soroca_10May_Optimal_85_MOHC

- The link to all material and slides presented in this workshop can be found at <https://github.com/Risk-Team/Moldova-workshop>
- Once you are on the correct page, you can download the whole repository to your local computer (**Desktop**)



In case you do not have AquaCrop installed

- Install [AquaCrop software](#) and [AquaCrop Plugin](#) in the documents folder



Folders location

- Where your data folder should be

The screenshot shows a Windows File Explorer window with the following directory path: This PC > Desktop > Moldova-workshop-main > Moldova-workshop-main. The contents of the folder are listed in a table:

Name	Date modified	Type	Size
slides	07/12/2022 16:07	File folder	
.gitignore	07/12/2022 16:07	GITIGNORE File	1 KB
README.md	07/12/2022 16:07	MD File	9 KB

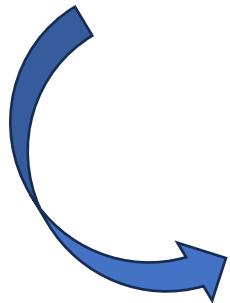
- Where your AquaCrop installations should be

The screenshot shows a Windows File Explorer window with the following directory path: This PC > Documents > AquaCrop. The contents of the folder are listed in a table:

Name	Date modified	Type	Size
GUI	06/12/2022 14:36	File folder	
plug-in	06/12/2022 15:02	File folder	

In case you do not have AquaCrop installed

- *To run the plugin the text file DailyResults.SIM is needed to be in the “SIMUL” folder of the plugin. Download and paste [this file](#).



C:\> FAO > Moldova > aquacrop-7.0-x86_64-windows >			
Nome	Ultima modifica	Tipo	Dimensione
LIST	17/05/2023 19:08	Cartella di file	
OUTP	16/05/2023 16:11	Cartella di file	
PARAM	17/08/2022 09:22	Cartella di file	
SIMUL	16/05/2023 12:53	Cartella di file	
aquacrop.exe	16/05/2023 12:19	Applicazione	1.740 KB
AUTHORS.md	16/05/2023 12:19	File MD	1 KB
LICENSE	16/05/2023 12:19	File	2 KB

Upload of the files

Go to the downloaded folders and **remove all the content** of your personal “DATA” folder.

Follow the shown path:

Nome	Ultima modifica
aquacrop-7.0-x86_64-windows	16/05/2023 12:19
1 GUI_AC7	18/05/2023 11:28

... > FAO > Moldova > GUI_AC7 >

Nome	Ultima modifica
2 AquaCropV70No17082022	17/05/2023 17:37

3	DATA	17/05/2023 17:27
	IMPORT	20/04/2023 11:06
	OBS	20/04/2023 11:06
	OUTP	20/04/2023 11:06
	SIMUL	17/05/2023 17:27
	_DEISREG.ISR	20/04/2023 11:06
	_ISREG32.DLL	20/04/2023 11:06
	AquaCrop.exe	20/04/2023 11:06
	AquaCrop.ico	20/04/2023 11:06
	DelsL1.isu	20/04/2023 11:06

In case you would like to reinitialize the AquaCrop default data you can find it in the “Data with default AquaCrop files” folder at the following link :
[https://github.com/Risk-Team/Moldova-workshop/tree/main/material for training sessions](https://github.com/Risk-Team/Moldova-workshop/tree/main/material_for_training_sessions)

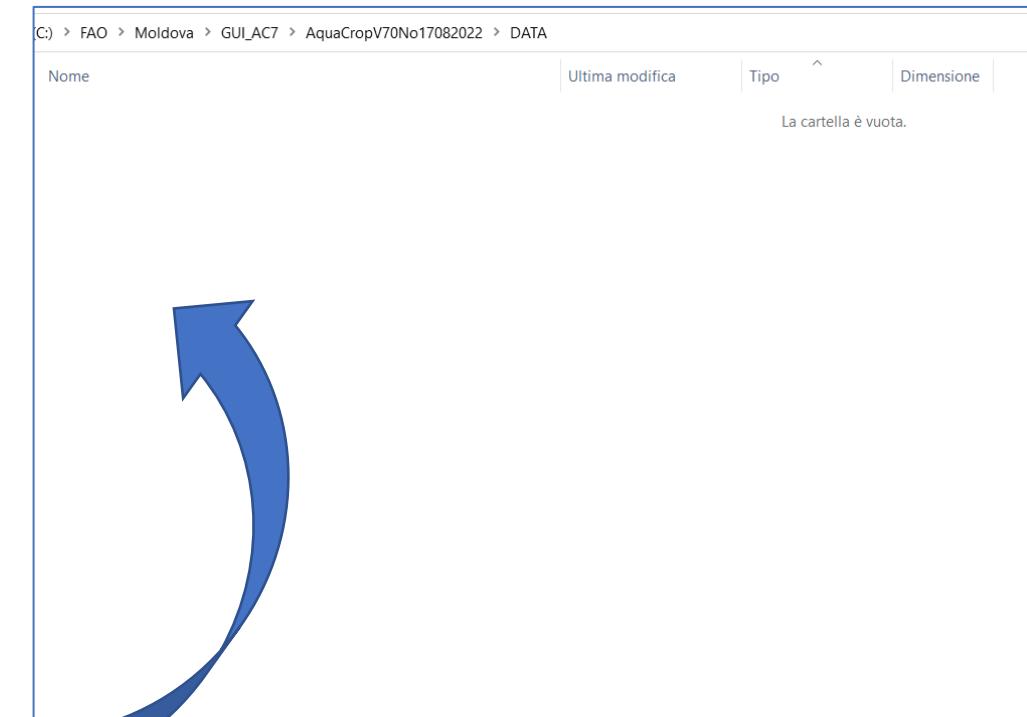
Upload of the files

Copy and paste the “Follow_up” folder content to your personal **DATA folder**.

[Here](#) you can find the "Follow_up" data folder content

Nome	Ultima modifica	Tipo	Dimensione
10May.CAL	20/04/2023 15:28	File CAL	1 KB
Cahul_MOHC-HadGEM2-ES_rcp26.CLI	11/11/2022 17:12	File CLI	1 KB
Cahul_MOHC-HadGEM2-ES_rcp85.CLI	11/11/2022 17:12	File CLI	1 KB
Soroca_MOHC-HadGEM2-ES_rcp26.CLI	11/11/2022 17:12	File CLI	1 KB
Soroca_MOHC-HadGEM2-ES_rcp85.CLI	11/11/2022 17:12	File CLI	1 KB
RCP2-6.CO2	21/10/2022 16:02	File CO2	3 KB
RCP4-5.CO2	21/10/2022 16:02	File CO2	3 KB
RCP6-0.CO2	21/10/2022 16:02	File CO2	3 KB
RCP8-5.CO2	21/10/2022 16:02	File CO2	3 KB
SSP1_1.9.CO2	21/10/2022 16:02	File CO2	2 KB
SSP1_2.6.CO2	21/10/2022 16:02	File CO2	2 KB
SSP2_4.5.CO2	21/10/2022 16:02	File CO2	2 KB
SSP3_7.0.CO2	21/10/2022 16:02	File CO2	2 KB
SSP5_8.5.CO2	21/10/2022 16:02	File CO2	2 KB
Maize-short.CRO	03/05/2023 16:31	File CRO	7 KB
Optimal.MAN	16/05/2023 14:48	File MAN	2 KB
Cahul_MOHC-HadGEM2-ES_rcp26.PLU	11/11/2022 17:12	File PLU	510 KB
Cahul_MOHC-HadGEM2-ES_rcp85.PLU	11/11/2022 17:12	File PLU	510 KB
Soroca_MOHC-HadGEM2-ES_rcp26.PLU	11/11/2022 17:12	File PLU	510 KB
Soroca_MOHC-HadGEM2-ES_rcp85.PLU	11/11/2022 17:12	File PLU	510 KB
North_South.SOL	27/10/2022 15:04	File SOL	1 KB
Cahul_MOHC-HadGEM2-ES_rcp26.TNX	11/11/2022 17:12	File TNX	935 KB
Cahul_MOHC-HadGEM2-ES_rcp85.TNX	11/11/2022 17:12	File TNX	935 KB
Soroca_MOHC-HadGEM2-ES_rcp26.TNX	11/11/2022 17:12	File TNX	935 KB
Soroca_MOHC-HadGEM2-ES_rcp85.TNX	11/11/2022 17:12	File TNX	935 KB
Cahul_MOHC-HadGEM2-ES_rcp26.ETO	11/11/2022 17:12	WPS Spreadsheets...	510 KB
Cahul_MOHC-HadGEM2-ES_rcp85.ETO	11/11/2022 17:12	WPS Spreadsheets...	510 KB

Personal DATA folder



CTRL + C - CTRL + V

Creation of the project files (.PRM)

1. Open AquaCrop software (double click on “AquaCrop.exe”)

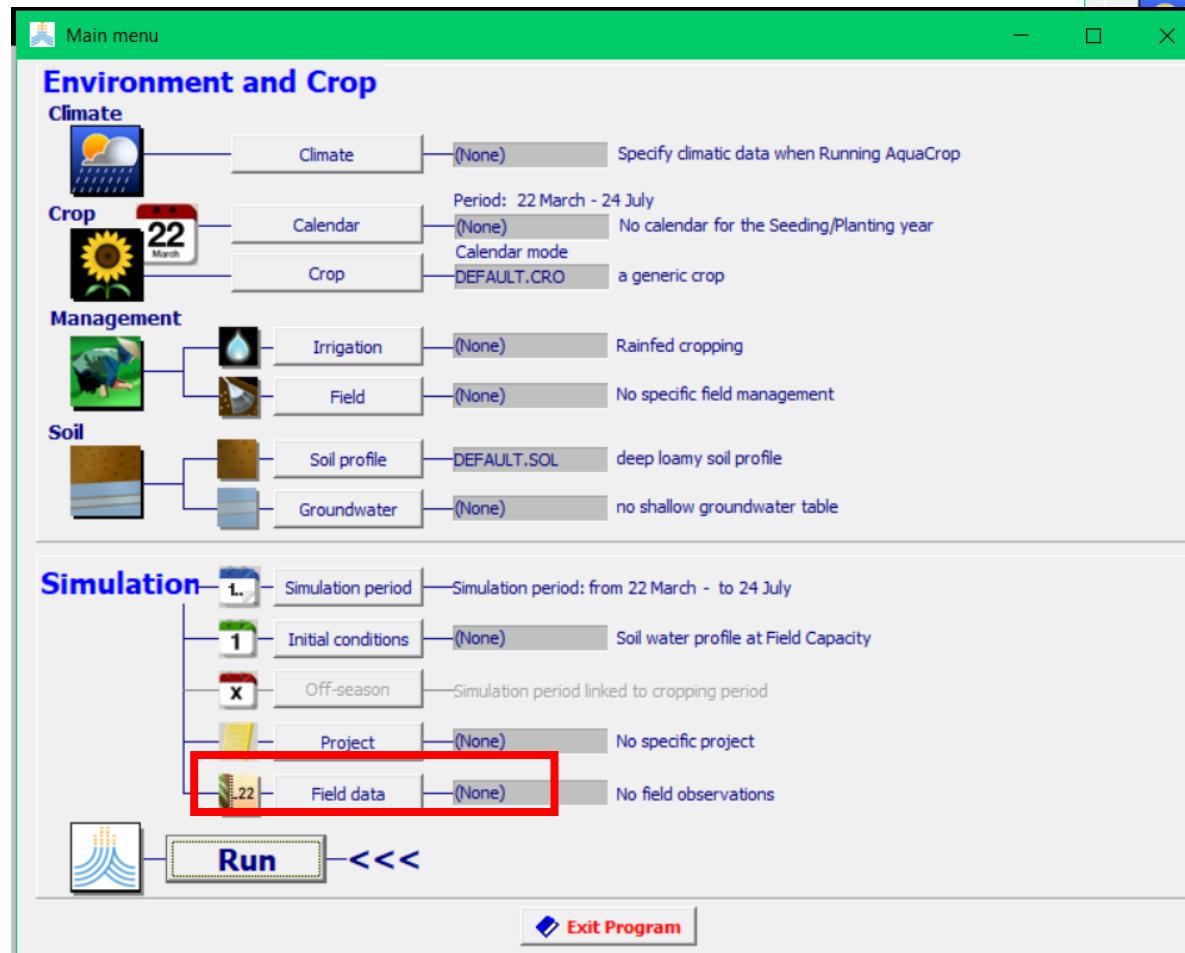
DATA	17/05/2023 17:27
IMPORT	20/04/2023 11:06
OBS	20/04/2023 11:06
OUTP	20/04/2023 11:06
SIMUL	17/05/2023 17:27
_DEISREG.ISR	20/04/2023 11:06
ISREG32.DLL	20/04/2023 11:06
AquaCrop.exe	20/04/2023 11:06
AquaCrop.ico	20/04/2023 11:06
DelsL1.isu	20/04/2023 11:06

2. Select language and press Start

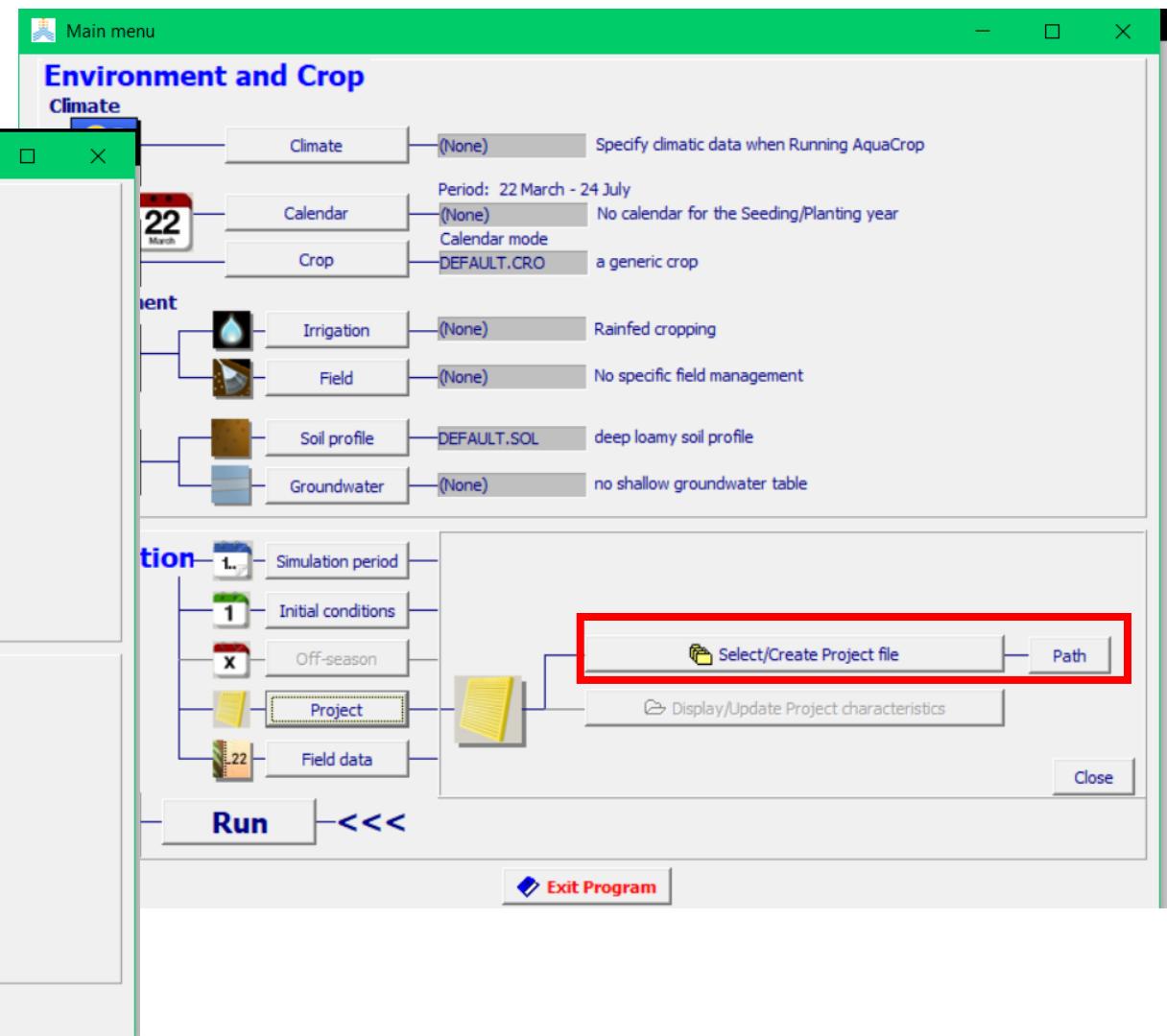


Creation of the project files (.PRM)

Press the “Project” button to create the project file

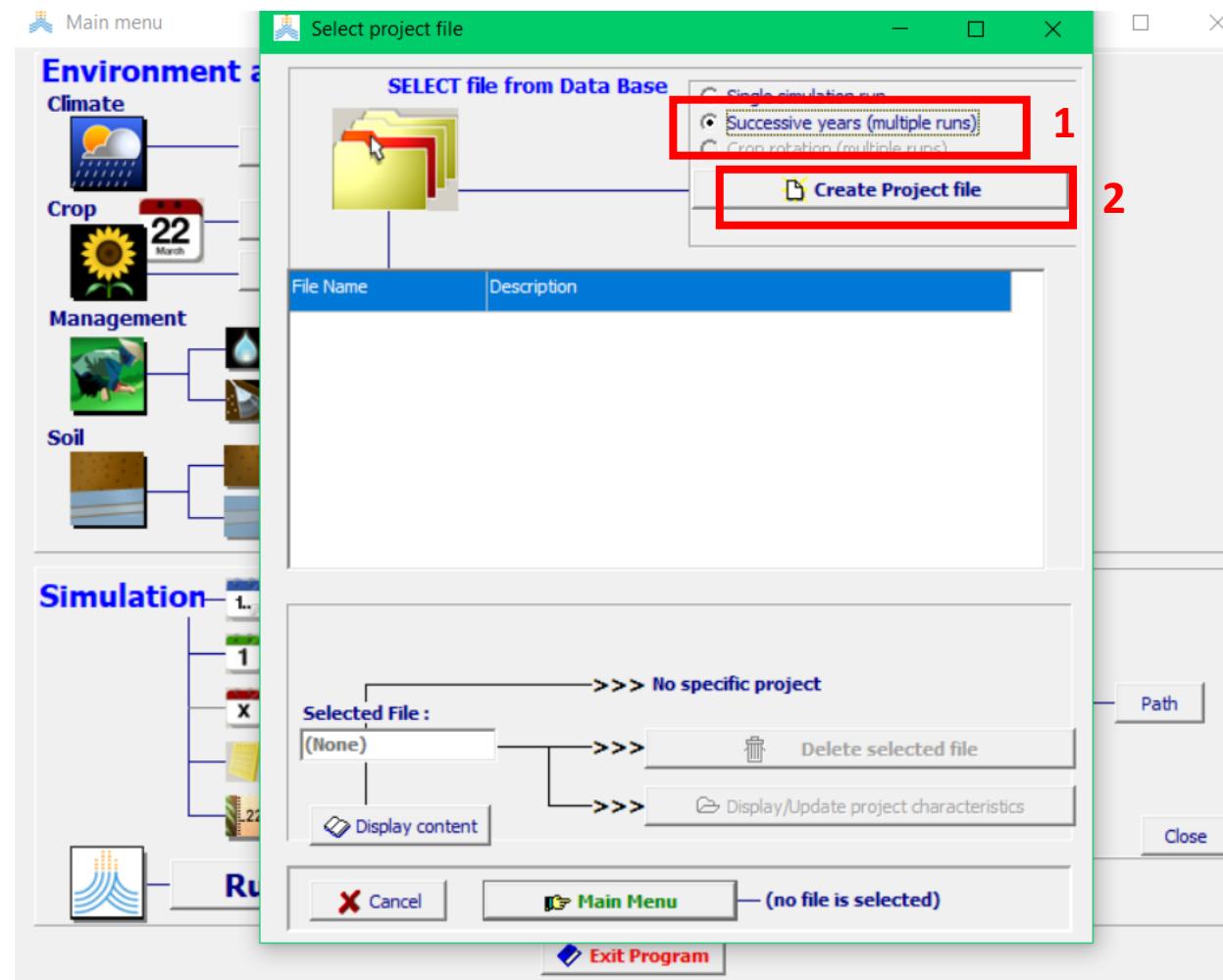


Click on “Select/Create Project file”



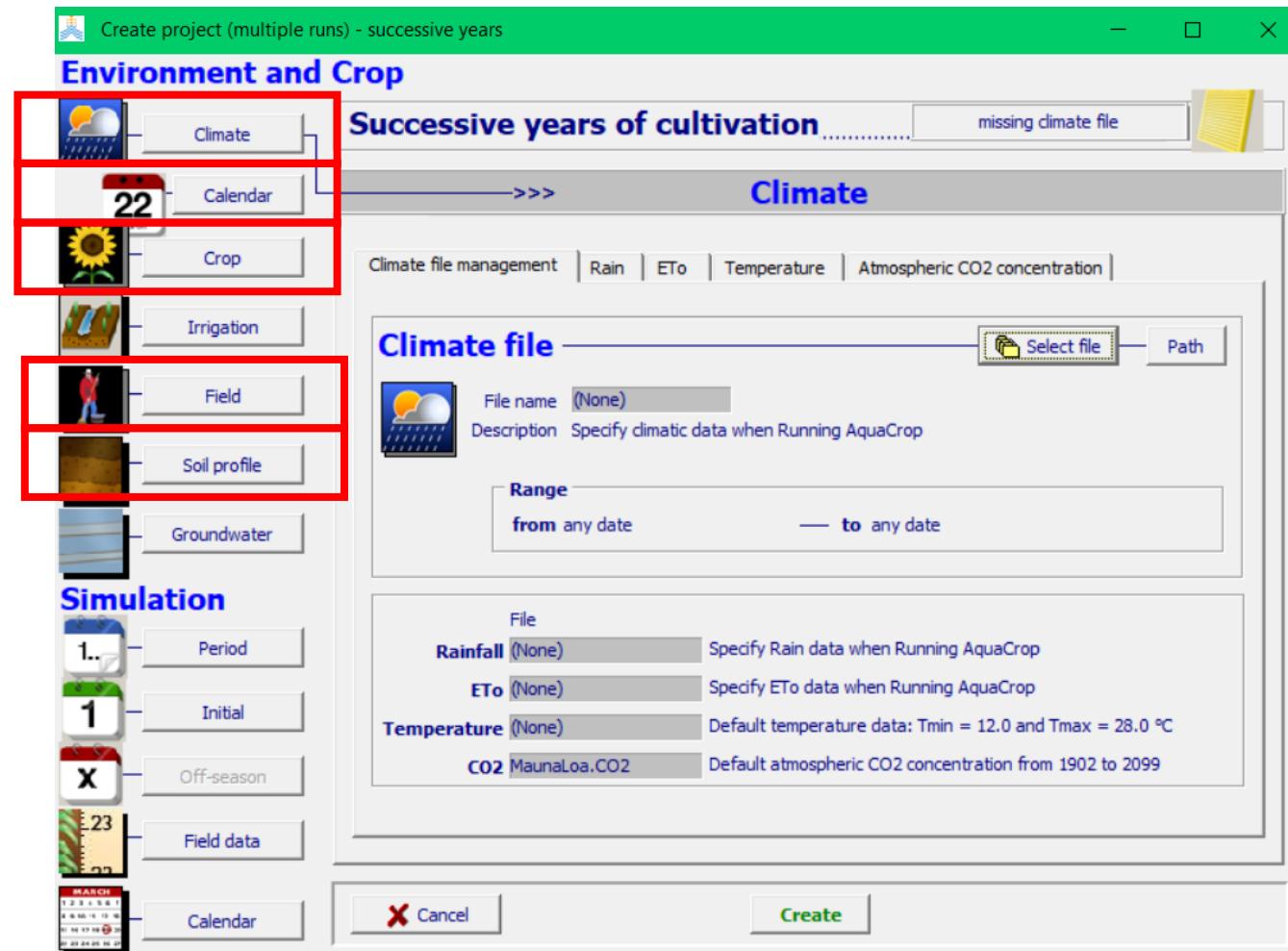
Creation of the project files (.PRM)

1. Press “successive years (multiple runs)” since we are using a climate file with data from 2030 to 2099
2. Click the below “create project file” button



Creation of the project files (.PRM)

One by one, we will go through each of the highlighted components of the menu and select the correct files to create the PRM file.

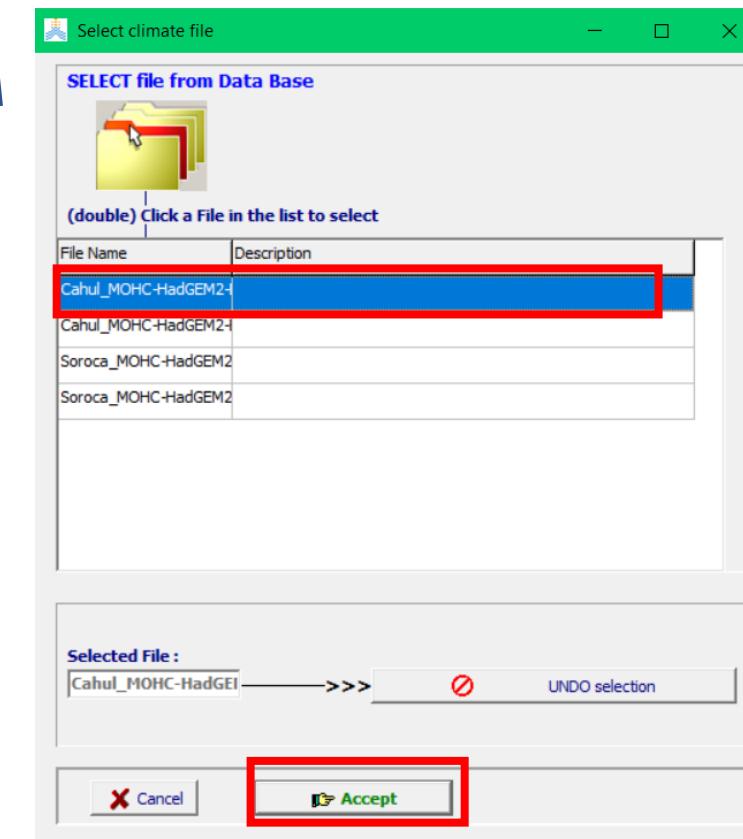
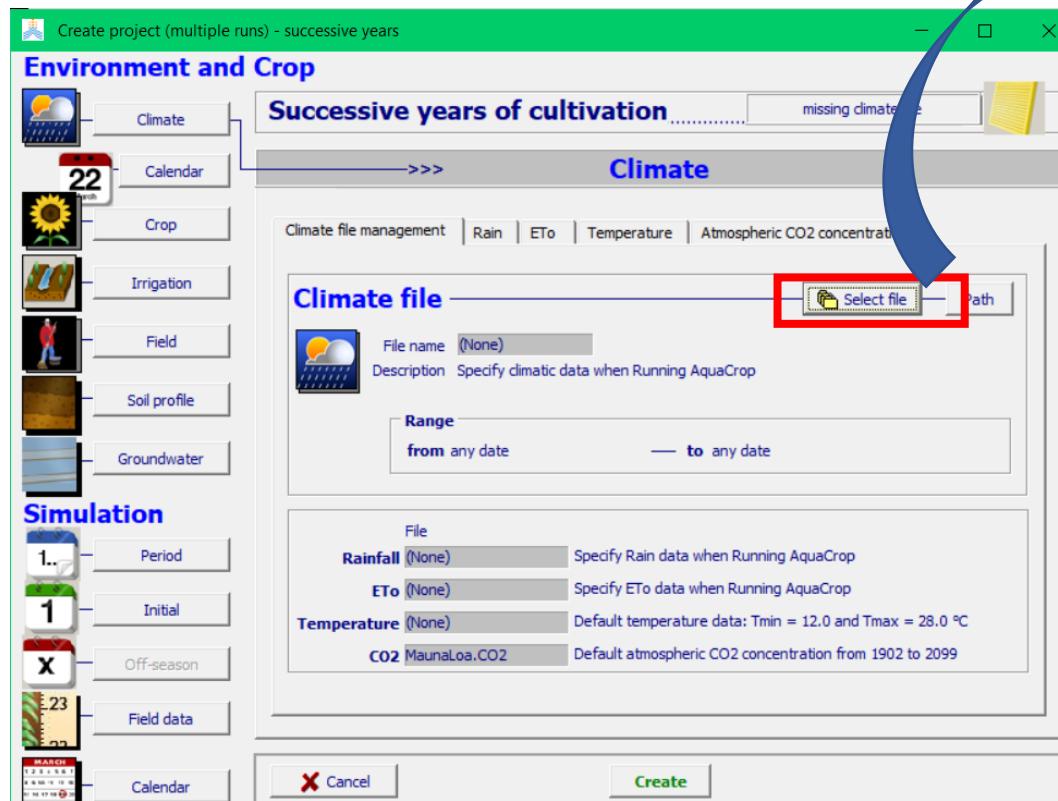


Climate module

1. Climate file

Select the first file “Cahul_MOHC-HadGEM2-”
Press the “Accept” button

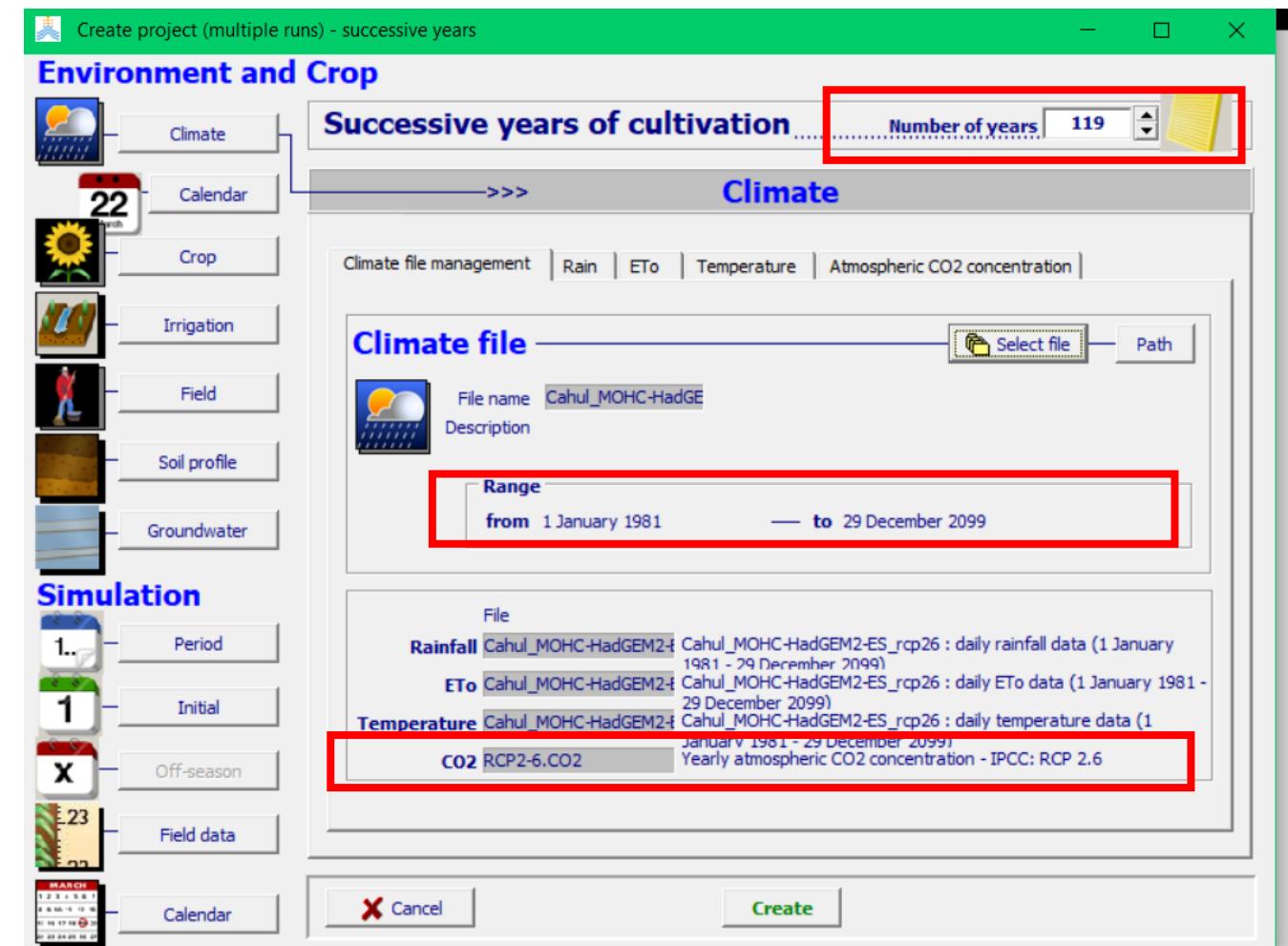
Press “Select file”



Creation of the project files (.PRM)

Here you can check the content of the selected file:

- **119 years:** 1 January 1981 to 29 December 2099
- **MOHC:** Global Climate Model
- **RCP2.6:** representative concentration pathway (2.6 - low emission scenario)

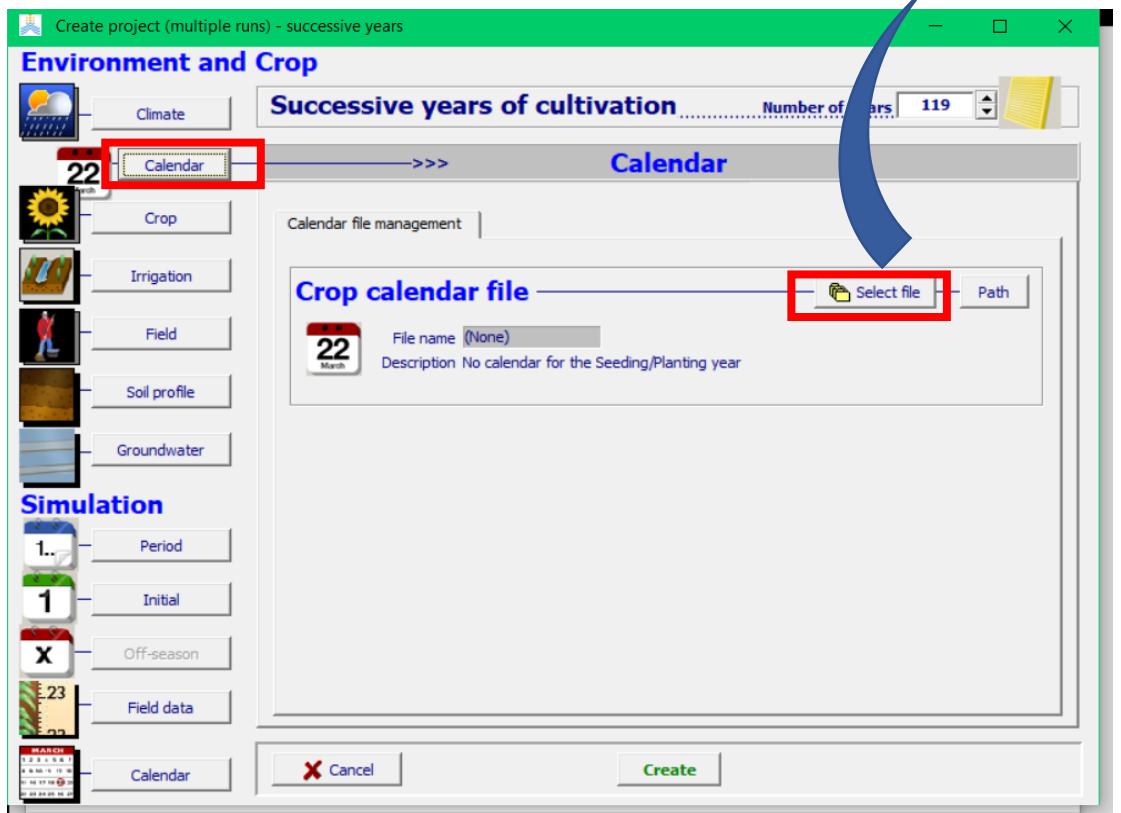


Calendar module

2. Calendar file

Select the file “10May”
Press the “Accept” button

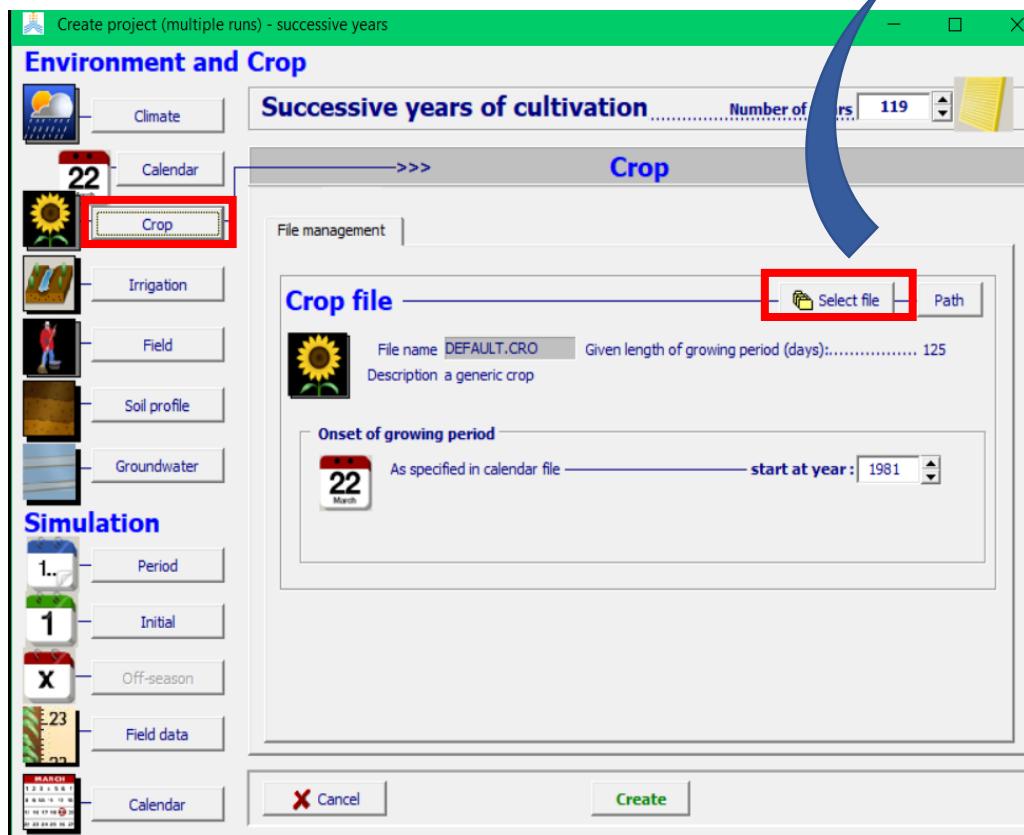
Press “Select file”



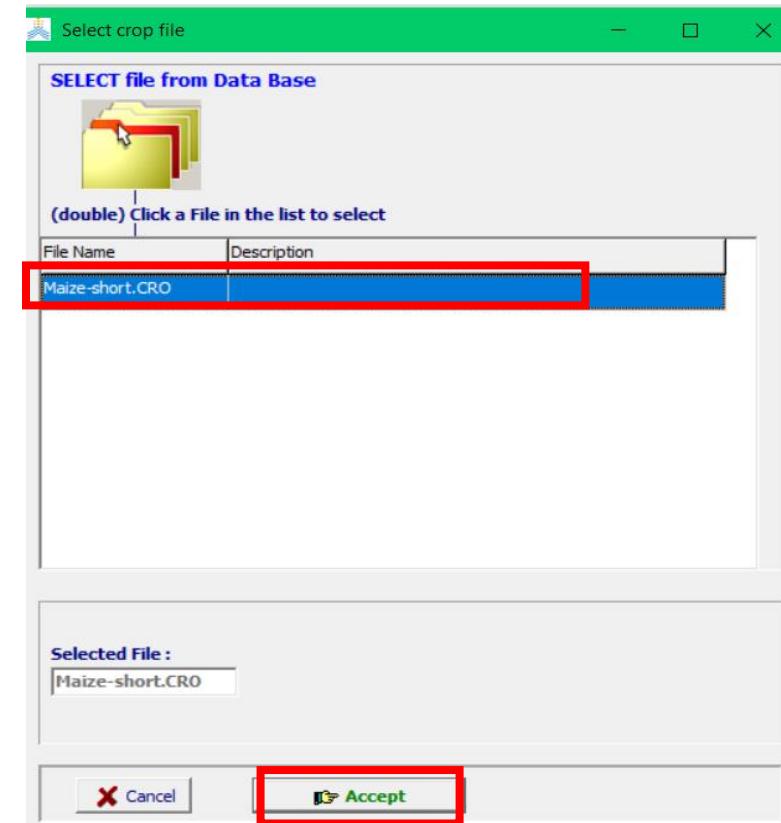
Crop module

3. Crop file

Press “Select file”



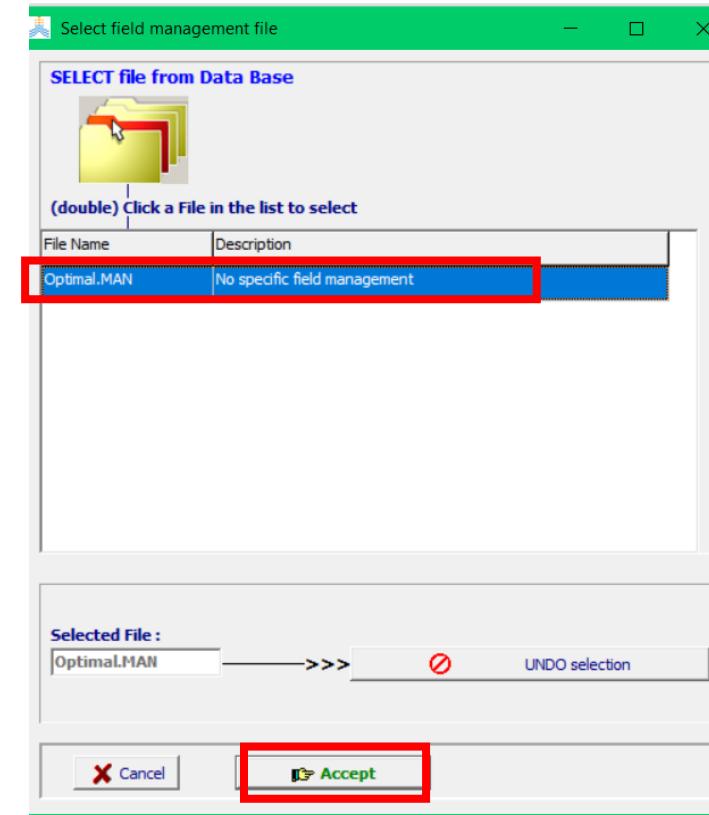
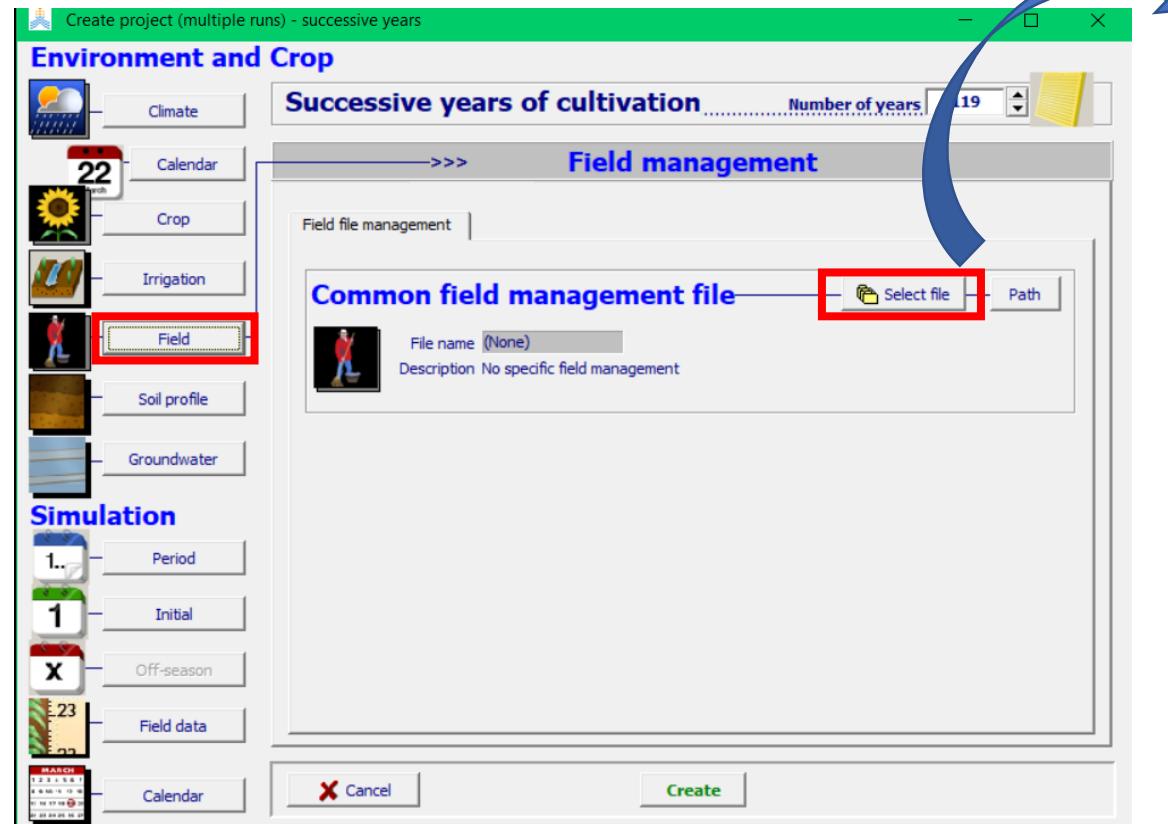
Select the file “Maize-Short”
Press the “Accept” button



4. Field management file

Select the file “Optimal”
Press the “Accept” button

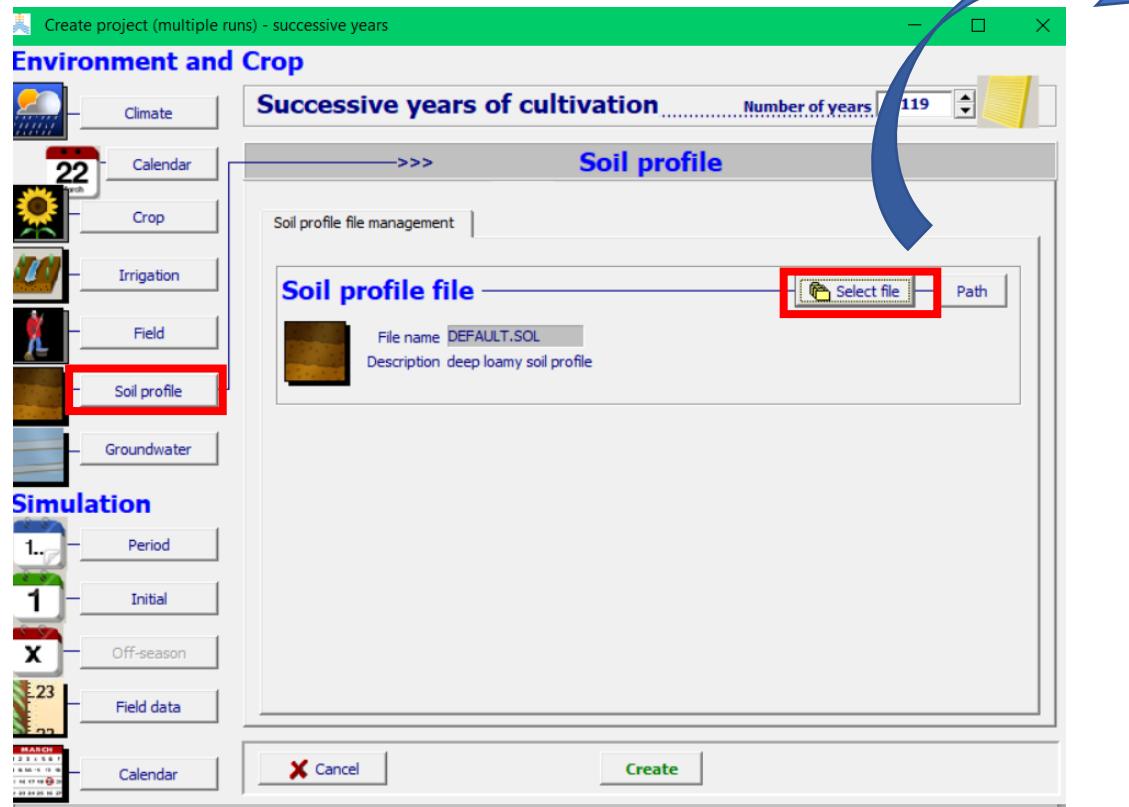
Press “Select file”



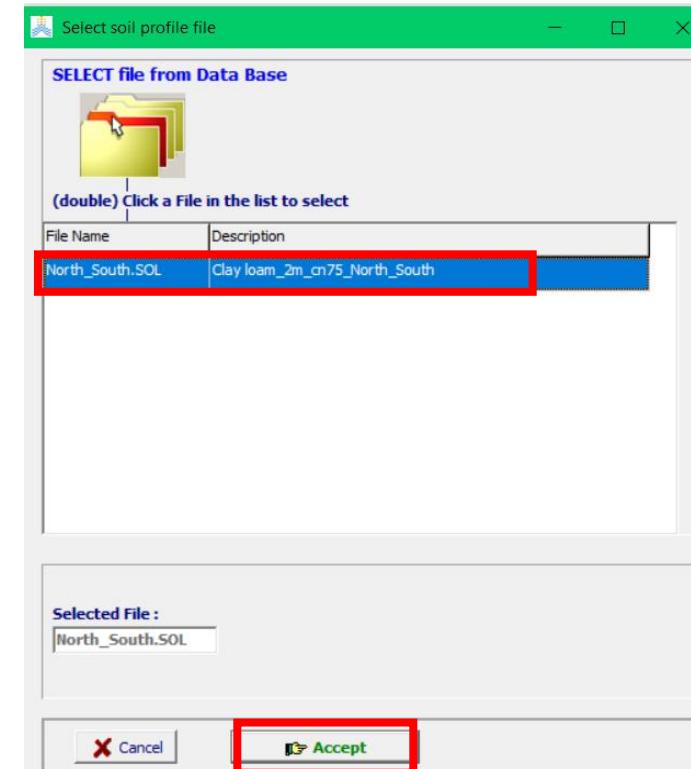
Soil module

5. Soil file

Press “Select file”

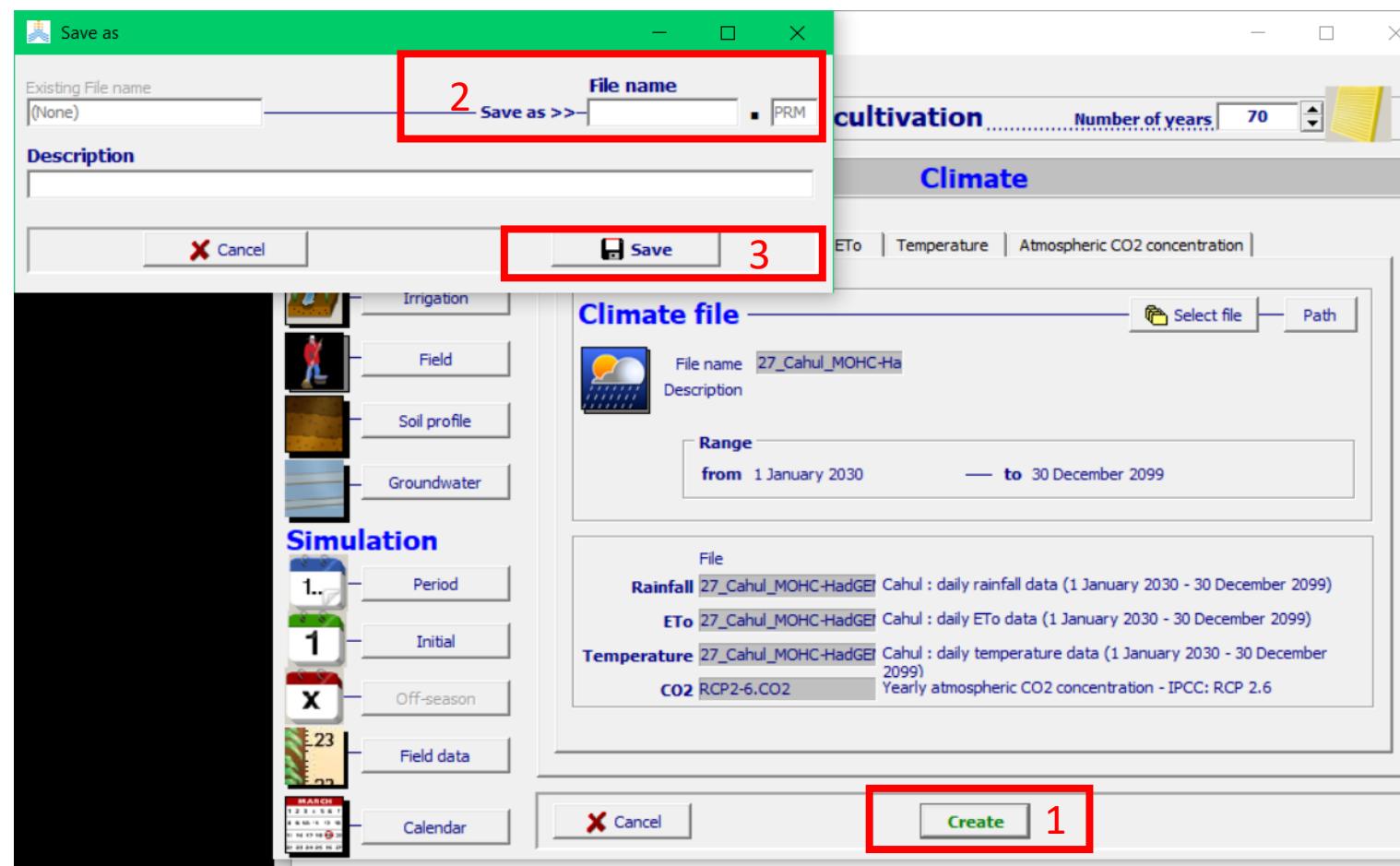


Select the file “North_South”
Press the “Accept” button



Saving project files (.PRM)

1. Press “CREATE”
2. Fill the “File name” with the name: **Maize_Short_Cahul_10May_Optimal_26_MOHC**
3. Press the “Save” button





Creation of new project files (.PRM)

HOW TO CREATE OTHER PROJECT FILES
WITH DIFFERENT VARIABLES

Creation of new project files (.PRM)

Variables scheme

Maize_Short_Cahul_10May_Optimal_26_MOHC



Maize_Short_Cahul_10May_Optimal_85_MOHC



Step →

Change the Climate file to Cahul RCP 8.5

Maize_Short_Soroca_10May_Optimal_26_MOHC



Step →

Change the Climate file to Soroca RCP 2.6

Maize_Short_Soroca_10May_Optimal_85_MOHC

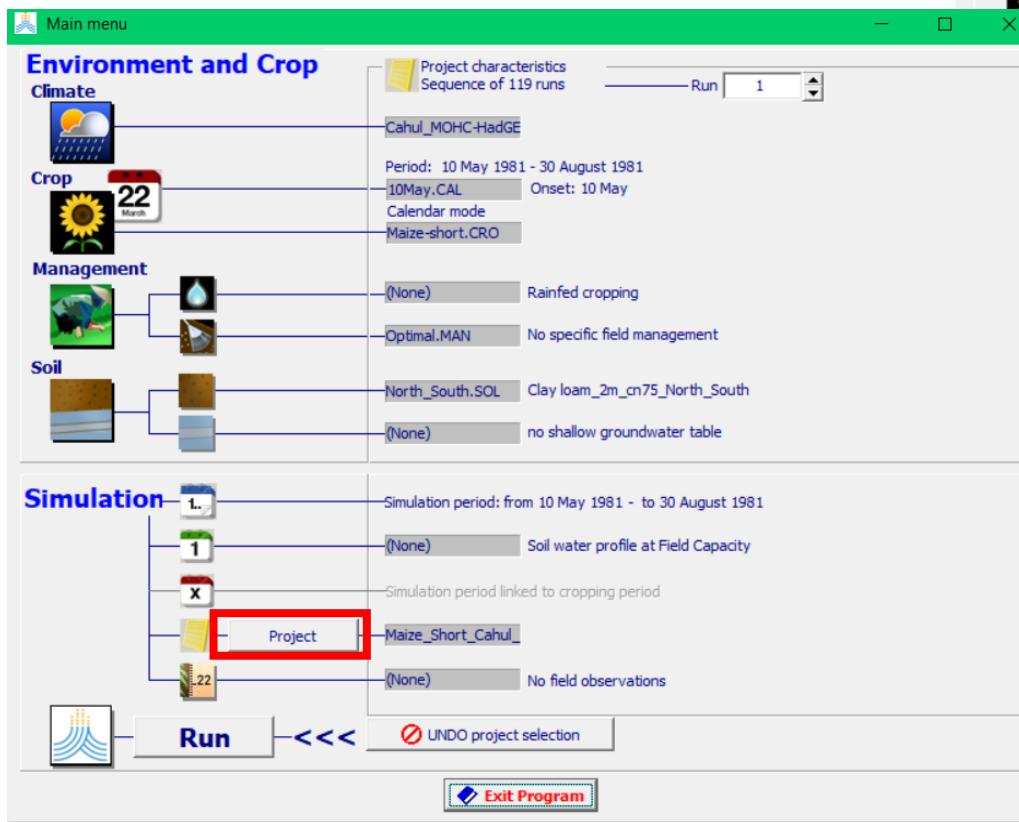


Step →

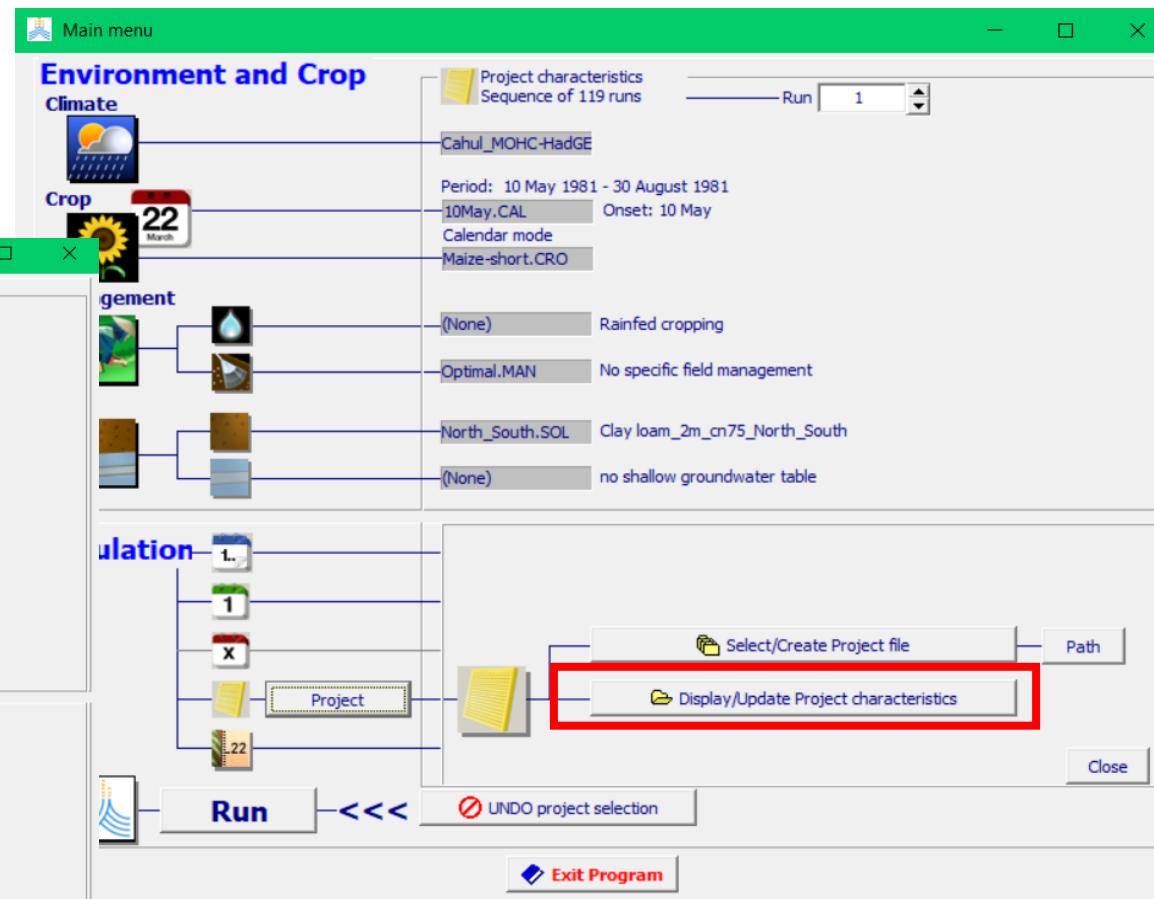
Change the Climate file to Soroca RCP8.5

Creation of new project files (.PRM)

1. Press “Project” button

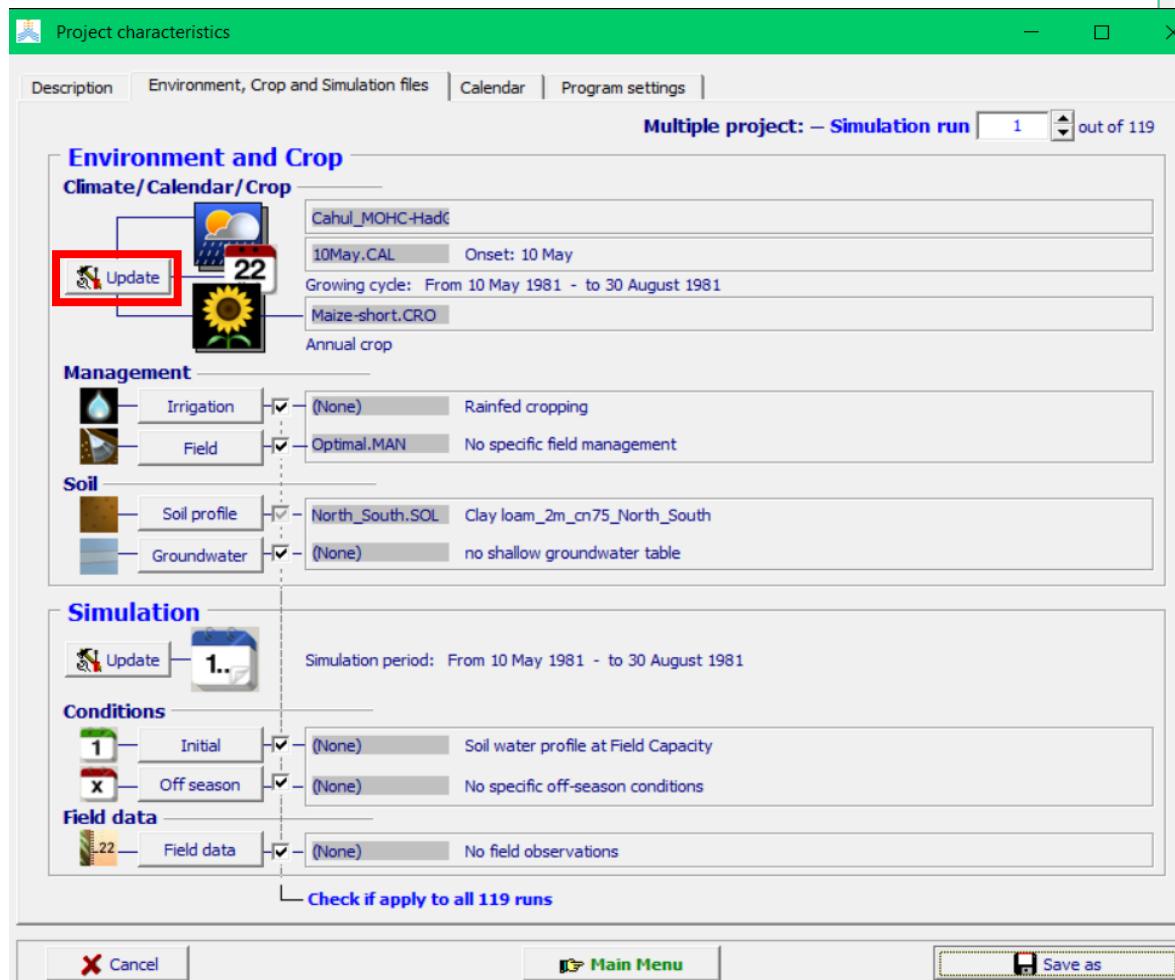


2. Select Display/Update Project characteristics

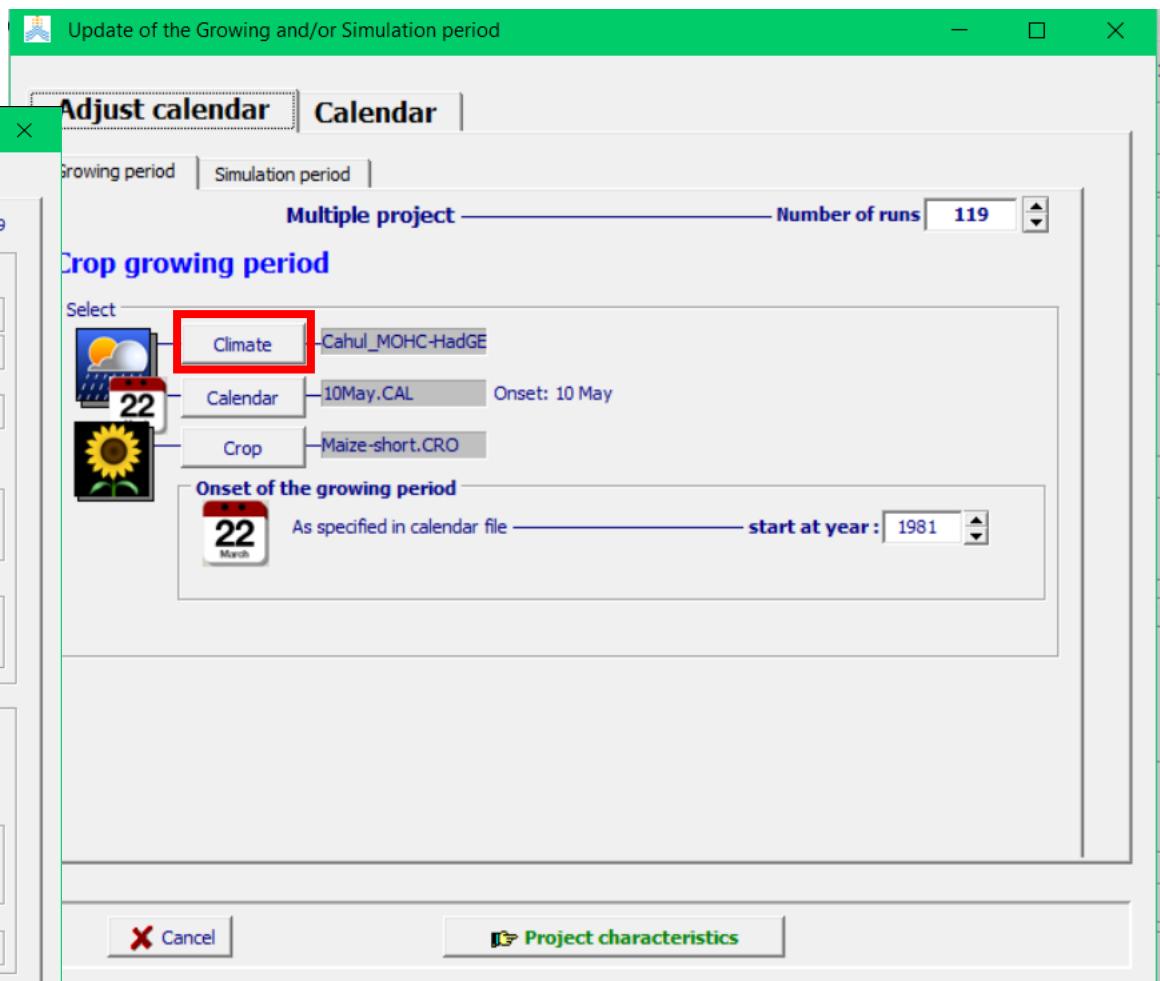


Creation of new project files (.PRM)

3. Press “Update” button

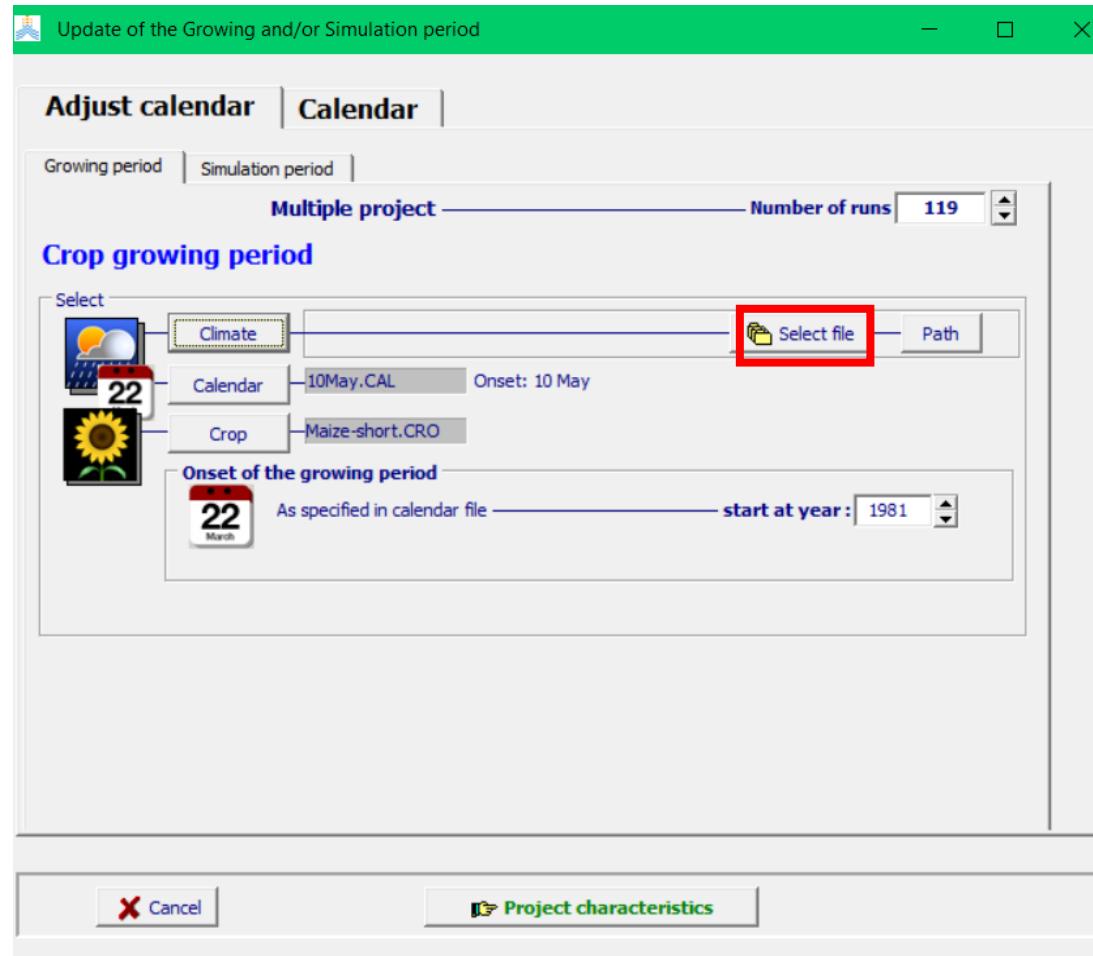


4. Click on Climate

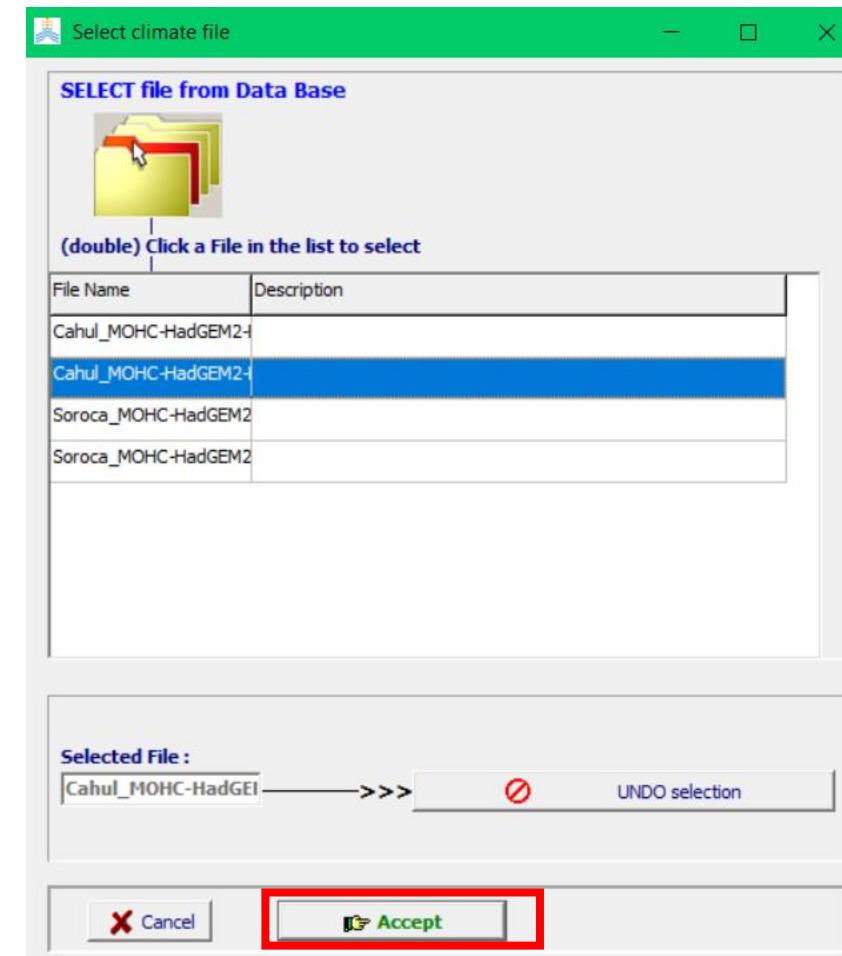


Creation of new project files (.PRM)

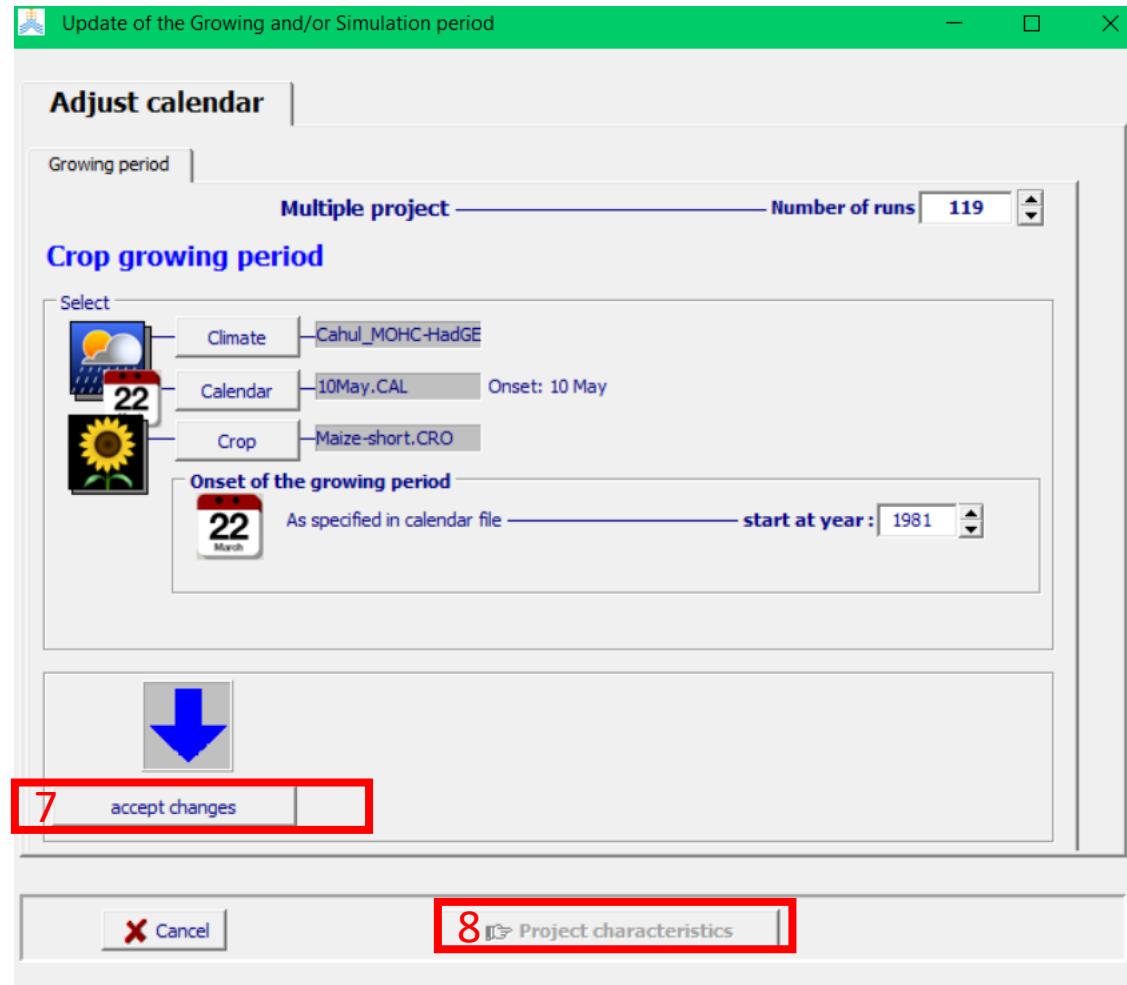
5. Click on “Select file”



6. Select the second file “Cahul_MOHC-HadGEM2-”



Creation of new project files (.PRM)

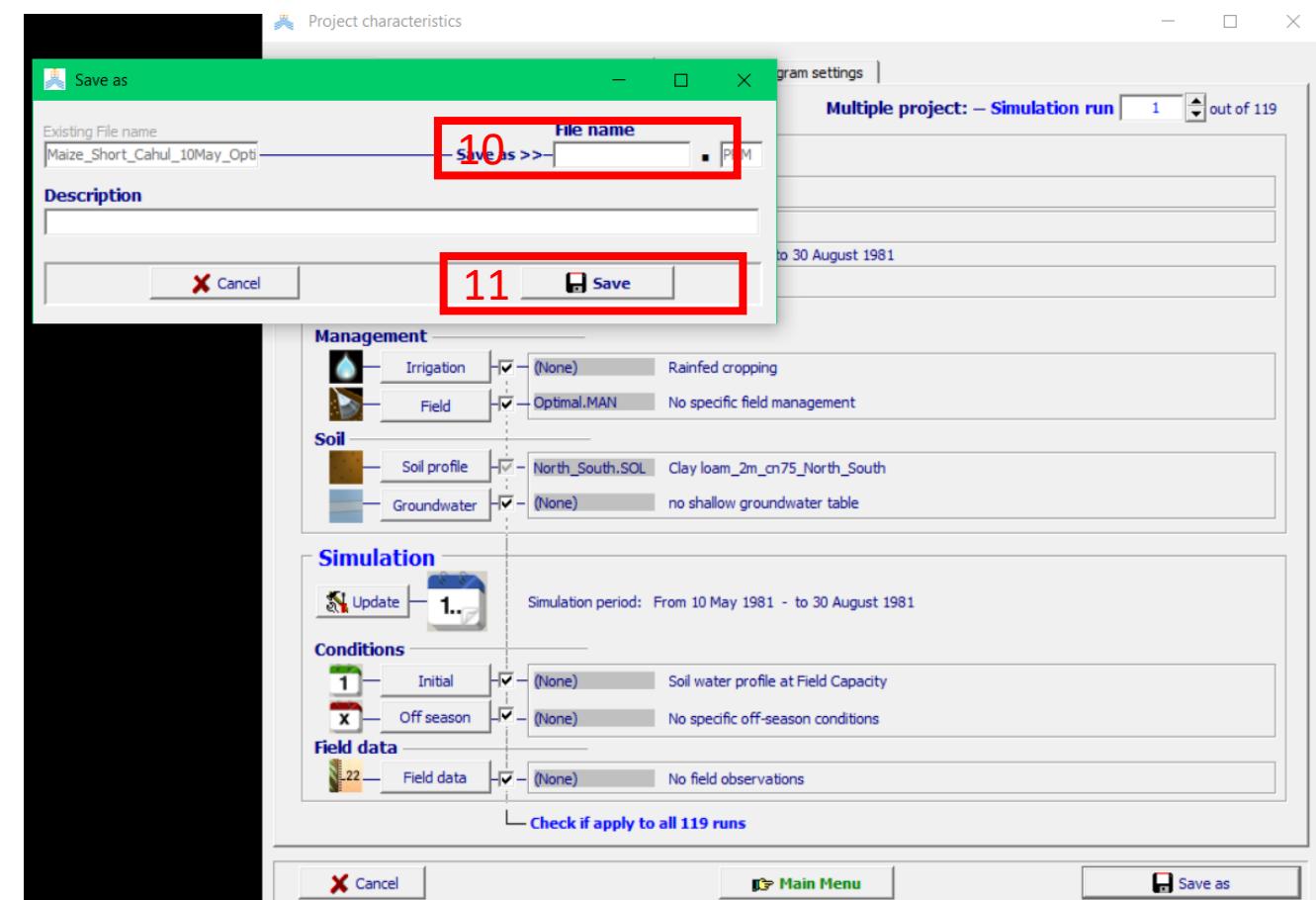
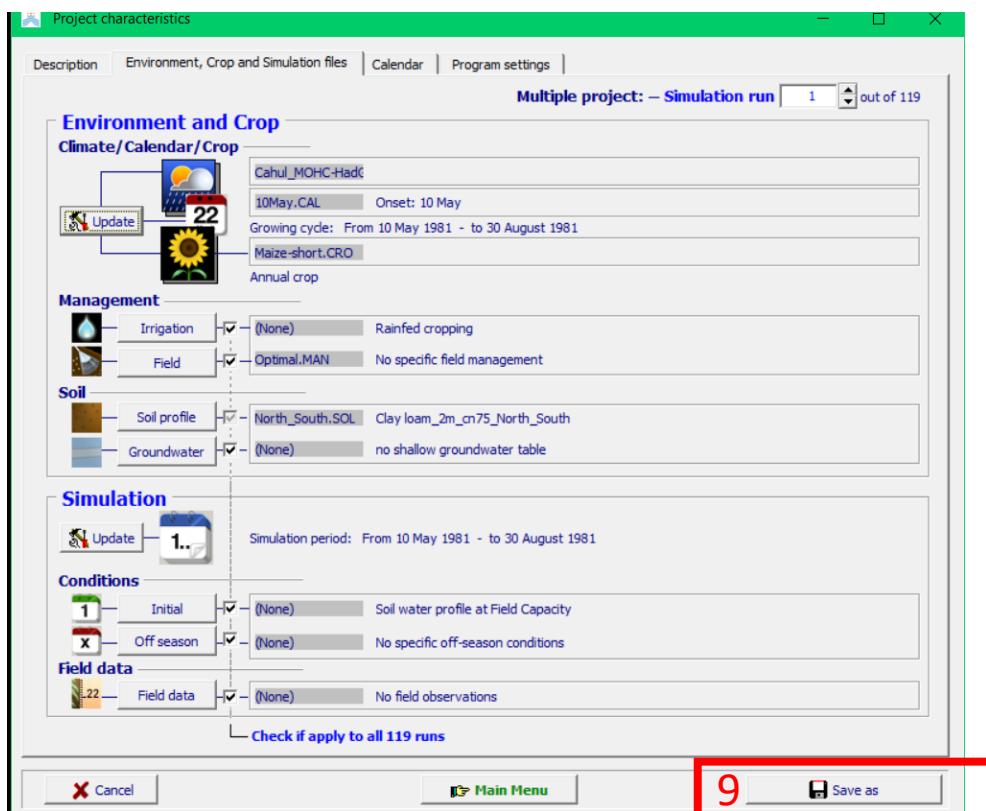


7. Press “Accept changes”
button

8. Click on “Project
Characteristics” to go back
on the main project page

Creation of new project files (.PRM)

9. Press “Save as” button
10. Fill the “File name” with: Maize_Short_Cahul_10May_Optimal_85_MOHC
11. Press the “Save” button



Variables scheme

Maize_Short_Cahul_10May_Optimal_26_MOHC X

Maize_Short_Cahul_10May_Optimal_85_MOHC X

Maize_Short_Soroca_10May_Optimal_26_MOHC Step → Change the Climate file to Soroca RCP 2.6

Maize_Short_Soroca_10May_Optimal_85_MOHC Step → Change the Climate file to Soroca RCP8.5



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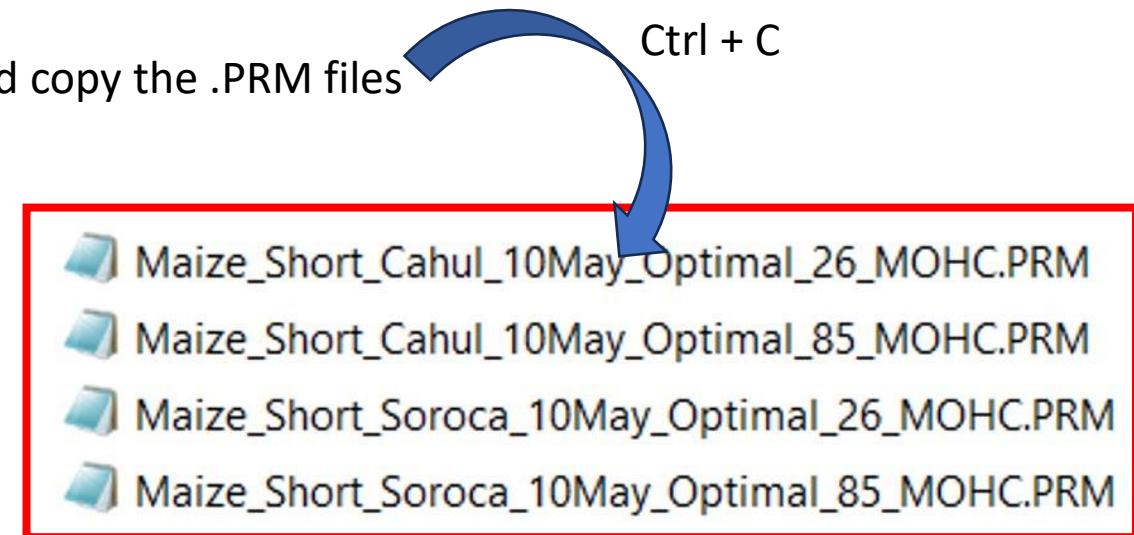
AquaCrop Plugin

May 30, 2022

Plug-in data

- Go to the DATA folder of "AquaCrop standard" and copy the .PRM files

(C:) > FAO > Moldova > GUI_AC7 > AquaCropV70No17082022 >	
Nome	Ultima modifica
DATA	25/05/2023 14:59
IMPORT	20/04/2023 11:06
OBS	20/04/2023 11:06
OUTP	20/04/2023 11:06
SIMUL	17/05/2023 19:37
_DEISREG.ISR	20/04/2023 11:06
_ISREG32.DLL	20/04/2023 11:06
AquaCrop.exe	20/04/2023 11:06
AquaCrop.ico	20/04/2023 11:06
DelsL1.isu	20/04/2023 11:06



Plug-in data

- Paste the .PRM files into the LIST folder of the Plug-in

C:\ > FAO > Moldova > aquacrop-7.0-x86_64-windows >	
Nome	Ultima modifica
LIST	25/05/2023 15:02
OUTP	16/05/2023 16:11
PARAM	17/08/2022 09:22
SIMUL	16/05/2023 12:53
aquacrop.exe	16/05/2023 12:19
AUTHORS.md	16/05/2023 12:19
LICENSE	16/05/2023 12:19

Ctrl + V

C:\ > FAO > Moldova > aquacrop-7.0-x86_64-windows > LIST	
Nome	U
Maize_Short_Cahul_10May_Optimal_26_MOHC.PRM	1
Maize_Short_Cahul_10May_Optimal_85_MOHC.PRM	1
Maize_Short_Soroca_10May_Optimal_26_MOHC.PRM	1
Maize_Short_Soroca_10May_Optimal_85_MOHC.PRM	1

Plug-in

- *To run the plugin the text file DailyResults.SIM is needed to be in the “SIMUL” folder of the plugin.

C:\ > FAO > Moldova > aquacrop-7.0-x86_64-windows >	
Nome	Ultima modifica
LIST	25/05/2023 15:02
OUTP	16/05/2023 16:11
PARAM	17/08/2022 09:22
SIMUL	16/05/2023 12:53
aquacrop.exe	16/05/2023 12:19
AUTHORS.md	16/05/2023 12:19
LICENSE	16/05/2023 12:19

(C:\ > FAO > Moldova > aquacrop-7.0-x86_64-windows > SIMUL	
Nome	Ultima modifica
AggregationResults.SIM	16/05/2023 12:19
DailyResults.SIM	16/05/2023 12:21
DEFAULT.CRO	17/05/2023 19:08
DEFAULT.SOL	17/05/2023 19:08
EToData.SIM	16/05/2023 17:31
MaunaLoa.CO2	16/05/2023 12:19
RainData.SIM	16/05/2023 17:31
TCrop.SIM	16/05/2023 17:31
TempData.SIM	16/05/2023 17:31

Plug-in

- Run the plug-in by double-clicking on aquacrop.exe

C:\ > FAO > Moldova > aquacrop-7.0-x86_64-windows >	
Nome	Ultima modifica
LIST	25/05/2023 15:02
OUTP	16/05/2023 16:11
PARAM	17/08/2022 09:22
SIMUL	16/05/2023 12:53
aquacrop.exe	16/05/2023 12:19
AUTHORS.md	16/05/2023 12:19
LICENSE	16/05/2023 12:19

Plug-in

- After the plug-in worked, you will find the .OUT files (daily and seasonal) in the OUTP folder

C:\ > FAO > Moldova > aquacrop-7.0-x86_64-windows >	
Nome	Ultima modifica
LIST	25/05/2023 15:02
OUTP	16/05/2023 16:11
PARAM	17/08/2022 09:22
SIMUL	16/05/2023 12:53
aquacrop.exe	16/05/2023 12:19
AUTHORS.md	16/05/2023 12:19
LICENSE	16/05/2023 12:19

C:\ > FAO > Moldova > aquacrop-7.0-x86_64-windows > OUTP

Nome
AllDone.OUT
ListProjectsLoaded.OUT
Maize_Short_Cahul_10May_Optimal_26_MOHCPRMday.OUT
Maize_Short_Cahul_10May_Optimal_26_MOHCPRMseason.OUT
Maize_Short_Cahul_10May_Optimal_85_MOHCPRMday.OUT
Maize_Short_Cahul_10May_Optimal_85_MOHCPRMseason.OUT
Maize_Short_Soroca_10May_Optimal_26_MOHCPRMday.OUT
Maize_Short_Soroca_10May_Optimal_26_MOHCPRMseason.OUT
Maize_Short_Soroca_10May_Optimal_85_MOHCPRMday.OUT
Maize_Short_Soroca_10May_Optimal_85_MOHCPRMseason.OUT

Plug-in

Create a new folder and copy and paste the PRMs and OUTs data.

(C:) > FAO > Moldova > aquacrop-7.0-x86_64-windows > OUTs+PRMs

Nome	Ultima modifica	Tipo	Dimensione
Maize_Short_Cahul_10May_Optimal_26...	16/05/2023 14:55	File PRM	192 KB
Maize_Short_Cahul_10May_Optimal_26...	16/05/2023 15:09	File OUT	10.186 KB
Maize_Short_Cahul_10May_Optimal_26...	16/05/2023 15:09	File OUT	49 KB
Maize_Short_Cahul_10May_Optimal_85...	16/05/2023 14:57	File PRM	192 KB
Maize_Short_Cahul_10May_Optimal_85...	16/05/2023 15:10	File OUT	10.186 KB
Maize_Short_Cahul_10May_Optimal_85...	16/05/2023 15:10	File OUT	49 KB
Maize_Short_Soroca_10May_Optimal_26...	16/05/2023 14:57	File PRM	192 KB
Maize_Short_Soroca_10May_Optimal_26...	16/05/2023 15:17	File OUT	10.186 KB
Maize_Short_Soroca_10May_Optimal_26...	16/05/2023 15:17	File OUT	49 KB
Maize_Short_Soroca_10May_Optimal_85...	16/05/2023 14:58	File PRM	192 KB
Maize_Short_Soroca_10May_Optimal_85...	16/05/2023 15:18	File OUT	10.186 KB
Maize_Short_Soroca_10May_Optimal_85...	16/05/2023 15:18	File OUT	49 KB



**Food and Agriculture
Organization of the
United Nations**



Simulation Scheme

May 30, 2022

Simulation scheme

Maize, tomato, green pea, sunflower

Varieties (x1)	Locations (x3)	Sowing dates (x3)	Management (x2)	RCPs (x2)	GCMs (x3)
Soroca	Calibrated/validated	Optimum	8.5	2.6	MOHC-HadGEM2-ES
	15 days before	Non-optimum			NCC-NorESM1-M
	15 days later				MPI-M-MPI-ESM-LR

Total project files: 108 files

Name

file: Crop_Variety_Location_Sowingdate_Management_RCP_GCM

Time frames: 2010-2039 (near-term); 2040-2071 (mid-term); 2070-2099 (long-term)

Outputs: Yield; CWP; abiotic stresses (canopy expansion; stomatal closure)

Wheat

Varieties (x1)	Locations (x1)	Sowing dates (x3)	Management (x2)	RCPs (x2)	GCMs (x3)
National	Calibrated/validated	Optimum	8.5	2.6	MOHC-HadGEM2-ES
	15 days before	Non-optimum			NCC-NorESM1-M
	15 days later				MPI-M-MPI-ESM-LR

Total project files: 36 files

Name file:

Wheat_Variety_Location_Sowingdate_Management_RCP_GCM

Time frames: 2010-2039 (near-term); 2040-2071 (mid-term); 2070-2099 (long-term)

Outputs: Yield; CWP; abiotic stresses (canopy expansion; stomatal closure)

Thank you!

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