

AquaCrop: A Comprehensive Training Guide for Crop Simulation Modeling

Target Market

- ☐ Agricultural Researchers
- ☐ Agronomists
- ☐ Water Resource Managers
- ☐ Climate Change Analysts
- ☐ Environmental Scientists
- ☐ Irrigation Specialists
- ☐ Crop Modelers
- ☐ University Educators
- ☐ Graduate and Postgraduate Students
- ☐ Policy Makers in Agriculture and Water Management
- ☐ Extension Workers
- ☐ Farm Managers
- ☐ NGOs in Agricultural Development
- ☐ International Organizations (e.g., FAO, UNEP)
- ☐ Software Trainers and Technicians

Main Keyword: AquaCrop Model Tutorial, AquaCrop Training, AquaCrop plant simulation model, AquaCrop Training Guide, Learn AquaCrop, AquaCrop Simulation Tutorial, AquaCrop Crop Modeling, Crop Simulation Software, AquaCrop Crop Simulation Model, AquaCrop-Based Simulation Model, AquaCrop Water Simulation Model, AquaCrop Plant Yield Model, AquaCrop Agricultural Simulation Model, AquaCrop Plant Productivity Model, AquaCrop Simulation Training

Subkey Word: AquaCrop Crop Simulation Model, AquaCrop Plant Growth Model, AquaCrop-Based Simulation Model, AquaCrop Water Simulation Model, AquaCrop

Plant Yield Model, AquaCrop Agricultural Simulation Model, Advanced AquaCrop Simulation Model, AquaCrop Plant Productivity Model, Plant Simulation Model AquaCrop Plant, Crop Simulation AquaCrop Model, Plant Growth AquaCrop Model, AquaCrop Model for Plant Simulation, AquaCrop Training Guide, AquaCrop Tutorial Model, AquaCrop Simulation Training, AquaCrop Educational Model, AquaCrop Plant Simulation Tutorial, AquaCrop Learning Module.

Are you still relying on guesswork and outdated methods for predicting crop yields and managing water resources? The AquaCrop plant simulation model offers a data-driven approach for optimizing agricultural practices.

Predicting crop yield in different climate situations and farm management is an important aim for future scheduling and economical farming. Using crop growth models is one of the common tools for this prediction. One of the best ways to quantify the effect of climate change on crop production is to use crop growth models to predict the harvestable yield of different crops in climate change. On the other hand, precise crop yield prediction can be used for annual economic planning in farms. Crop yield prediction used to be experimental data according to the past available local data, but today the plant-growing simulation models provide trustworthy and valid crop yield data for economic planning. AquaCrop is one of the crop growth models developed by FAO in 2009 and updated several times for better application.

Nowadays, many crop growth models exist. Each of these models, based on their scope and purposes, is appropriate. The AquaCrop Simulation Model, which is freely available, is a water-based model and user-friendly interface software for predicting crop yield and water use efficiency.

The recent version of [AquaCrop 7.2](#) is available at the moment. This version is available in English and French. In this article, we aim to outline the steps of modeling using the AquaCrop 7.2 software to predict crop yield and water use efficiency under various climatic and management conditions.

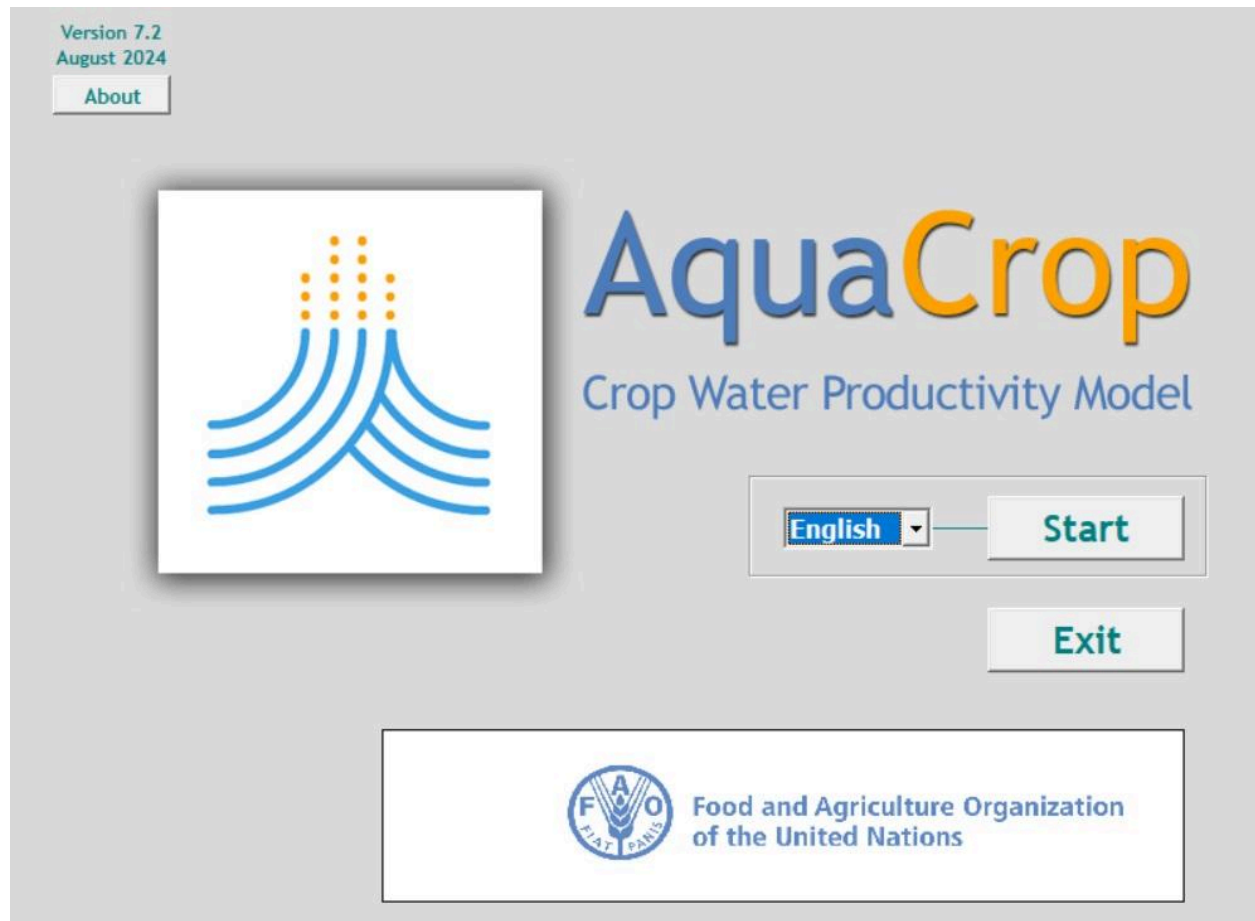


Fig. 1. AquaCrop 7.3 interface | AquaCrop Training Guide | AquaCrop Plant Simulation Model | AquaCrop Crop Simulation Model | AquaCrop Plant Growth Model | AquaCrop Learning Module

1. Crop Simulation Models

In every crop simulation calculation core, there are equations that estimate the biomass according to the growth involved parameters, such as carbon dioxide, water and solar radiation. All development models can be categorized in three types i) carbon dioxide-driven models ii) solar radiation-driven models and iii) water-driven models. In carbon dioxide-driven models, temperature, solar radiation and

atmospheric carbon dioxide are estimated and at the final stage, controlled by available water in the photosynthesis process to predict the crop yield. These models are complicated and need lots of data for running and calibration. WOFOST and CROPGRO are categorized in this type. Solar radiations base models predict crop yield by Radiation which uses efficiency (RUE) directly from solar radiations. These models are less complicated than type I which need less entry data. In these models, growth potential is a function of photosynthetically active radiation; the amount of absorbed radiation depends on leaf area index, row spacing, plant density, and the efficiency of radiation conversion to biomass. This model has the ability to quantify the main growth and development processes of crops, such as reproductive development and canopy cover development. Moreover, water-related processes, such as runoff, infiltration, drainage flow, etc. CERES models (CERES-Maize, CERES-Barley, CERES-Wheat, etc) are categorized in this type.

Water-based models predict the crop yield according to their evapotranspiration (ET) and normalizing water productivity (WP) index.

FAO developed the AquaCrop plant simulation model by combining the existing data from plant phenological reactions as a tool for predicting crop yield due to available water supply.

2. AquaCrop Conceptual Model

Crop response to water deficit described by empirical production functions.

Doorenbos and Kassam (1979) is a landmark mentioned in FAO [irrigation and drainage paper 33](#) to predict the yield response to water through the following equation:

$$\left(\frac{Y_x - Y_a}{Y_x} \right) = k_y \left(\frac{ET_x - ET_a}{ET_x} \right)$$

In this equation, Y_x and Y_a represented the maximum and actual yield, ET_x and ET_a represented the maximum and actual evapotranspiration and K_y is the proportionality factor between relative yield loss and relative reduction in evapotranspiration.

Conceptually, AquaCrop is a description of the Doorenbos and Kassam equation with some reformations. The crop evapotranspiration (ET) can be separated to soil evaporate (E) and crop transpiration (T) to omit the effect of non-productive use of water. This is so important, especially in the early days of growing when the canopy cover is uncompleted and soil evaporation may be the major component of ET.

Harvest index (HI) is the factor that AquaCrop crop yield prediction model uses for separating E and T in calculations. The harvestable yield is described as a function of biomass and HI to distinguish the environmental stress effect on biomass from what affected HI.

The core calculation of AquaCrop describes a function between crop transpiration and water productivity index as biomass, then crop yield is estimated by biomass and harvest index simply.

In AquaCrop, plant growth is described by developing canopy cover and accumulating biomass in daily time steps. The term of growing degree days (GDD) presents daily crop phenology over the season. Canopy cover (CC) development, transpiration, biomass production and yield are the terms of phenological simulation that are estimated in four steps.

1. canopy cover (CC): In AquaCrop, foliage development is expressed through green canopy cover (CC) and instead of Leaf Area Index (LAI). The green canopy cover (CC) is the fraction of the soil surface covered by the canopy. It ranges from zero at sowing to a maximum value during the growing season, which can be reached to 100 in full canopy cover mode. Estimating soil water content in daily steps helps AquaCrop track the stresses in the root zone. Soil water stress can affect the leaf and canopy expansion in early canopy senescence.

2. Crop transpiration (T_r): in well-watered conditions, T_r is a part of reference evapotranspiration (ET_o) which is calculated by using crop coefficient (K_cTr). The crop coefficient varies through the growing season.

3. Above-ground biomass: this term is related to cumulative crop transpiration and biomass productivity (WP). WP factor normalized to cover the effect of climate change, diverse seasons and CO_2 concentrations.

4. Crop yield (Y): the estimated above-ground biomass integrated all photosynthetic productions by crop during the season. Crop yield is the harvestable portion of biomass, which is extracted by using harvest index (HI). The actual HI is calculated by adjusting during the season.

Environmental stresses are described through stress coefficients in the AquaCrop plant growth model.

Fig. 2. presents the flowchart of yield calculations in AquaCrop. As it shows, soil-water balance is the start of the calculation process.

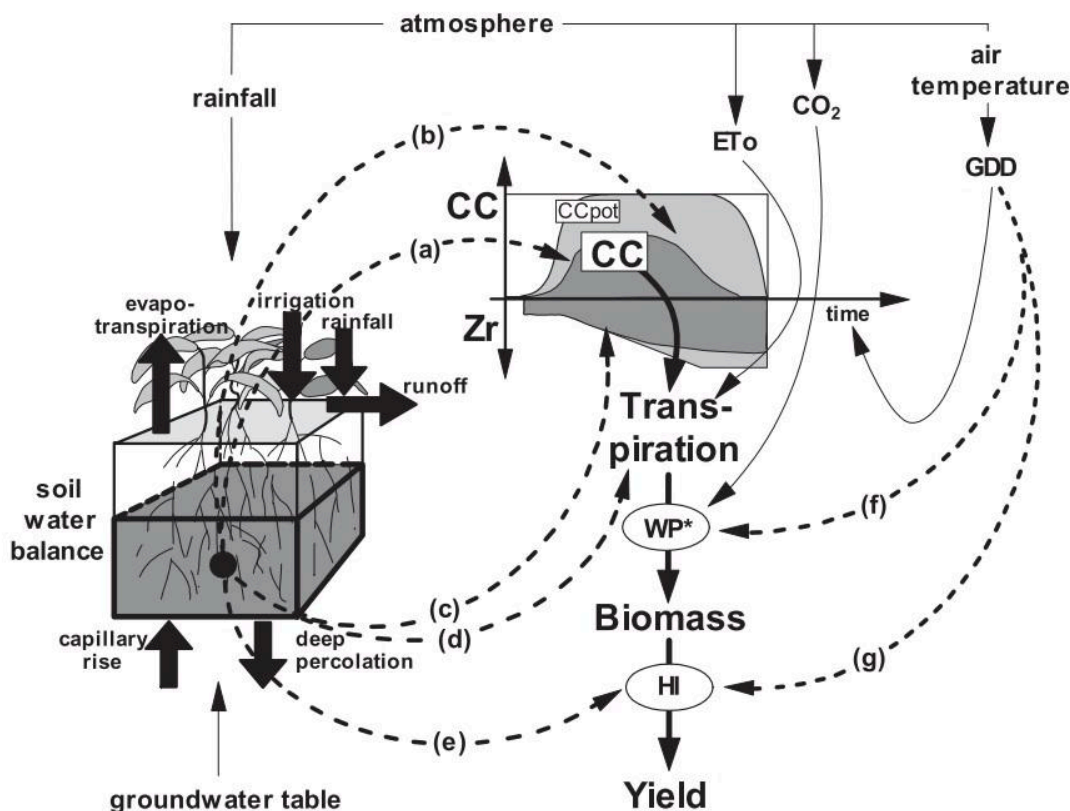


Fig. 2. AquaCrop calculation flowchart | AquaCrop Plant Simulation Tutorial | AquaCrop Plant Productivity Model | Plant Simulation Model AquaCrop Plant

3. Input Requirement

The AquaCrop plant growth model uses a small number of explicit parameters and a large number of related input variables explicitly. Inputs consist of weather data, crop and soil characteristics, management practice and describing the environment in which the crop will be developed. The explanations for each of these inputs will be presented in continuation.

In this article, the wheat yield in a farm located 24° 21 '8" N and 55° 49' 37" E in the United Arab Emirates in Al-Ain State, which is the center of agriculture farms in the United Arab Emirates, is shown. This farm uses a center pivot sprinkler irrigation system for planting (Fig. 3). The United Arab Emirates is located in an arid climate and efficient annual rainfall is lower than 50 mm. Agricultural production is a minor part of the United Arab Emirates but the number of farms increased during the last 20 years. Agricultural land depends on available water resources and it is needed to optimize water productivity and maximise the crop yield with available water resources. Considering that irrigation water plays a significant role in final crop yield, water productivity as an important indicator shows the efficiency of all farm management practices, especially irrigation practices.

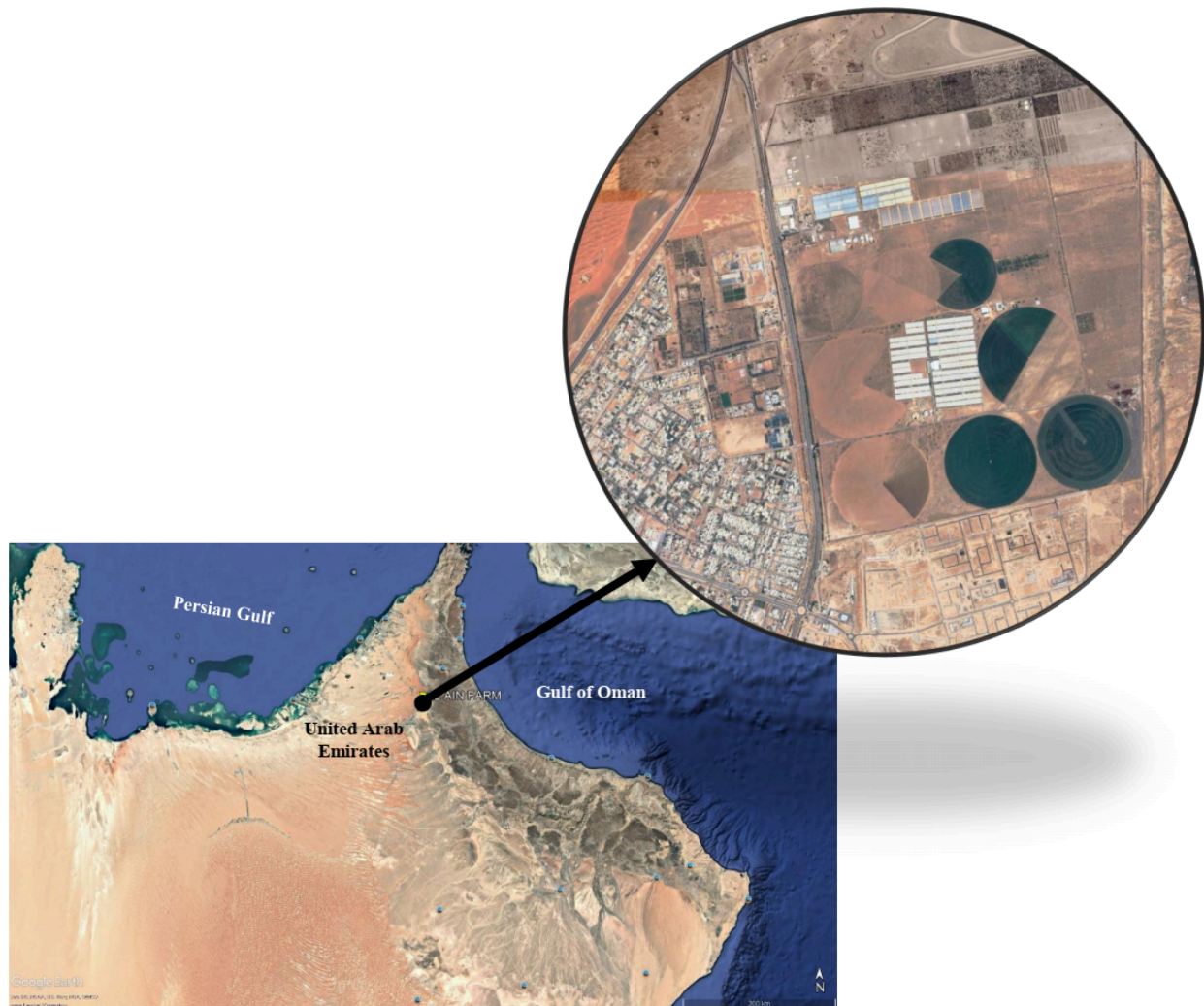


Fig. 3. Location of wheat farm in United Arab Emirates (UAE)

3.1. Climate Data

In the main window of the AquaCrop simulation model, there are some bottoms for data entry. The climate bottom leads you to a subwindow that lets you create new climate data, you can use an existing climate file or update it (Fig. 4).

Minimum climate data for the AquaCrop crop simulation model is minimum and maximum air temperature, references to evapotranspiration (ET_o), rainfall (none) and CO_2 concentration. ET_o calculator is a useful joint software that helps you to calculate ET_o with the FAO-Penman-Monteith equation and import them to AquaCrop easily.

You can use The [ET_o calculator training sample](#) for more information.

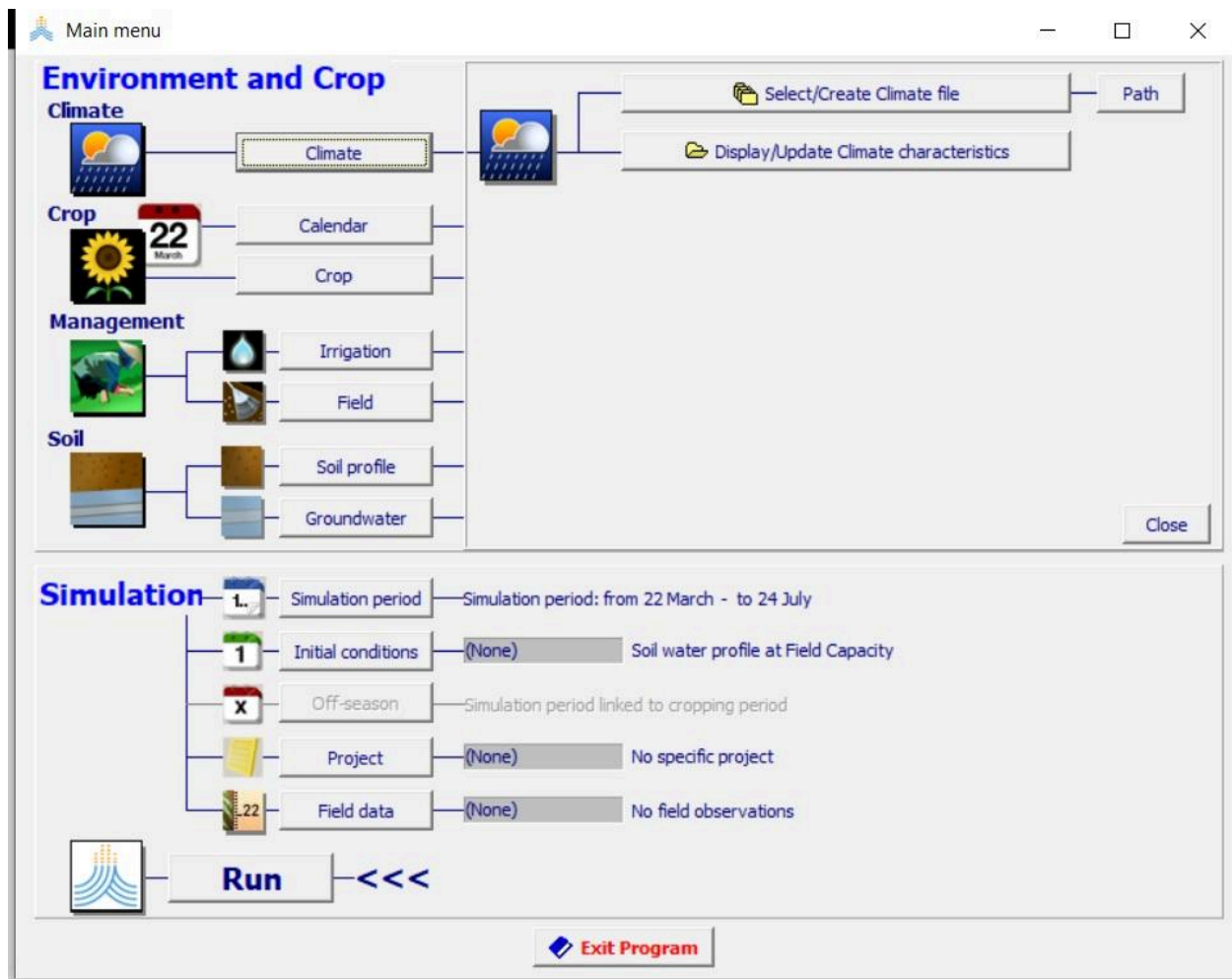


Fig. 4. Climate data entrance main window

The other way for climate data entry is to import the data from a text file manually. In this case, you have to create a text file (*.txt) from your climate data in order and without any headers and introduce the file to the AquaCrop plant productivity model. For each tab, you need to introduce the time range and units of your data (Fig. 5). Climate data time steps could be daily, 10 days, or monthly. You can define the value for the missing data. The default value of the model is -999. The upper and lower limit defaults of each data series should be adjusted due to your real data.

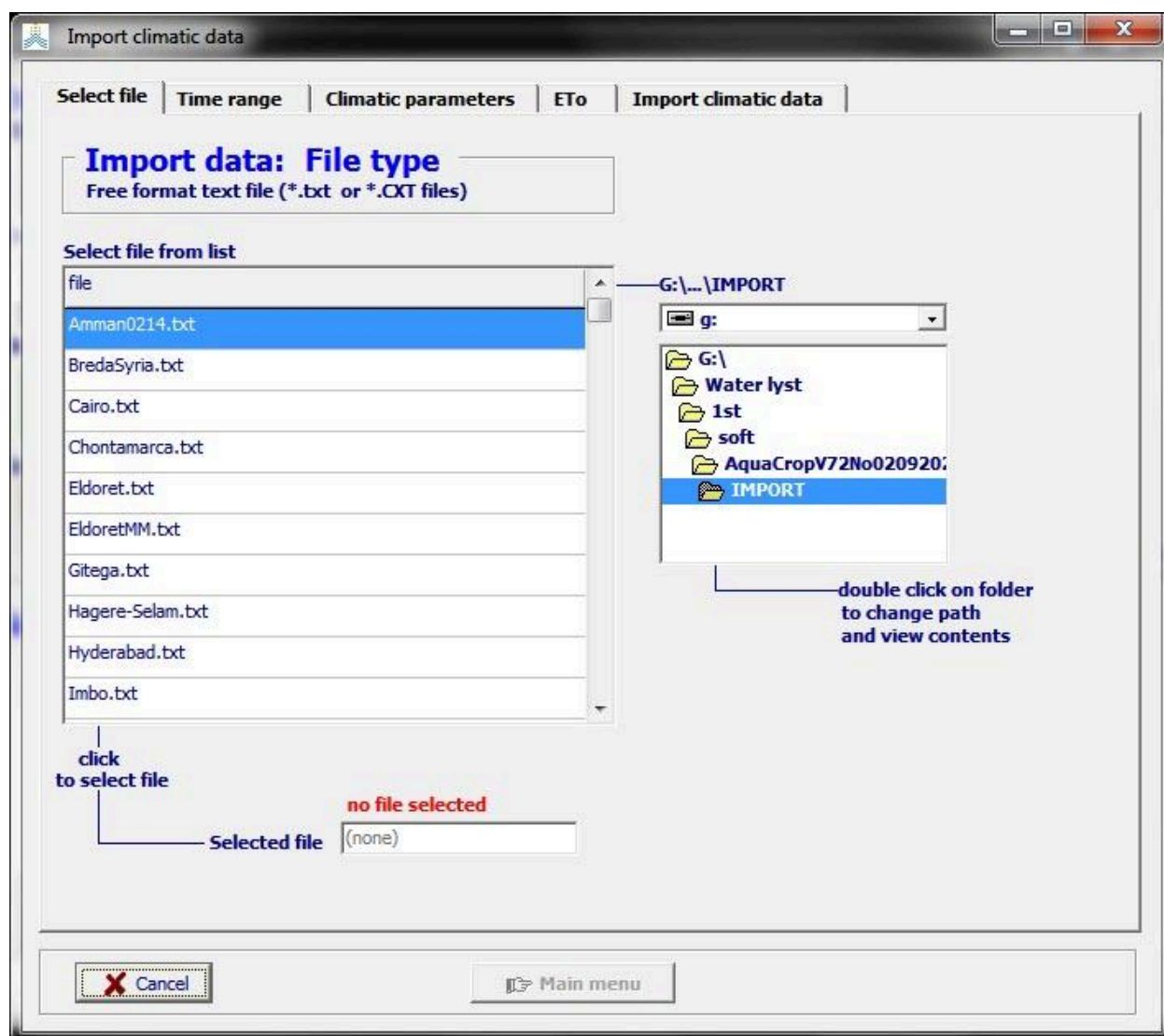


Fig. 5. Import Climate data main window | AquaCrop Model for Plant Simulation

After completing data entry, you can create a climate file that can be updated in each model run.

In simulations with historical climatic data or for the near future, there is no need to create a CO₂ file since the 'IPCC-BERN_A1B.CO2' file can be used. It contains the mean annual atmospheric CO₂ concentration measured at Mauna Loa Observatory since 1958. The 'GlobalAverage.CO2' file, which was added in the newest version of AquaCrop, including the observed CO₂ concentrations up to 2023, has been updated with the latest published results on the [NOAA website](#).

For future simulation and assessment of the effect of climate change, a CO₂ concentration should be created due to your [climate change scenario](#). In this case, you can use the default file and paste the new value in it.

For Al Ain Farm, we use the data from the nearest weather station, including minimum and maximum temperature and rainfall daily data, in an ET_o calculator and import the files to AquaCrop for creating new climate data. For CO₂ concentration, the 'GlobalAverage.CO2' file has been used.

3.2. Crop Data

In crop data, two different bottoms will be noticed that both of them are related to the crop. The bottom of calendar data and the crop data bottom are related to the crop physiology data.

3.2.1 Calendar

In the calendar, you can use a specific day as the start of crop growth simulations, like the case of sowing dates or you can define a criteria related to rainfall or temperature parameters as the start point of crop growth simulations. It is essential to enter your crop data before creating a calendar file. For example, rainfall criteria could involve a minimum threshold of accumulated rainfall within a specific period, while temperature criteria might consider a consistent average temperature over several days suitable for crop germination. Use rainfall or temperature criteria mostly used for winter planting. In Al Ain Farm, the common time for wheat planting is from the middle of November to the middle of December. So the sewing date was the 4th of December. This selection ensures optimal soil moisture levels and temperature conditions necessary for wheat germination and early growth. Adhering to these parameters helps improve yield consistency and reduces the risk of weather-related planting failures.

3.2.2. Crop Characteristics Data

This bottom lets you enter the physiology data of your crop. In the AquaCrop plant growth model, more than 30 crop files exist. Each crop has two kinds of simple and GDD versions, which let you simulate a normal or off-season crop planting. These default files come from many calibration experiences and validated data around the world. Therefore, it is recommended using a default file and personalizing it for your farm or case study. Conservative crop parameters do not need to be tuned since they do not change much with time, management practices, geographic location, climate and cultivar. In Fig. 5, a crop characteristic window is presented. The default of software is limited set parameters that show only the cultivar-specific and non-conservative parameters that might require an adjustment when selecting a cultivar different from the one considered for crop calibration or when the environmental conditions differ from the conditions assumed at calibration.

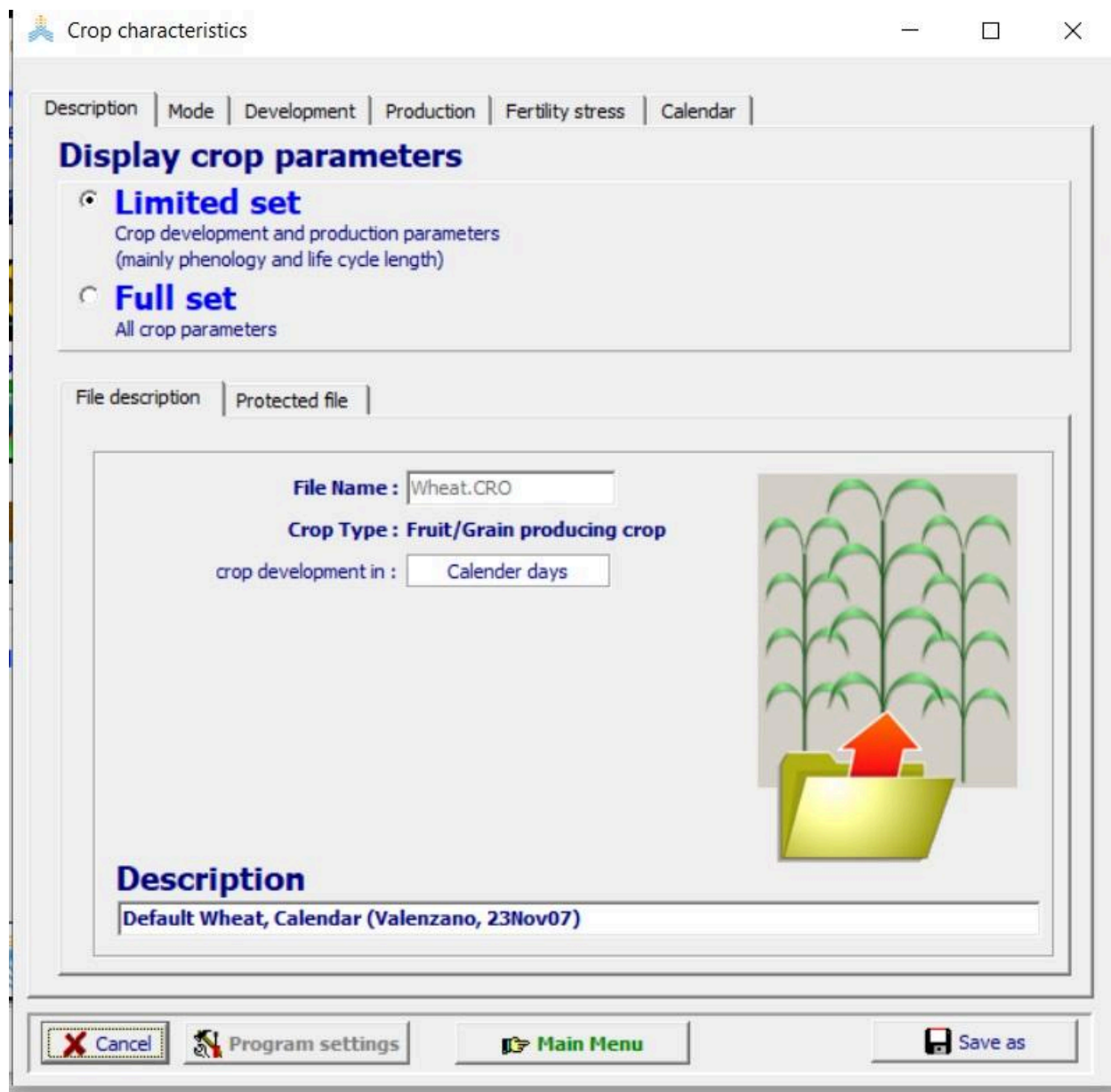


Fig. 6. Crop Characteristics Window | Crop Simulation AquaCrop Model

AquaCrop makes a distinction between direct sowing and transplanting. In direct sown size, when the crop is sown, the size of the canopy of the germinating seedling is given as a conservative parameter. These parameters can be reached in full mode only. In transplanting, the size of the transplant seedling should be specified by the user.

In the development tab (Fig. 7), the initial canopy cover depends on your type of planting method and plant density.

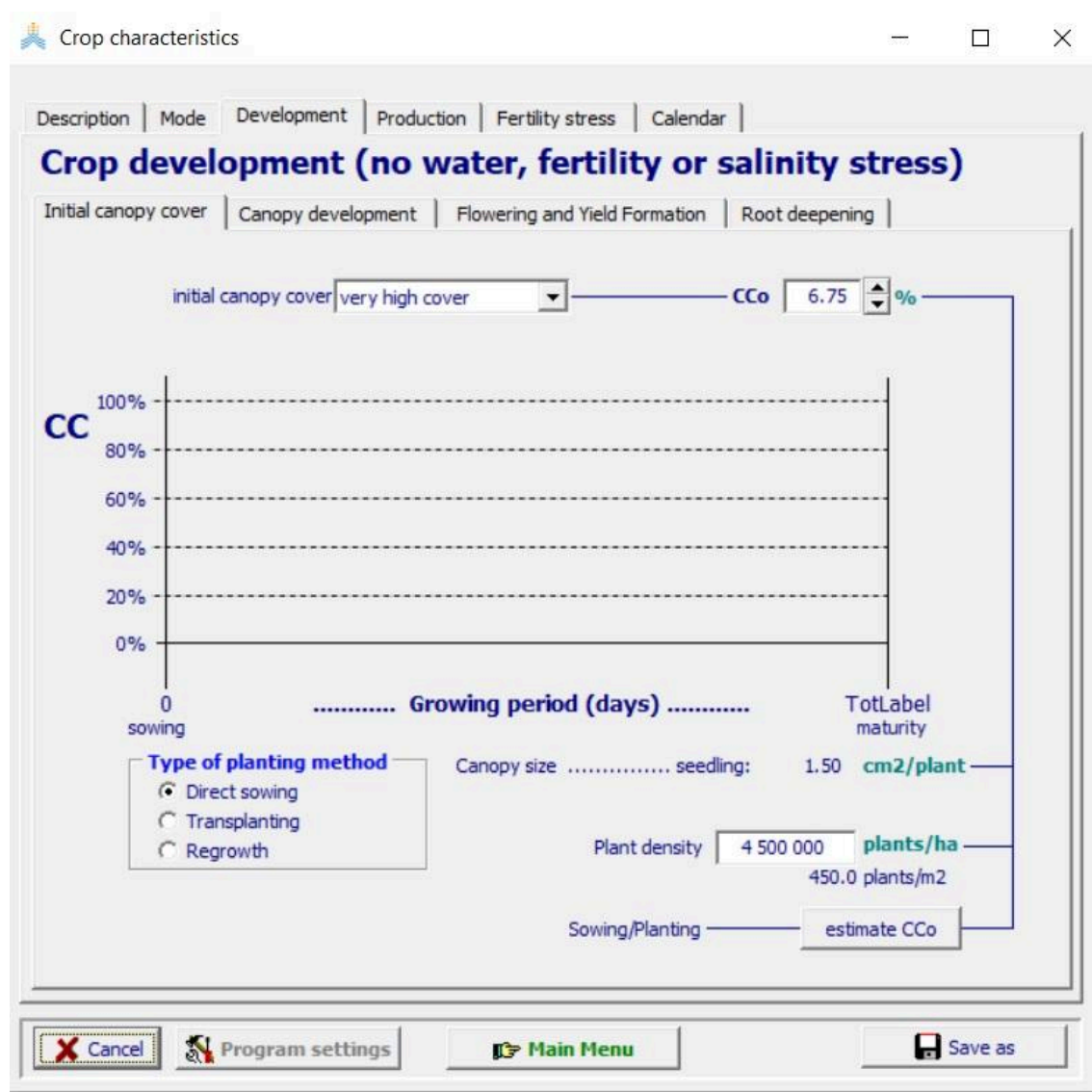


Fig. 7. Development tab of crop characteristics window

In the canopy development tab, the canopy development should be adjusted through your field observations and data. These parameters are directly used in crop-growing simulation and they should be adjusted for each cultivar and location separately (Fig. 8). Maximum canopy cover (CCx), that will be reached at mid-season, is generally around 75% up to 100%. CCx varies with crop type but it is also determined by

planting density. CCx is specified by selecting one of the predefined classes or as direct input. The predefined classes are categorized based on typical canopy cover values observed under varying planting densities and crop management practices. Alternatively, direct input allows for the specification of exact CCx values tailored to experimental data or field-specific conditions.

Accurate specification of CCx is crucial, as it directly influences the simulation of crop growth dynamics, light interception, and potential yield outcomes. Ensuring compatibility between planting density and CCx parameters improves the model's reliability for decision-making in agricultural planning.

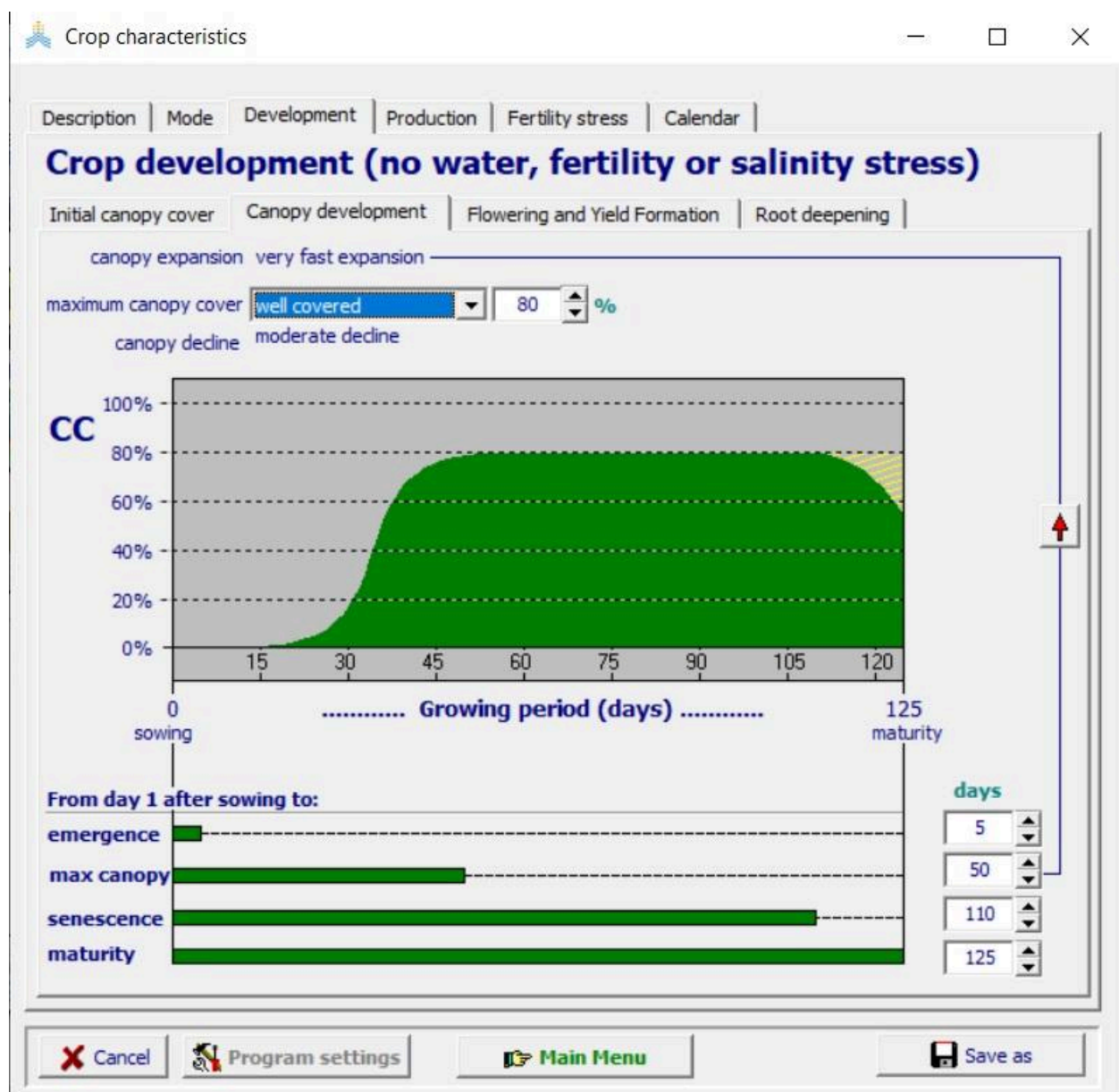


Fig. 8. Canopy development tab in crop characteristics main window

The root, depending on the last tab of developing input data, refers to the root zone of your plant. These parameters will be used for calculating the capillary rise in the root zone.

Maximum effective root depth could be affected by your soil characteristics. Although it could be one of your specific cultivar characteristics that should be entered by the user directly (Fig. 9).

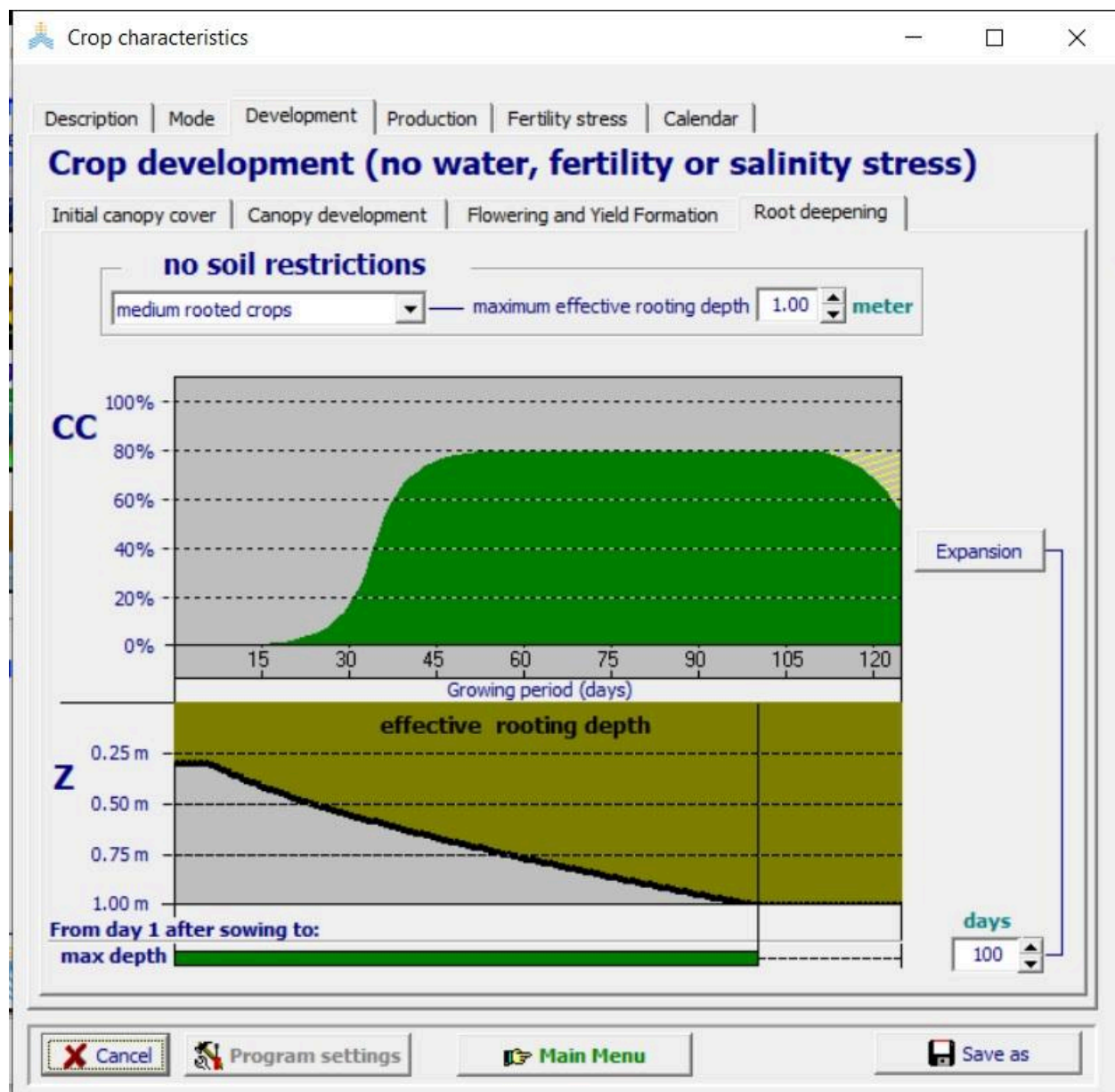


Fig. 9. Root deepening tab in crop characteristics main window

After completing this part in the production tab, the unique parameters of the AquaCrop model for simulating crop yield appear, including crop water productivity and harvest index. Water productivity is one of the conservative parameters that are estimated by the direct input data and adjusted during the simulation due to the effect of water and nutrient stress in the growing season. Harvest index is one of the important parameters that can be defined by the user directly. This parameter presents the harvestable portion of the produced biomass. This parameter is one of the key variables in the model calibration stage.

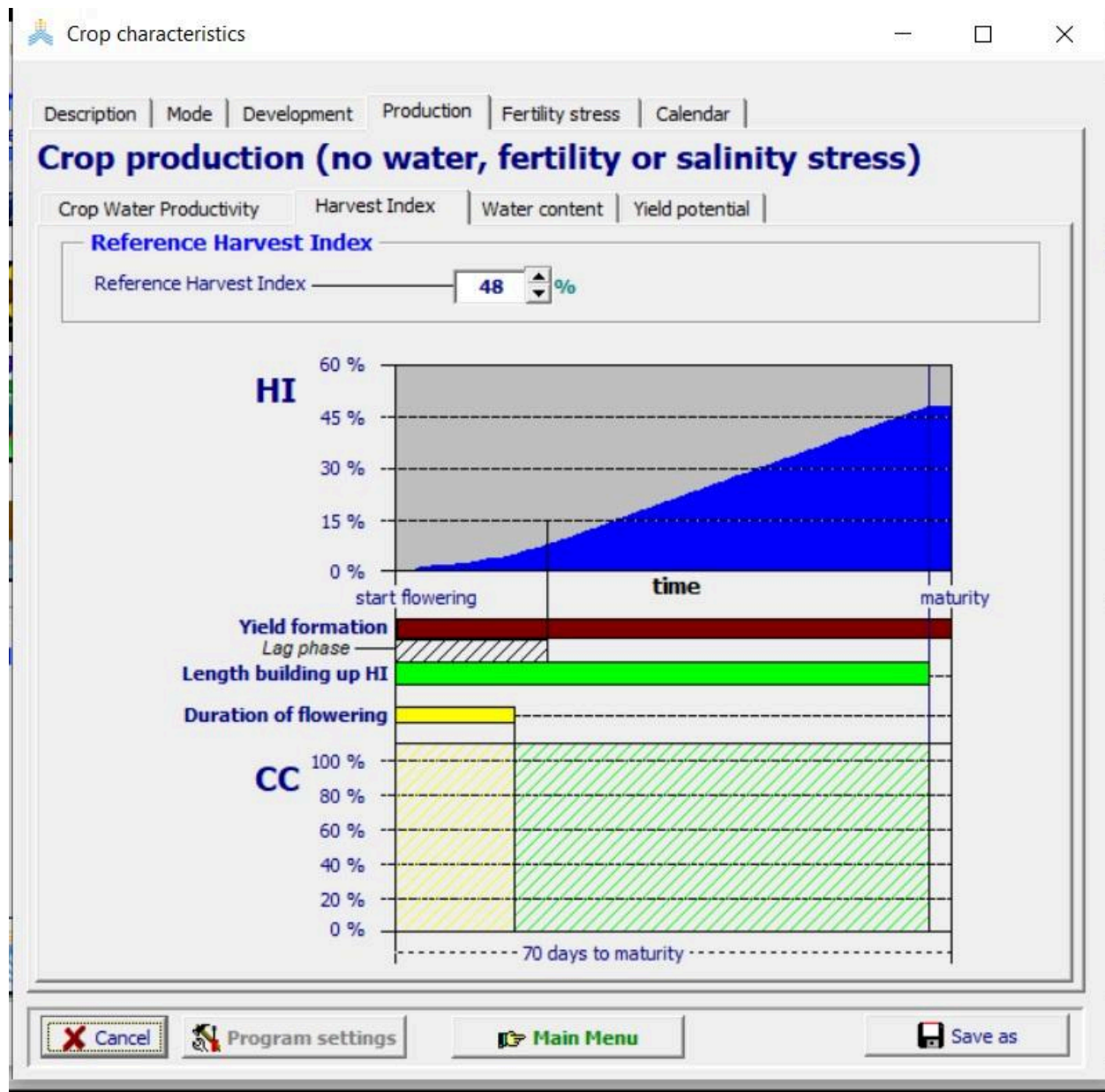


Fig 10. Harvest index tab in crop characteristics main window

In the yield potential tab, the combination of input data in crop development and production and the potential biomass and yield have been shown. This could help with adjustments before the final run of the model.

Fertility stress caused aboveground biomass (B) will be limited during the growing season. This is the result of a smaller canopy cover (CC) and a decrease of the biomass water productivity (WP). The soil fertility level during simulation is a field management characteristic, while the crop response to soil fertility stress should be

defined as a crop characteristic . Since the effect of soil fertility stress is affected by the type of limiting nutrients and environmental conditions, such as climate and soil type, a calibration of the crop response to soil fertility stress is required and will most likely have to be repeated for each type of environment.

In Fig. 11, the main window of soil fertility calibration is presented. The effect of soil fertility is described by reductions in canopy cover, water productivity and biomass. These data should be gathered through field observation. These parameters could be defined as a reduction rate or final fixed values and directly entered by the user as input data in the model.

The calendar tab is the final tab of crop characteristics in limited mode (Fig. 12). All the important dates during the growing season will be shown here and there is a last chance for any adjustment in this tab.

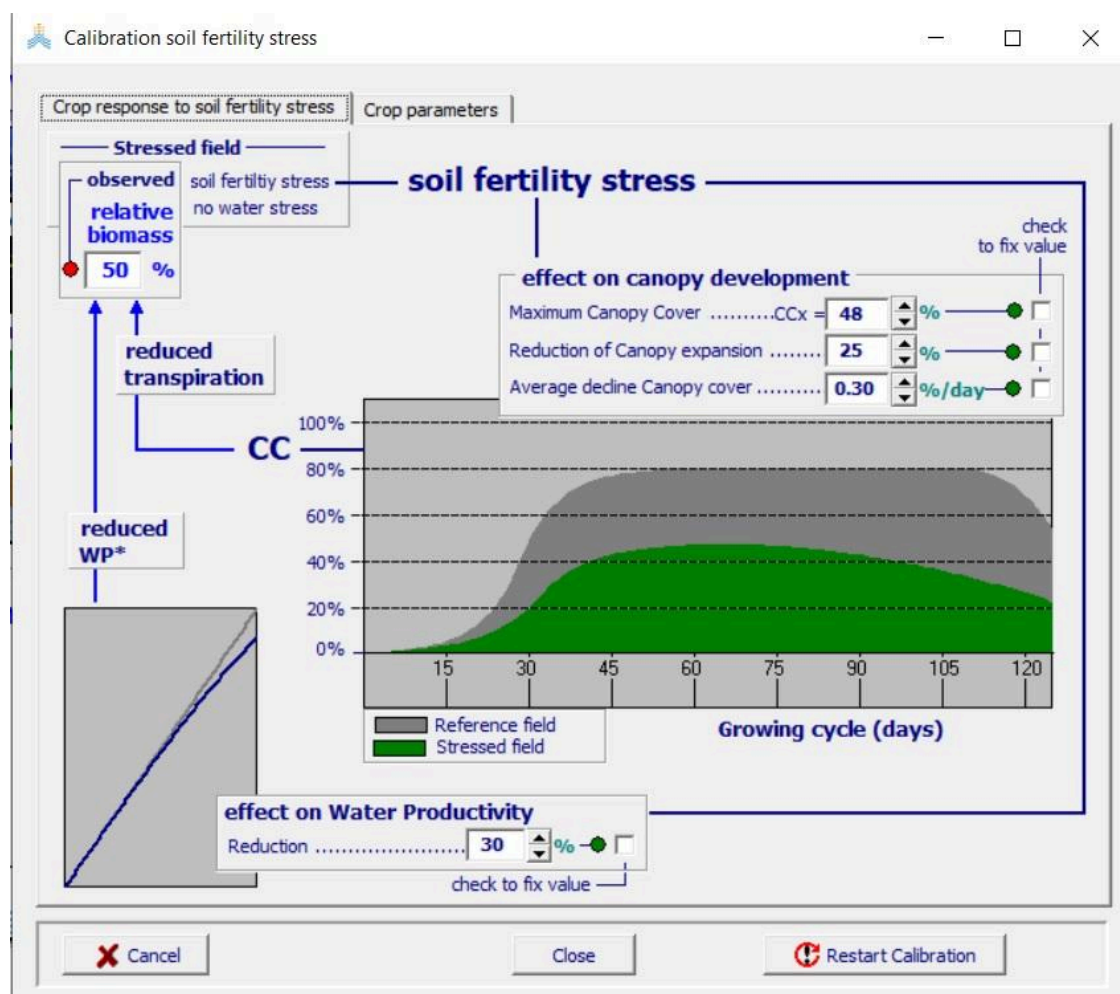


Fig. 11. Calibration soil fertility stress main window

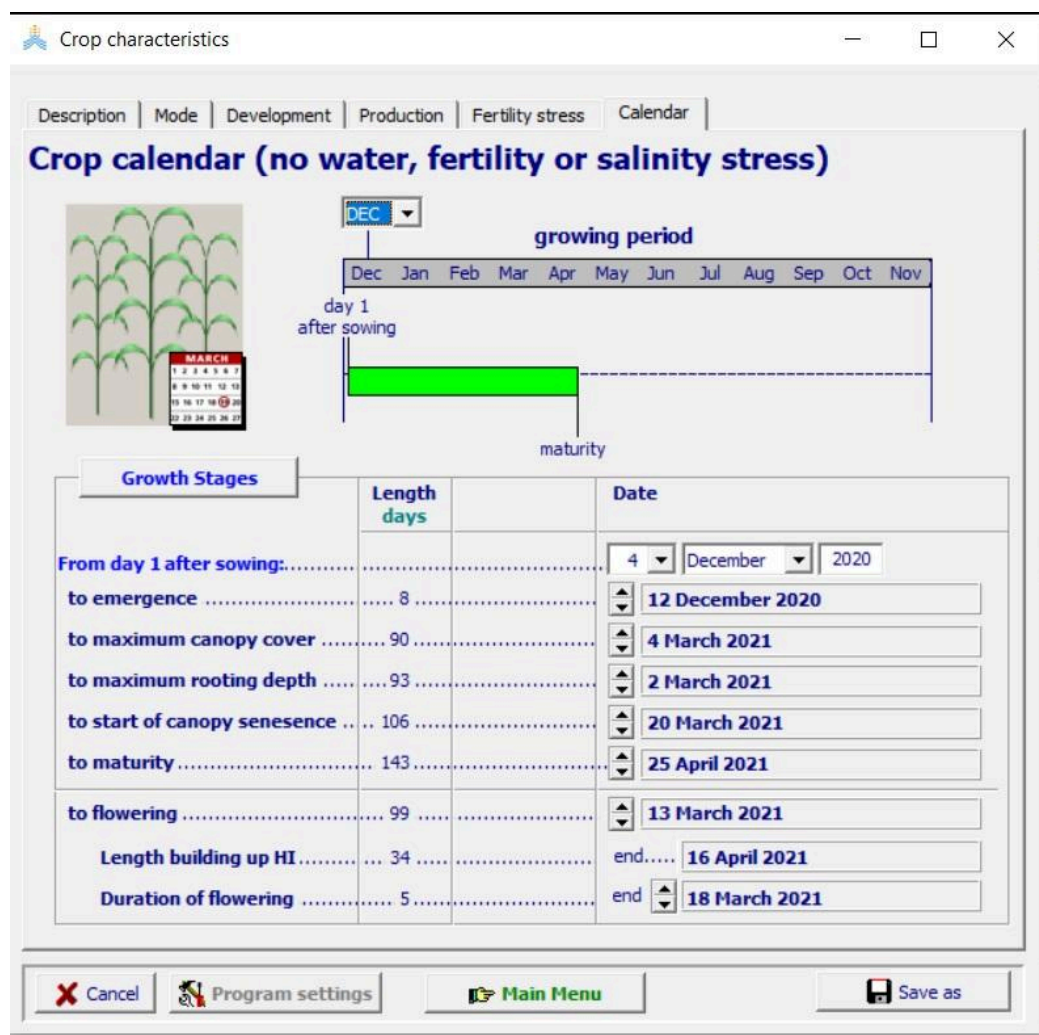


Fig. 12. Calendar tab in crop characteristics main window

The common wheat root depth is 1.2 meters, and with no soil horizon, the root deepening in Al Ain farm was 1 meter. The appropriate time for wheat harvest is from the middle of April to the middle of May; that varies due to the temperature and sewing date. There is no fertility stress in soil and no water stress by the given irrigation schedule. The initial harvest index was determined to be 33% to gain the almost 4.5 tons/ha dry yield. Initial canopy cover was determined to be very high because of very intensive planting with direct sowing methods on the farm.

3.3. Management Data

In management data, all management activities will be entered as input data by the user. There are two categories for data entry: **1.** irrigation management and **2.** field management, and each of these will be explained as below:

3.3.1. Irrigation Data

AquaCrop as a crop simulation model could estimate the net irrigation water requirement, generate an irrigation schedule or determine the efficiency of an existing irrigation schedule By using the irrigation schedule in the irrigation file window (Fig. 13). You can enter your irrigation schedule as input data to model. The rainfed cropping could be simulated in the model as well. At the end of the model run, irrigation adequacy could be assessed by the user with water balance estimated data.

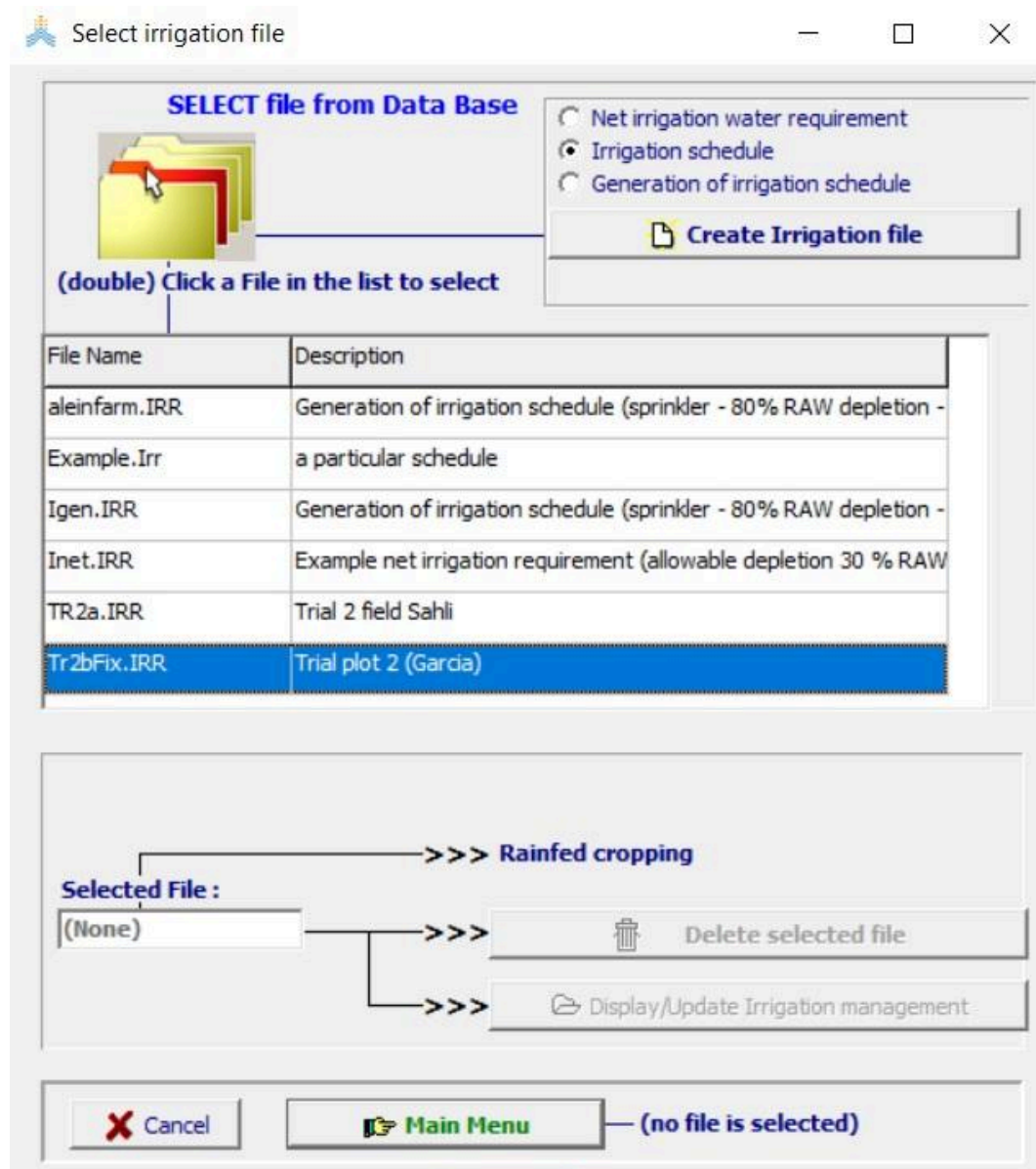


Fig. 13. Irrigation file selection main window

To enter the irrigation data, the first step is to choose the irrigation method and percentage of soil surface wetted in irrigation events. A guide for the upper and lower limits of each irrigation method is in the info bottom but generally this data should be determined by the irrigation designer or farm manager during the irrigation events.

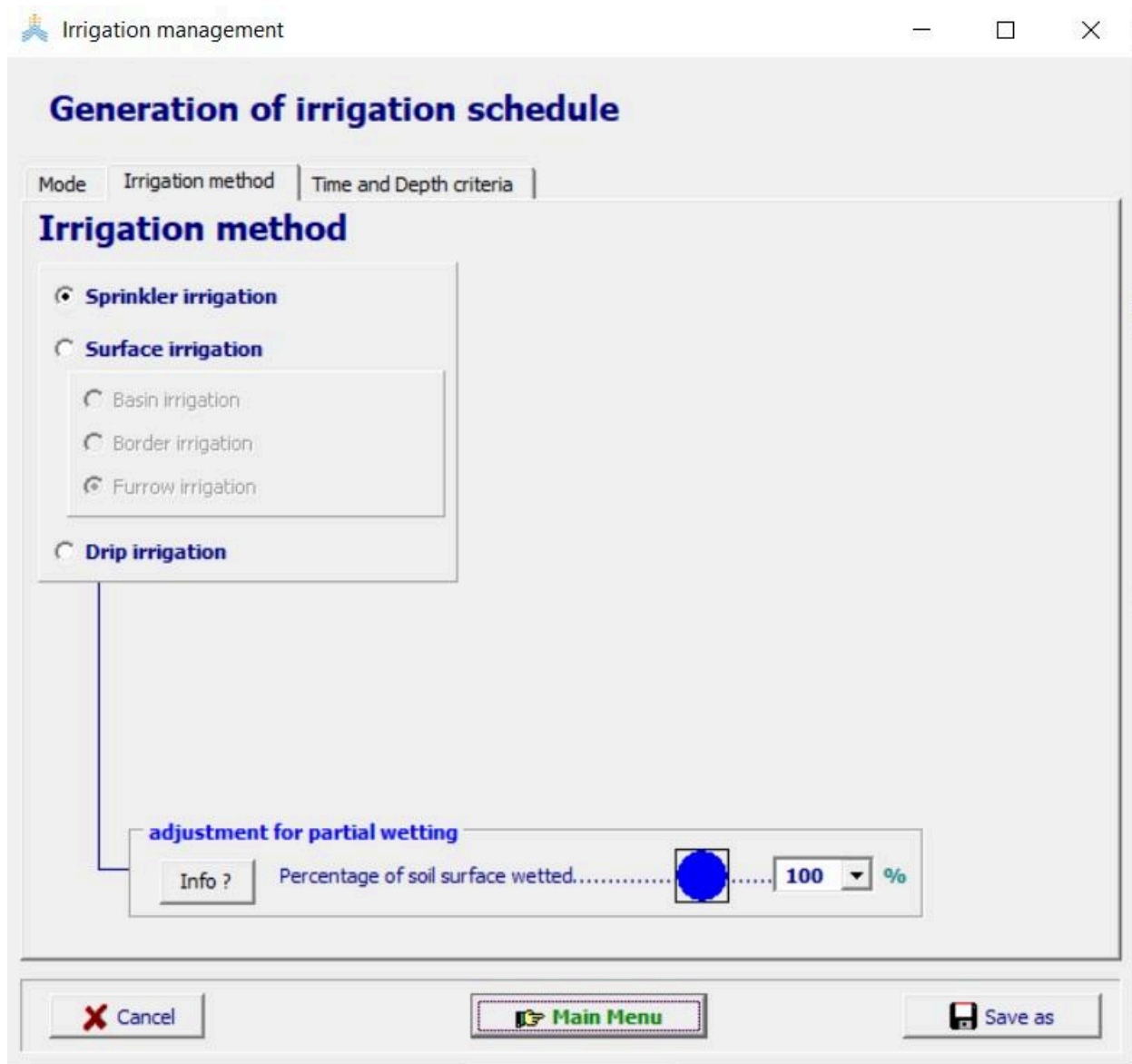


Fig 14. Irrigation method tab in irrigation management main window

The data required for the irrigation schedule includes the time and depth of irrigation water in all irrigation events during the growing season. The EC_w, which shows the salinity of irrigation water, is an important parameter. This data is used in soil salinity calculations and salinity stress during the growing season.

For generating irrigation schedules by AquaCrop plant growth model, the model needs a criteria for calculating the time of irrigation event. This criteria could be a fixed interval that is usually used for irrigation design on farms, or it could be more

complicated and use the soil water characteristics like allowable depletion and readily available water as it shows in Fig. 15. The depth of irrigation water could be fixed depending on soil characteristics .

Generation of irrigation schedule

Mode | Irrigation method | Time and Depth criteria

Time and depth criteria

soil bunds

Time Criteria

- ☐ Fixed interval
- ☐ Allowable depletion (mm water)
- ☒ Allowable depletion (% of RAW)
- ☐ Water layer between bunds

Depth Criteria

- ☒ Back to Field Capacity
- ☐ Fixed net application

Irrigation water quality

excellent

EC_w 0.0 dS/m

assign

Day No. 1 - day 1 after sowing: 4 December 2020

valid From When? Depth? Quality

| Date | Day No. | Depleted % RAW | To FC +/- (mm) | dS/m |
|-----------------|---------|----------------|----------------|------|
| 4 December 2020 | 1 | 80 | 0 | 0.0 |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

Growing period

Canopy Cover

Thresholds

Day No. 197 - maturity: 18 June 2021

Clear All Events

Cancel Main Menu Save as

Fig. 15. Generation of irrigation schedule main window

In Al Ain Farm, the present [irrigation system](#) is center pivot machines, which are categorized as [sprinkler irrigation](#). The given schedule was 20 mm. Irrigation water at a fixed interval of 10 days with a moderate quality ($EC_w = 1.5$ ds/m) enters the model manually and the irrigation file is created.

3.3.2. Field Management Data

Other field management than irrigation will be determined in this part, including soil fertility, mulches, field surface practice, weed management and multiple harvests.

Soil fertility calibration will be determined as a crop characteristic that was explained before. You can control the calibration in this window but for any changes, it's needed to go back to the crop characteristics window.

Mulches affect the soil evaporations and the type of these mulches and the coverage area are so important in the water balance simulated by the model.

The user-specific mulches could be defined by the reduction fraction in soil evaporation in the model.

The screenshot shows a software window titled "Field management" with a tabbed interface. The "Field surface practices" tab is active. It contains four radio button options: "do NOT affect surface runoff", "affect surface runoff" (selected), "prevent surface runoff", and "soil bunds". The "affect surface runoff" option is expanded, showing a diagram of a soil profile with a "soil profile characteristic" of CN = 61. This is adjusted by 10% to a new value of CN = 67. A "guide to adjustments" icon is also present. To the right, under the heading "surface runoff", there are four panels illustrating different runoff scenarios: 1) "soil profile characteristic CN = 61" with a blue arrow indicating runoff; 2) "increased by management CN = 67" with a red arrow indicating increased runoff; 3) "surface runoff inhibited CN = N/A" with a red X over a blue arrow; and 4) "storage of excess water CN = N/A" with a red X over a blue arrow. The bottom of the window has a toolbar with buttons for "Cancel", "Program settings", "Main Menu", and "Save as".

Fig. 16. Mulches tab in field management main window

Field surface practice, including any Practices affecting or inhibiting surface runoff should enter as input data in the AquaCrop simulation model. These practices are categorized in four types due to their effect on runoff or soil bunds. In the case of affecting surface runoff, their affection in increasing or decreasing the curve number of surface soil could be defined by user (Fig. 16)

In AquaCrop, weed infestation is expressed by the relative cover of weeds (RC), which is the ratio between the ground area covered by leaves of weeds and the total canopy cover of weeds and crop. RC is easily determined by estimating the fraction of the total canopy cover that is weed. It can be assessed by a visual estimate in the field or by analysing photographs taken vertically from above the crop.

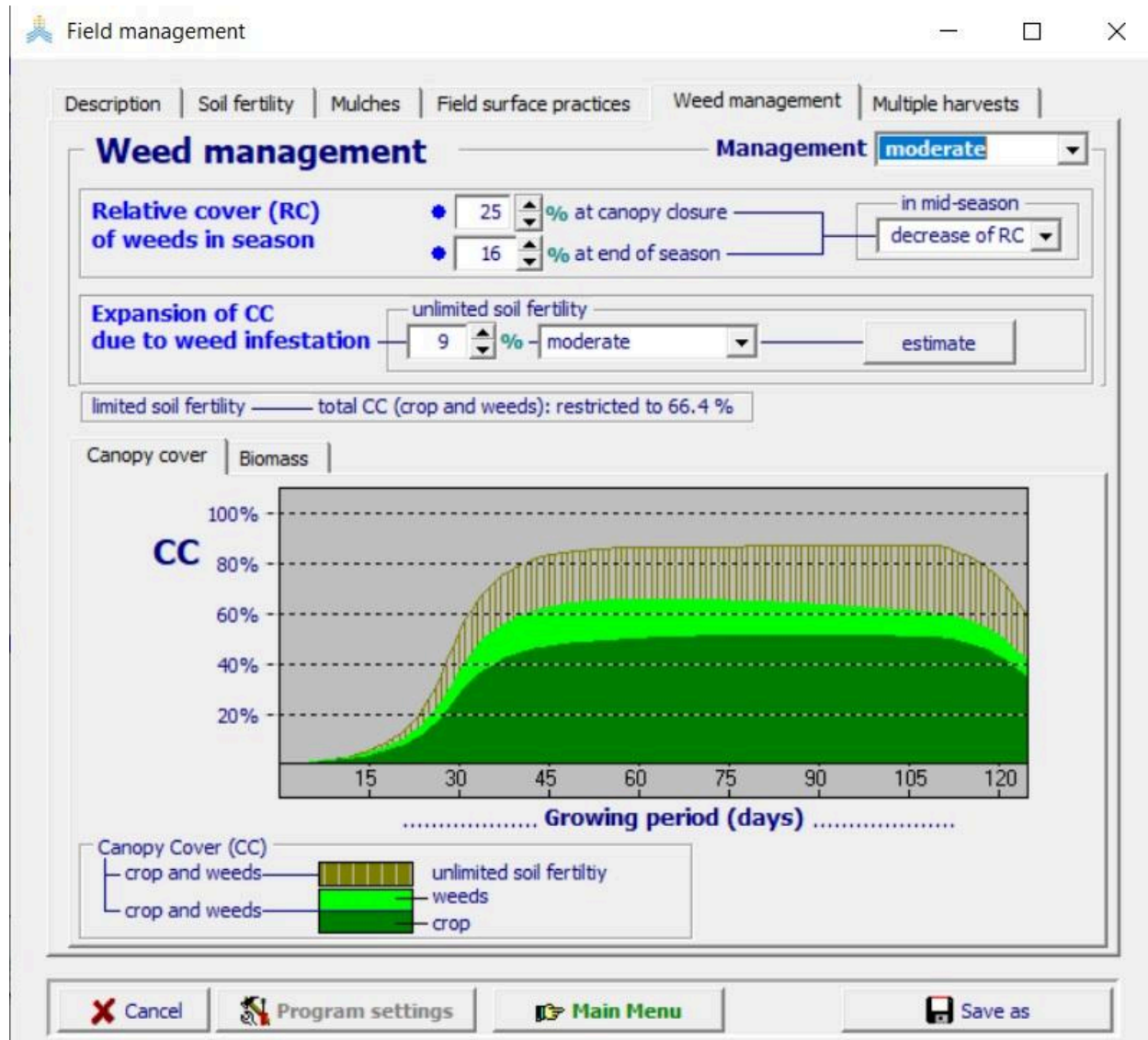


Fig. 17. Weed management tab in field management main window

In the 'Canopy cover' tab of Weed management (Fig. 17), the corresponding total canopy cover of crop (dark green) and weeds (light green) in the weed-infested field is displayed. The canopy cover for weed-free conditions (black line) is given as a reference.

3.4. Soil Data

Soil data consists of soil profile data and groundwater data will be entered by the user in this part. Although there are pre prepared soil files according to different soil

textural classes as default data in the model, we can use some other models to specify the hydraulic characteristics of soil or use the laboratory data instead.

3.4.1. Soil Profile Data

The first step of soil profile is to determine the number of soil horizons and their depth (Fig. 18). Soil profile data usually comes from field tests but there are some soil data banks of soil profiles that could help recognize the soil texture around the world. These data banks make data accessible with appropriate accuracy.

Create soil profile file

File al ein farm SOL

Description :
United Arab Emirates wheat farm

Number of Soil horizons 2

1
2
3

Soil textural class

Specify Soil Type

Specify Soil Type

Thickness

0.30 meter

0.70

Cancel Create


Fig. 18. Soil profile main window

In the second step, all characteristics of each soil horizon consist of texture and critical soil moisture point and hydraulic conductivity at saturation, which should be entered as input data (Fig. 19).

Soil profile characteristics

Description | Characteristics of soil horizons | Soil surface | Capillary rise

Characteristics



Number soil horizons
2

Click button to select indicative hydraulic properties from list

Plot
soil water


| horizon | description | thickness m | TAW mm/m | Soil water | | | Stoniness | Penetrability | | |
|---------|-------------|----------------|-------------|---|------|------|-----------|-------------------------------------|--------|------|
| | | | | retention in fine soil fraction vol % | | | | hydraulic conductivity mm/day | | |
| | | | | PWP | FC | SAT | | Ksat | tau | |
| 1 | sandy loam | 4.00 | 113 | | 10.0 | 22.0 | 41.0 | | 1200.0 | 1.00 |
| 2 | horizon 2 | 0.10 | 200 | | 10.0 | 30.0 | 50.0 | | 500.0 | 0.76 |

Update list of soil hydraulic characteristics

Cancel Program settings Main Menu Save as

Fig. 19. Characteristics of soil horizon tab

There is a guide in the model that can be used for updating the soil characteristics by their texture class (Fig. 20).


Edit of soil hydraulic characteristics

Indicative values for soil hydraulic characteristics

| Soil textural class | SAT | FC | PWP | TAW | Ksat | tau |
|---------------------|------|------|------|------|--------|------|
| | vol% | vol% | vol% | mm/m | mm/day | - |
| sand | 36.0 | 13.0 | 6.0 | 70 | 3000.0 | 1.00 |
| loamy sand | 38.0 | 16.0 | 8.0 | 80 | 2200.0 | 1.00 |
| sandy loam | 41.0 | 22.0 | 10.0 | 120 | 1200.0 | 1.00 |
| loam | 46.0 | 31.0 | 15.0 | 160 | 500.0 | 0.76 |
| silt loam | 46.0 | 33.0 | 13.0 | 200 | 575.0 | 0.80 |
| silt | 43.0 | 33.0 | 9.0 | 240 | 500.0 | 0.76 |
| sandy clay loam | 47.0 | 32.0 | 20.0 | 120 | 225.0 | 0.58 |
| clay loam | 50.0 | 39.0 | 23.0 | 160 | 125.0 | 0.47 |
| silty clay loam | 52.0 | 44.0 | 23.0 | 210 | 150.0 | 0.50 |
| sandy clay | 50.0 | 39.0 | 27.0 | 120 | 35.0 | 0.30 |
| silty clay | 54.0 | 50.0 | 32.0 | 180 | 100.0 | 0.43 |
| clay | 55.0 | 54.0 | 39.0 | 150 | 35.0 | 0.30 |

Textural class —>>

Update

Delete

New

X Cancel

Save and Exit

Fig. 20. Guide for soil profile characteristics available in AquaCrop model

Soil surface tab describes the curve number of soil surface. There are some guidelines for determining the curve number of soils and their classifications.

The maximum total depth of water that can be evaporated from the surface soil layer which is termed "total evaporable water," or TEW and the maximum total depth of water that can be evaporated during stage 1 is termed "readily evaporable water," or REW. Table 1 includes recommended values for REW.

Table 1. Recommended value for REW ([Allen, 1998](#))

| Soil Texture Classification | REW (mm) |
|-----------------------------|----------|
| Sand | 2 - 7 |
| Loamy sand | 4 - 8 |
| Sandy loam | 6 - 10 |
| Loam | 8 - 10 |
| Silt loam | 8 - 11 |
| Silt | 8 - 11 |
| Silt clay loam | 8 - 11 |
| Silty clay | 8 - 12 |
| Clay | 8 - 12 |

Table 1. Recommended value for REW

The last tab in soil profile characteristics describes the capillary rise, which is related to the depth of groundwater in the farming lands. The most important point in capillary rise is its direct affection in water balance in the root zone. If the depth of groundwater is more than 10 meters, the capillary rise effect will be zero.

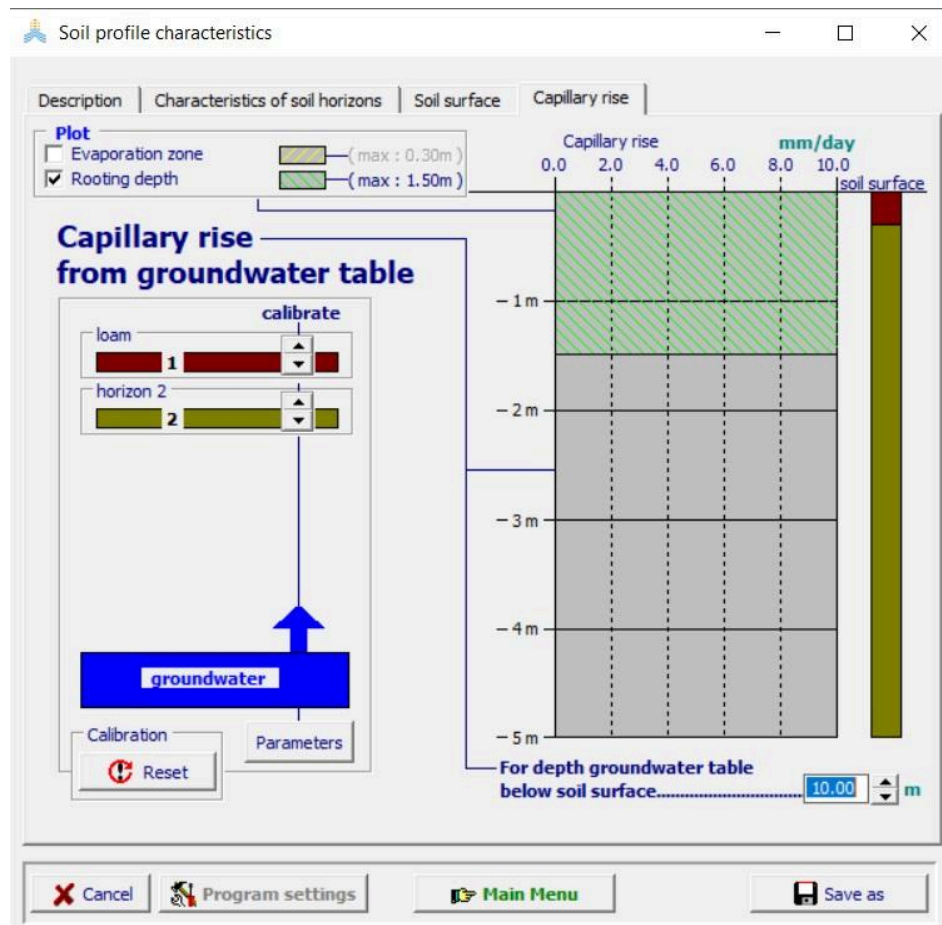


Fig. 21. Capillary rise tab in soil profile main window

Soil data for Al Ain farm was extracted from [Harmonized World Soil Database v2.0](#) and the soil profile characteristics were extracted by AquaCrop soil guide in the model.

3.4.2. Groundwater Data

The groundwater table could be constant or varying during the growing season. These input data are usually based on long-term observed data around the field. This data is linked to the capillary tab and will be corrected after creating and saving the groundwater file.

There is no Aquifer in the Al Ain farm zone. Therefore, no capillary rise will happen during the growing season, which means that no groundwater table is determined in the model.



Fig. 22. Groundwater data min window

The needed data for the groundwater table is the time, depth and salinity of each data observation event.

3.5. Simulation

To start the simulation process, most of the needed data have been described in previous stages. One of the needed data points for starting the simulation is initial conditions. One of the common initial conditions is soil water and salinity that let users define the final condition of soil water and salinity before sewing for more

accuracy in the simulation process. [Soil moisture meters](#) could give live and updated data, which helps you to improve the accuracy of your simulation.

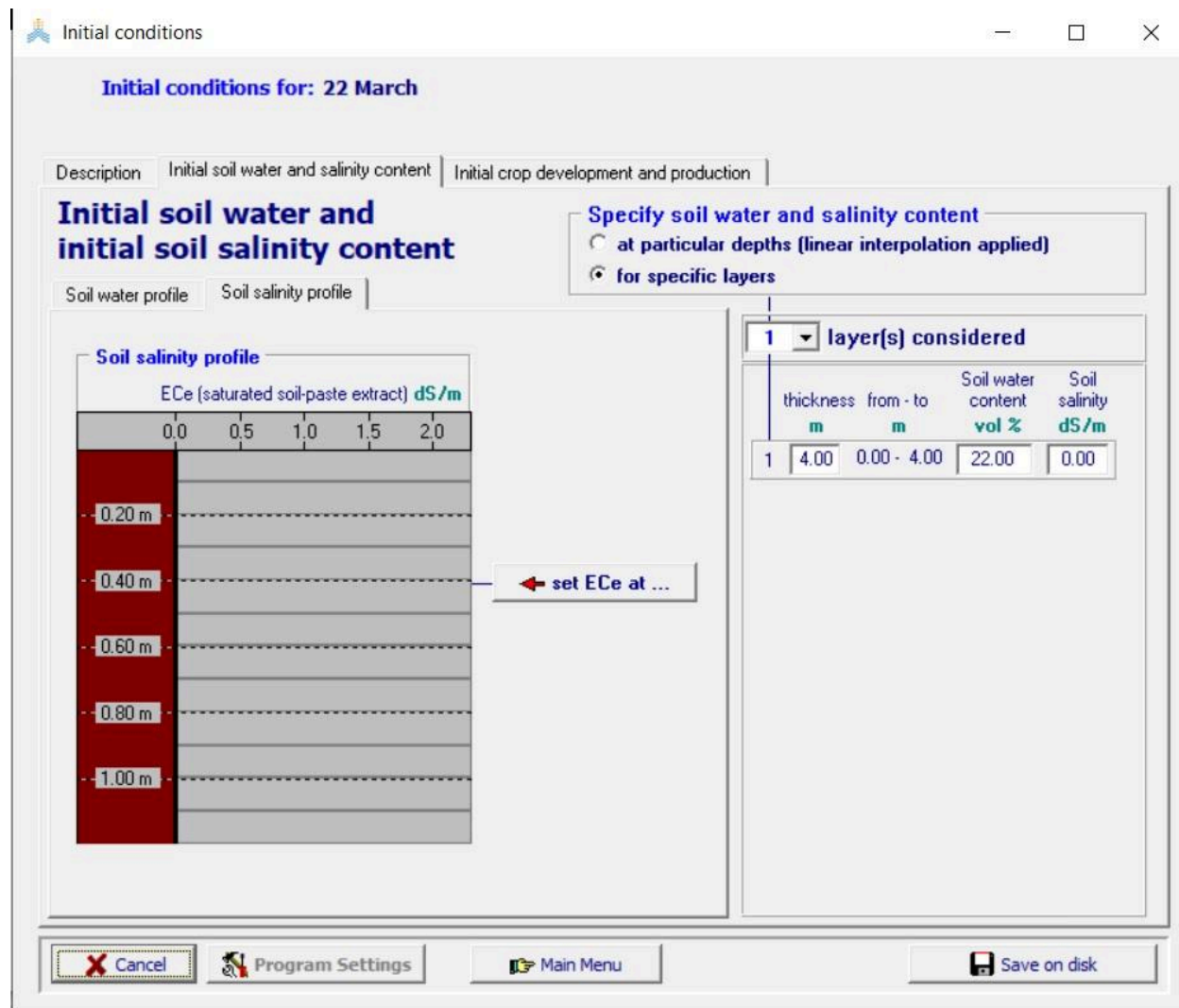


Fig. 23. Initial condition for soil water and salinity tab

Initial crop development and production are linked with the crop characteristics main window, the tab of development and production that describe before.

The project bottom lets you save all files as a project and run them in single or multiple runs for successive years.

Field data bottom lets you add your observation data and compare them with simulated values.

In the simulation run main window, you can choose the time step of running or choose a specific date in the growing season for showing the result of simulation. The default of the model is to simulate the end of the season and all results will be at the end date (Fig. 24).

4. Output Data

In the simulation main window and after running the program (Fig. 23), the main information is the simulated biomass and yield at the end of the season. The stress box indicates the stresses that affected your crop yield during the season.

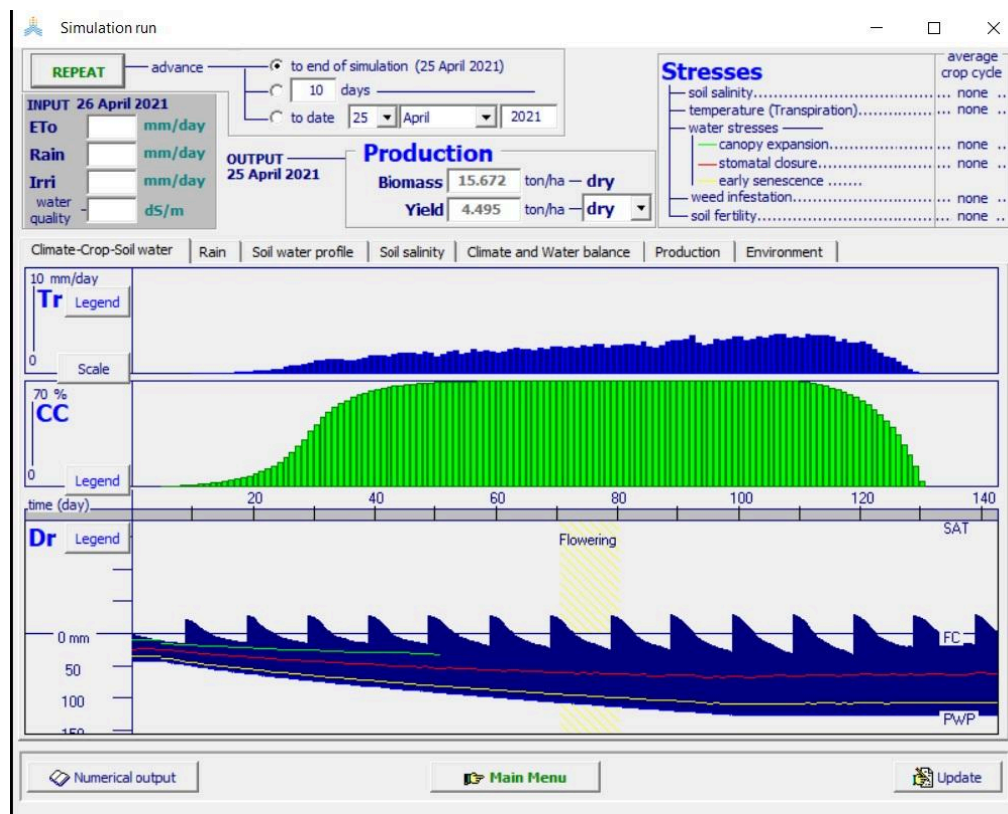


Fig. 24. Simulation run main window

AquaCrop plant growth simulation models have the option of graphical data in the simulation main window. In the rain tab, by choosing any parameter, the simulation values and their fluctuation during the season will be shown graphically. In Fig. 25, the deep percolation presented during the growing season graphically.

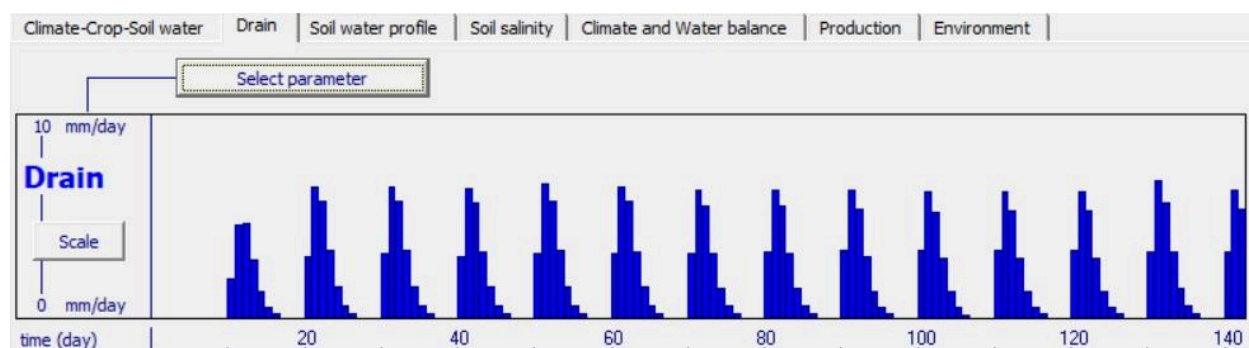


Fig 25. Deep percolation graphical show

One of the most important outputs of AquaCrop is water balance at the end of season (Fig. 26) In this box, the estimated values of evaporation, transpiration and runoff, infiltrated and drained water during the season will be shown. These data could be used for assessment given the irrigation schedule.

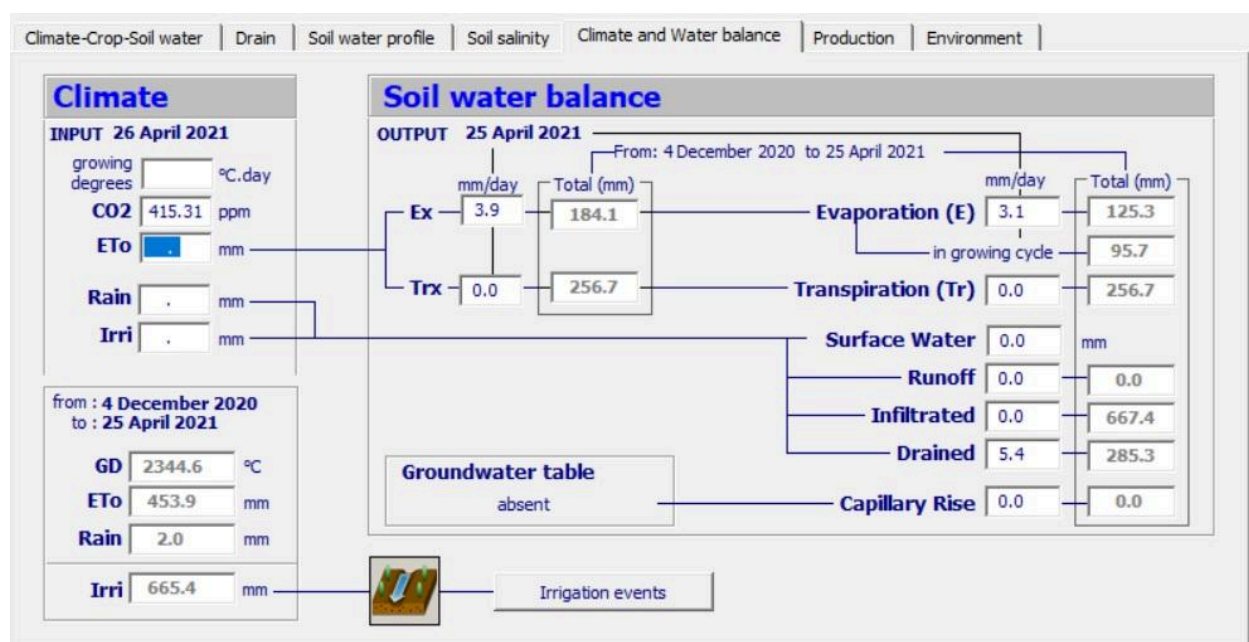


Fig 26. Climate and water balance box in simulation run main window

In the production tab, the actual production and adjusted HI will be shown. Besides, the calculated ET water productivity will be presented as well.

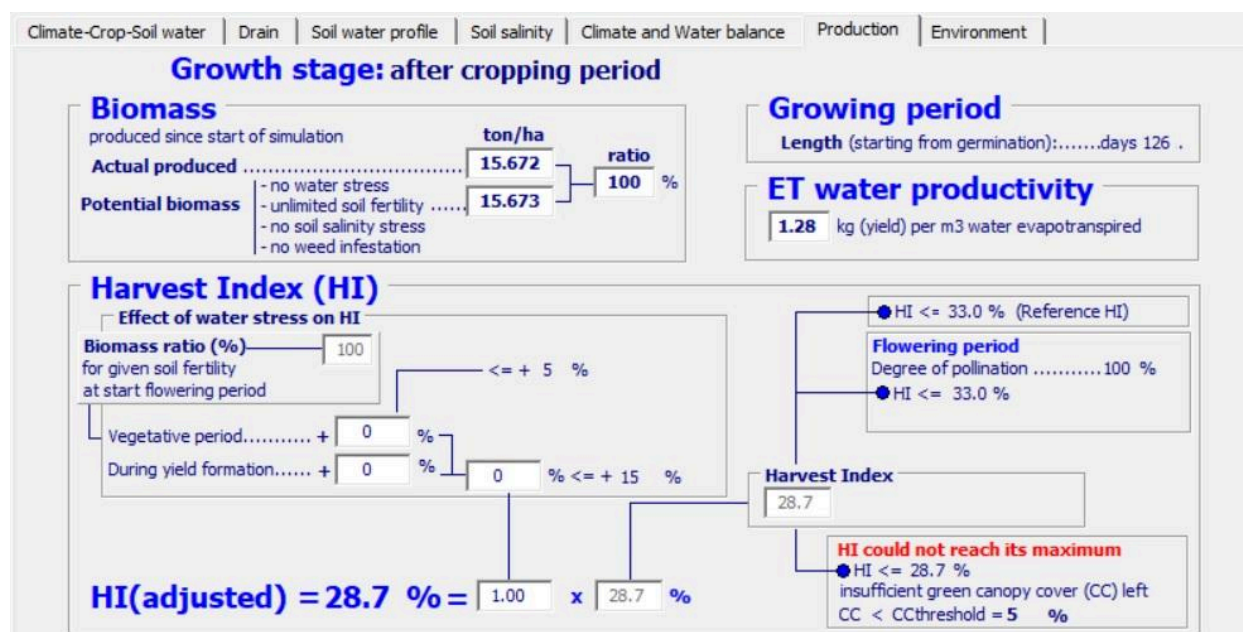


Fig. 27. Production tab in simulation run main window

All data in the simulation run main window can be presented as a table in the numerical output bottom. This data could be saved as text files before leaving the simulation run window (Fig. 28).

In Al's farm, the calculated yield is 4.5 tons/ha, which is compatible with observed data. The adjusted harvest index in this farm is 28%, which is lower than the initial value and the model commented that insufficient canopy cover caused the HI to not reach the maximum value. This means that the growth of canopy cover is limited so it is essential to revise the planting density of time of sewing in the future.

The total evapotranspiration on this farm is 453 mm and the total irrigation is 665 mm. According to the low amount of rainfall in the growing season, all needed water for planting comes from irrigation water, But the amount of drained water shows that more than one-third of irrigation water was drained from the root zone. This means that the irrigation schedule could be improved and redesigned to decrease the drained water. The soil salinity shows the cumulative amount of salt in the root zone. This accumulation could cause salinity in the future. In this case, the leaching portion of irrigation water should be revised every few years according to the live situation of soil salinity and irrigation water quality.

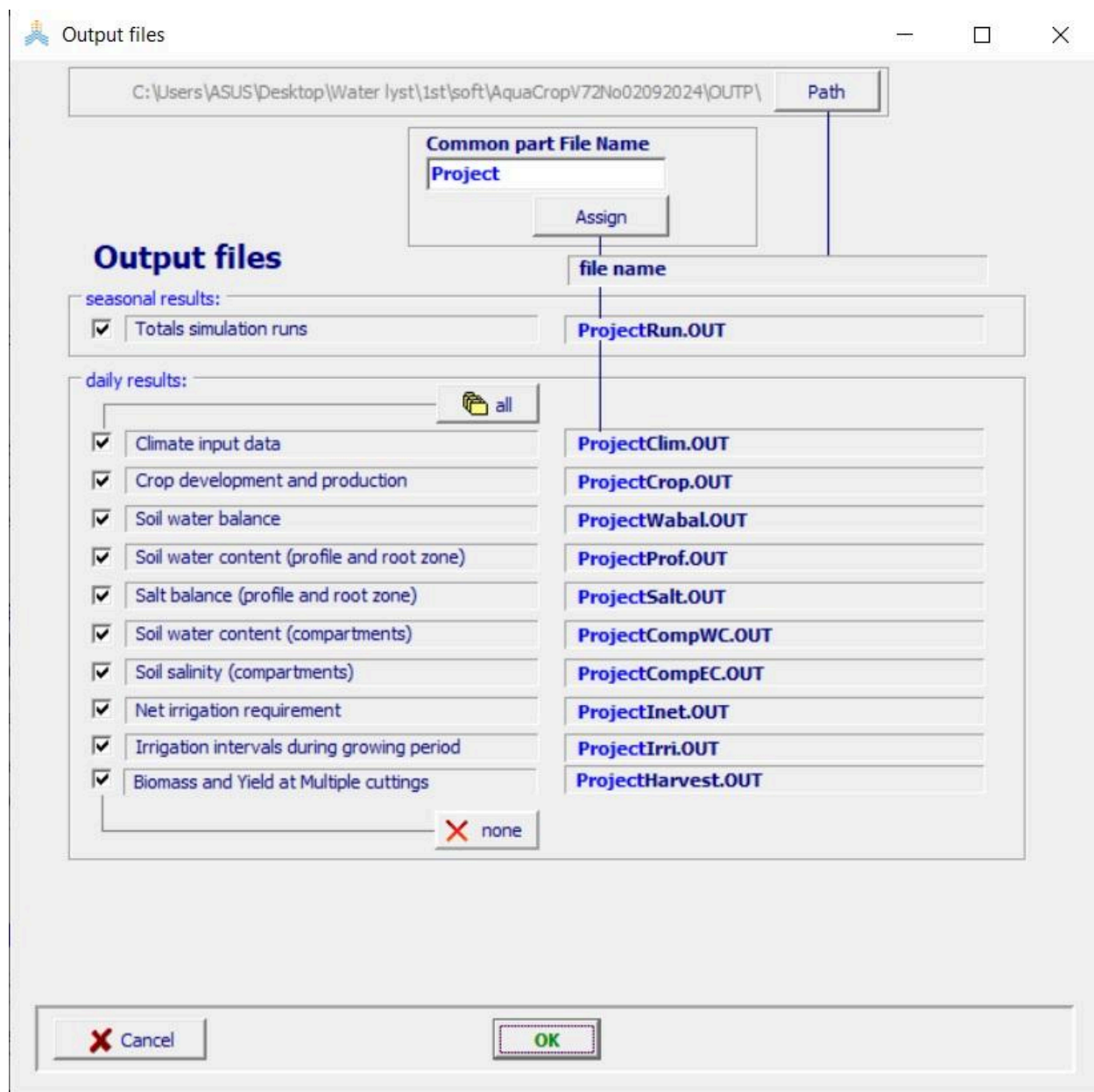


Fig. 28. Output file save window

5. Calibration

The Advanced AquaCrop simulation model key point is user-friendly and has few input data. From 2009 till 2023, various studies were conducted to calibrate this model around the world. Most of these studies are available as default crop files in the

model. On the other hand, there are some options in the model that let you create new crop files through your studies.

In crop data, there is a full mode that lets you reach conservative crop parameters that are not related to the local environment of planting.

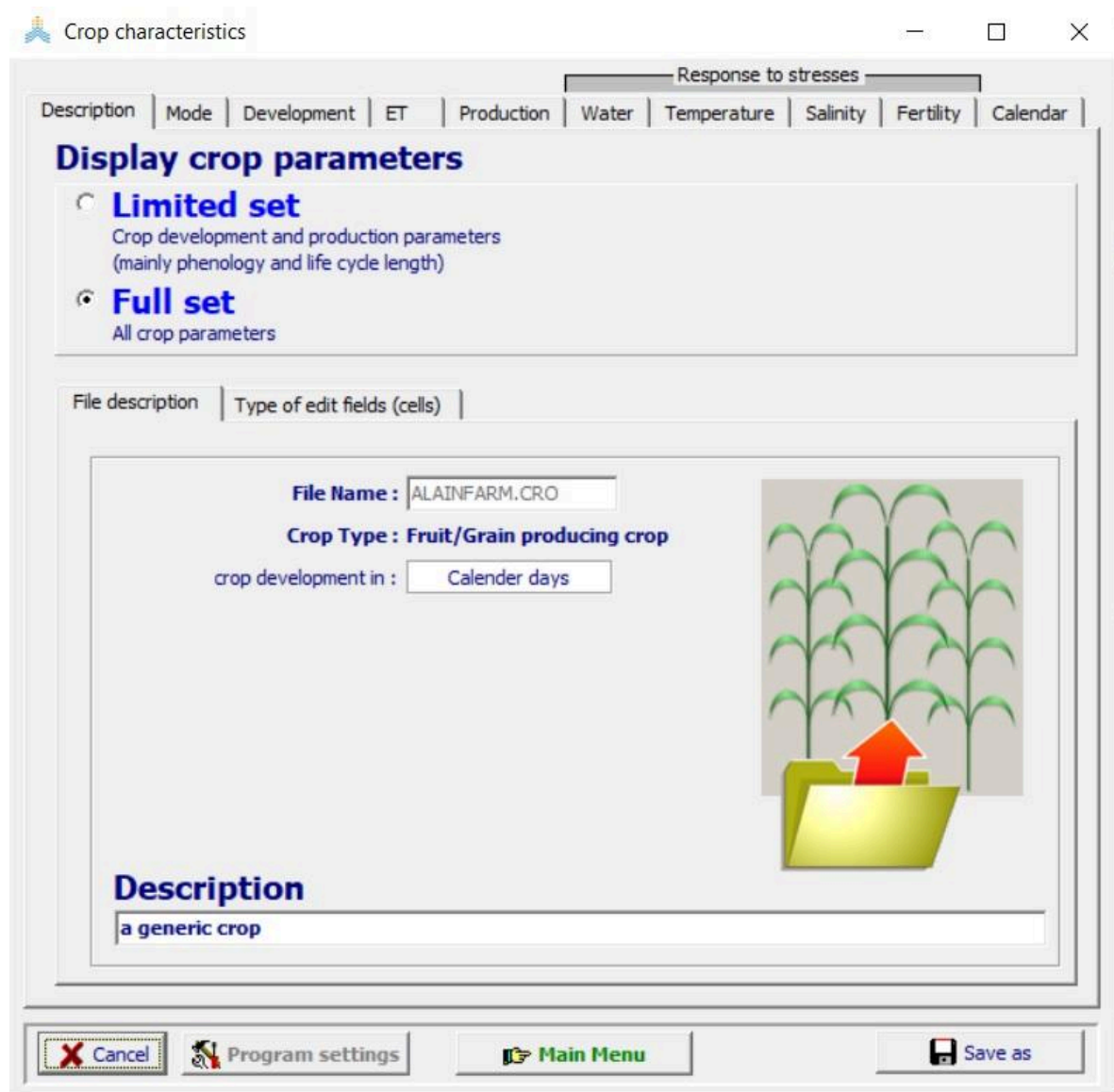


Fig. 29. Crop characteristics main window in full mode

Fig. 29 presents the crop characteristics main window in full mode. In this mode, some new tabs will appear for professional users to have the deep calibration or even define a new crop.

Crop transpiration is calculated by multiplying the reference evapotranspiration (ET_o) with the crop transpiration coefficient (K_{cTr}) and by considering a water stress (K_s) and cold stress ($K_{sTr,x}$) coefficient, which are 1 when stress does not induce stomatal closure.

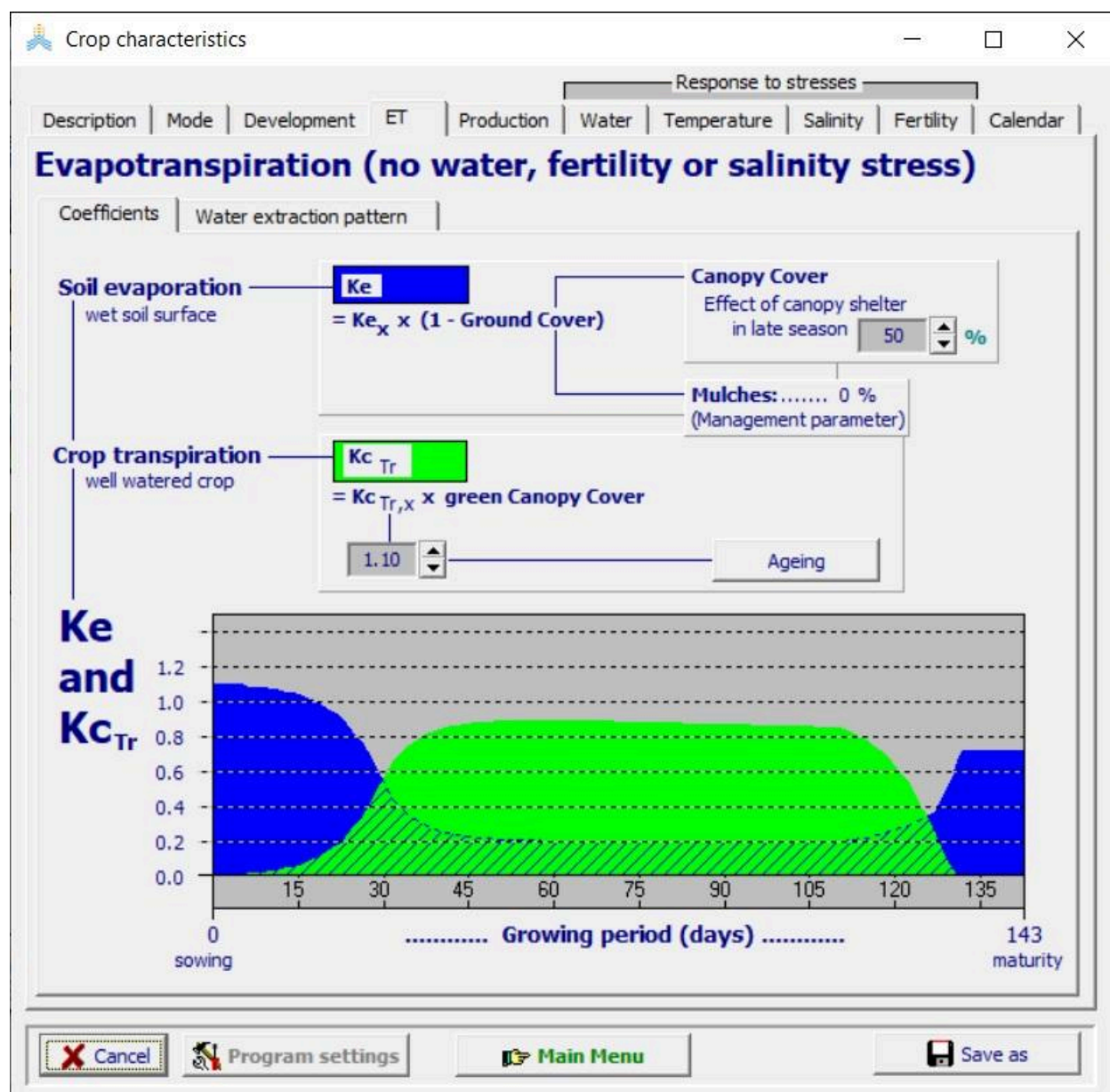


Fig. 30. ET tab in crop characteristics full mode

where $K_{cTr,x}$ is the crop coefficient for maximum crop transpiration (determined by the characteristics that recognize the crop with a complete canopy cover from the

reference grass). For most crops, $K_{cTr,x}$ is in the range of 1.05 up to 1.20. $K_{cTr,x}$ which is adjusted downwards for aging throughout the crop cycle and senescence of the crop.

The effect of water stress on crop transpiration is simulated by the water stress coefficient (K_s) with $K_{cTr,x}$ as the main crop parameter. If the stress is caused by the shortage of water, a soil water stress coefficient for stomatal closure (K_{ssto}) is considered. If the stress is caused by the excess of water, a soil water stress coefficient for water logging or deficient aeration (K_{saer}) is considered. When the water content in the root zone drops below the threshold for K_{saer} or is above the threshold for K_{saer} , the stress coefficient becomes smaller than 1 and crop transpiration declines. These coefficients are the professional tools for deep calibration.

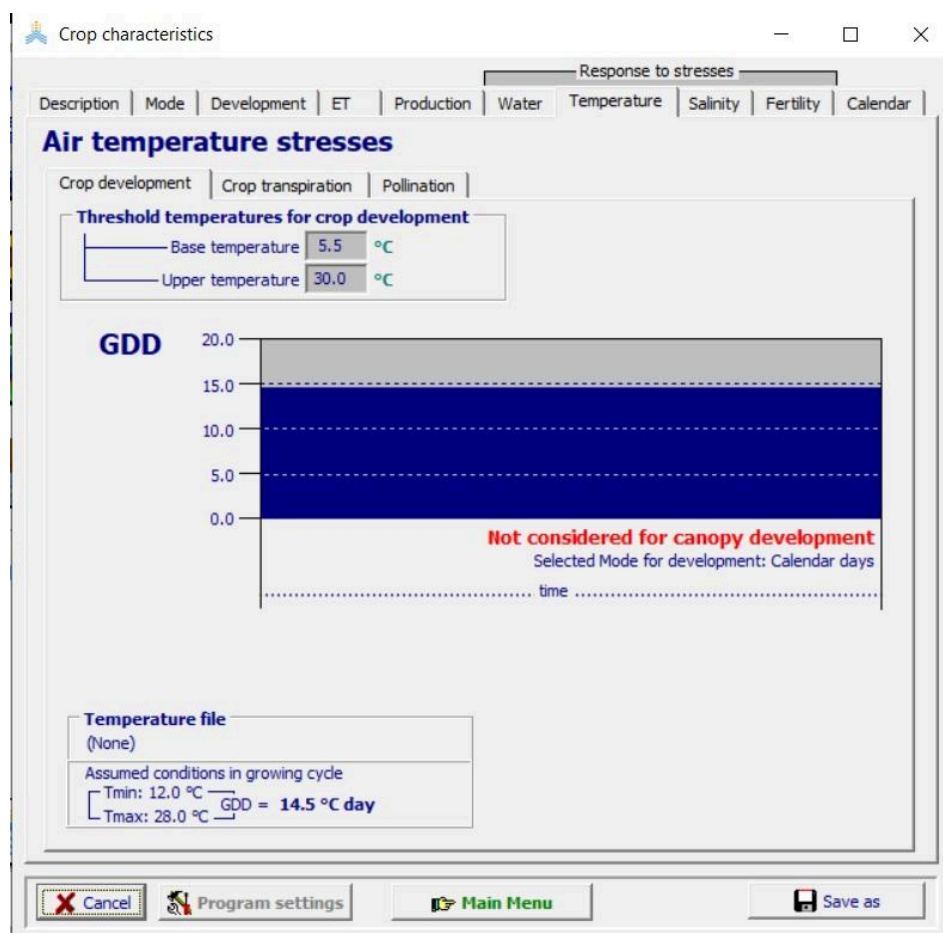


Fig. 31. Temperature tab in crop characteristics full mode

In the temperature tab (Fig. 31), the needed data for cold stress will appear, including the upper and base temperatures for crop development. To simulate the effect of cold stress, a temperature stress coefficient for crop transpiration (K_{sTr}) will be considered. The growing degree days (GDD), which can be generated in a day, are used as the stress indicator to describe cold stress on crop transpiration.

Soil salinity stress is simulated with a soil salinity stress coefficient (K_{ssalt}). The average electrical conductivity of the saturation soil (EC_e) from the root zone is the indicator for soil salinity stress. The upper and lower thresholds for EC_e are crop-specific. In the temperature tab (Fig. 31), the needed data for cold stress will appear, including the upper and base temperatures for crop development. To simulate the effect of cold stress, a temperature stress coefficient for crop transpiration (K_{sTr}) will be considered. The growing degree days (GDD), which can be generated in a day, are used as the stress indicator to describe cold stress on crop transpiration.

Soil salinity stress is simulated with a soil salinity stress coefficient (K_{ssalt}). The average electrical conductivity of the saturation soil (EC_e) from the root zone is the indicator for soil salinity stress. The upper and lower thresholds for EC_e are crop-specific and will be the input data in this tab.

Soil salinity stress causes smaller canopy cover (CC) and a closure of the stomata.

Smaller canopy cover: Soil salinity stress decreases the growing capacity of the crop as well as the maximum canopy cover (CC_x) that can be reached at mid-season. Due to the salinity stress in the soil, canopy cover will steadily decline at mid-season.

Stomatal closure: Due to osmotic forces, the salts in the root zone make the water less available to the crop, which will be the input data in this tab.

Soil salinity stress causes smaller canopy cover (CC) and a closure of the stomata.

Smaller canopy cover: Soil salinity stress decreases the growing capacity of the crop as well as the maximum canopy cover (CC_x) that can be reached at mid-season. Due to the salinity stress in the soil, canopy cover will steadily decline at mid-season.

Stomatal closure: Due to osmotic forces, the salts in the root zone make the water less available to the crop.

When soil salinity stress occurs, AquaCrop adjusts the values of stress coefficients (affecting canopy development and stomatal closure), which means that the simulated crop transpiration and the corresponding biomass (B) become equal to the required reduction given by K_{salt} .

Soil salinity calibration should be done with caution that reminds the developer of the model (Fig. 32). This calibration needs a high theoretical background and is very detailed laboratory tests.

6. Conclusion

The AquaCrop crop simulation model is one of the user-friendly and water-driven models developed by FAO. This model could help in predicting the crop yield and generating an irrigation schedule or net water requirement of your planting schedule during the season. However, it could help you to calculate the effect of water deficit or other stresses like temporal or salinity stress in your expected yield at the end of the season.

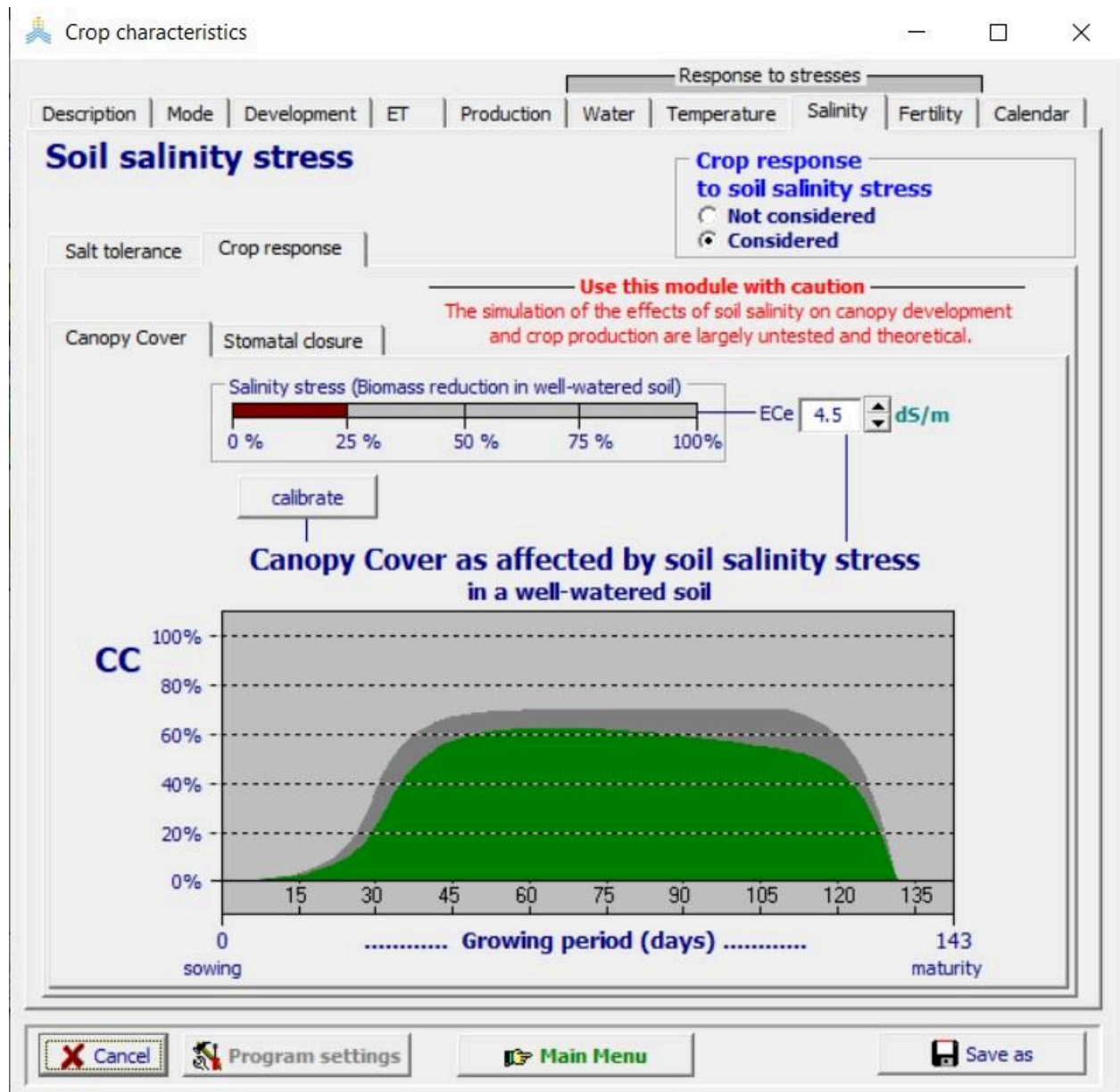


Fig. 32. Salinity tab in crop characteristics full mode

This model provides good tools for academic and practical studies related to crop yield and water productivity. As the [AquaCrop source code](#) is available, it can be used in combination with other models and software to vast the area of studies.

This model could be used for any feasibility studies or economical assessment of new farms all around the world through the difference in climate and water resources

quality and quantity. Farmers and engineers are the practical users of this model. Although global warming and climate change, this model can be used for any climate change assessment in agricultural production.

Quiz

To test the material learned in this article, you are invited to answer the quiz raised from the text.

About Software

1. What is the core calculator category of the AquaCrop model?

- A) carbon dioxide-driven model
- B) solar radiation-driven models
- C) water-driven**
- D) None

2. How does AquaCrop predict the crop yield?

- A) By calculating evapotranspiration
- B) By using soil water balance
- C) By normalizing water productivity
- D) By calculating evapotranspiration and normalizing water productivity**

3. What is the AquaCrop specific criteria in crop yield simulation?

- A) WP
- B) HI**
- C) LAI
- D) BIOMASS

4. What is the first step in crop simulation in AquaCrop?

- a) Soil water balance**
- b) Crop evapotranspiration
- c) Crop canopy cover development
- d) Germination

5. What is the main equation in AquaCrop for yield prediction?

- A) Doorenbos and Kassam (1979)**
- B) FAO- Penman- Monteith
- C) Soil water balance equation
- D) Noun

Input Data

6. What is ET?

- A) Crop transpiration
- B) Reference evapotranspiration
- C) Crop evapotranspiration**
- D) None

7. What criteria could be defined in the calendar file?

- A) Temperature threshold
- B) Precipitation threshold
- C) Sowing date
- D) All**

8. Which of the field management practices can not be simulated in the AquaCrop model?

- A) Soil fertilizing
- B) Weed management
- C) Multiple harvest
- D) crop dusting**

9. Which parameter is not essential data for soil data input in AquaCrop?

- A) Soil horizons number
- B) Total available water (TAW)**
- C) Soil permanent wilting point (PWP)
- D) Soil Electrical Conductivity (EC)

10. What is the default value for missing climate data in AquaCrop?

- A) -99
- B) -999**
- C) -90
- D) -9999

Data Analysis

11. When is the GDD crop file used?

- A) In normal crop simulations
- B) In rainfed crop simulations
- C) In off-season crop simulations
- D) In rainfed or off-season crop simulations**

12. Which parameters can be calculated by the AquaCrop model?

- A) Net irrigation requirement
- B) Irrigation schedule
- C) Planting schedule
- D) Net irrigation requirement and generate Irrigation schedule**

13. What type of irrigation methods are supported in AquaCrop?

- A) Surface irrigation and drip irrigation
- B) Sprinkler irrigation and drip irrigation
- C) Surface irrigation only
- D) Surface irrigation, drip and sprinkler irrigation**

14. Which calibration needs detailed laboratory data?

- A) Soil salinity calibration**
- B) Air temperature stress
- C) Canopy cover stress
- D) Water stress calibration

15. What is the maximum level that capillary rise from groundwater could occur?

- A) 10 meters**
- B) 5 meters
- C) 15 meter
- D) 2 meters

Output Data

16. What are the final output data time steps in AquaCrop?

- a) Daily**
- b) 10-days
- c) Monthly
- d) Depends on entered data time step

17. Which of the stresses can Be simulated by the AquaCrop model?

- A) Water stress and temperature stress
- B) Water stress and salinity stress
- C) Soil salinity stress and fertility stress
- D) Water, salinity and temperature stress**

18. Which of the soil water balance parameters are calculated in the AquaCrop model?

- A) Infiltration
- B) Soil transpiration
- C) Runoff
- D) All**

19. What is the common format of AquaCrop outputs?

- A) *.OUT**

- B) *.REP
- C) *.TMP
- D) *.IRR

20. AquaCrop calibration related to which input data?

- A) Field management data
- B) Crop characteristics data**
- C) Climate data
- D) Soil data

FAQs

1. What is the most important checkpoint for assessing model accuracy?

AquaCrop is a crop simulation model, due to the conceptual model the most important checkpoint in this model is crop yield. This output lets you know how the other outputs are reliable before calibration. The second parameters that help users to identify the accuracy of the model in first application are soil water balance parameters such as runoff, precipitation, infiltrated and drained water. These parameters are the simplest and most accurate way for model calibration through the field data.

2. How simulate rainfed crop yield with no specific sowing date in AquaCrop?

In rainfed crops that their actual growth starts at a specific precipitation threshold or temperature, AquaCrop lets users define these thresholds in the calendar tab. By creating a new calendar file users can define the essential precipitation or temperature threshold for starting the simulation of crop growing cycle.

3. How to define a new crop in AquaCrop?

By choosing the button to create a new crop file, users can define a new crop in AquaCrop. New crops can be an annual crop or permanent crop. The most important point in defining a new crop for the model and accurate simulation is the crop specific coefficients which need laboratory results for calibration and model validations.

4. Can AquaCrop be used for different crops in a field at the same time or more than one field?

Standard version of AquaCrop is a point base model and can simulate one crop in one field with specific soil characteristics and management. But other versions of AquaCrop such as the stand alone version or GIS-version let users have multiple simulations in an area (more than one field) or for crop variation in one field.

5. What is the difference between AquaCrop versions?

All AquaCrop versions use the same conceptual model and equations. In each new version of AquaCrop some graphical or numerical output options had been added to improve the simplicity and availability of model results. For each version of the model there is a release note that describes the changes from the older version. These notes are available at the official model website.

6. Why is the result of the model 0.00 at the end of the season?

Zero yield means the crop does not have any production during the season. This comes from some calculation error due to entered data. In the first step check the calendar file. If the sowing date isn't compatible with your climate the yield will be 0.00. Pay attention to the red message in the main menu that alerts you "simulation period does not cover crop growing period". For second planting or any off season planting it is recommended to use the GDD crop file for more accurate results.

7. How to estimate the plant density as a crop characteristic ?

The plant density is the number of plants planted in one hectare. This parameter depends on crop specific and local climate generally. Asking the farmers or the local expertise is the most trustable way to determine this parameter.

8. How essential is it to calibrate the model?

According to the equations and conceptual model of AquaCrop and due to different climate effects on crop growth cycle, it is strongly recommended to calibrate the model in first application. Any application without calibration could cause some errors in output results.

9. If the input climate data time step will not be daily can the model run in daily time step?

The quality of entered data is affected by the accuracy of the model but the standard time step for the AquaCrop model is the daily time step. The model can not be run in time step less than a day but simulation will happen daily and users could have the daily output finally.

10. Does AquaCrop need installation system configurations?

AquaCrop in all versions does not need any installation but during downloading the related version you need to choose the appropriate version that is compatible with your operating system such as windows or macintosh or linux (32 or 64 bit).

11. Is the result of the older version of AquaCrop still trustable?

According to the concept of AquaCrop model and due to the release note for each version, most of the changes in AquaCrop different version back to model interface improvement and in some cases improve the accuracy of equations used for stress simulation in the model. But the general result of the all version of AquaCrop has appropriate accuracy.

12. How to create a graphical output in AquaCrop?

In general AquaCrop does not link to any external graphic module. Users can screenshot the graphics created in the main window of output data by changing the label of the axis on their own. For any other graphics you can use the output data and import them to other software for better results.

13. Will the older version of AquaCrop be updated to the new versions?

For any application of the new version of AquaCrop, users should uninstall the older versions and download and install the new version of software. The older version could not be updated but it will not expire and can be used as they are installed.

14. How to enter the irrigation data for subsurface irrigation in AquaCrop?

Subsurface irrigation is not supported in AquaCrop yet. For this kind of the application the irrigation method should be considered to the nearest method to subsurface irrigation with some consideration. The output result should be controlled with soil water content in the calibration stage.

15. How to enter the off season field management practice in AquaCrop model?

The off season field management practices could not enter the model as the direct input data but their effect will be entered in the initial condition tab at the beginning of the growing season or after sowing date. These practices, such as soil preparation, residue management, or irrigation during the off-season, are indirectly reflected by adjusting the initial conditions like soil moisture, fertility, or residue cover. It is important to carefully assess how these practices impact the field's starting conditions to ensure accurate modeling of crop growth and yield.

CTA

Types and Categories

Types

- | | | |
|---|---|---------------------------------------|
| <input type="checkbox"/> Product Base | <input checked="" type="checkbox"/> Educational | <input type="checkbox"/> Solution |
| <input type="checkbox"/> Researched Based | <input type="checkbox"/> Specialized | <input type="checkbox"/> Storytelling |

Categories

- | | | |
|--|--|--|
| <input type="checkbox"/> Applications | <input type="checkbox"/> Hydrology | <input type="checkbox"/> Water Chemistry |
| <input type="checkbox"/> AI in Water Science | <input checked="" type="checkbox"/> Irrigation | <input checked="" type="checkbox"/> Water Conservation |
| <input type="checkbox"/> Climate Change | <input type="checkbox"/> Precipitation | <input type="checkbox"/> Water Distribution |
| <input type="checkbox"/> Distilled Water | <input type="checkbox"/> Product | <input type="checkbox"/> Water Harvesting |
| <input type="checkbox"/> Drinking Water | <input checked="" type="checkbox"/> Rainwater | <input type="checkbox"/> Water Management |
| <input checked="" type="checkbox"/> Drought | <input type="checkbox"/> Remote Sensing | <input type="checkbox"/> Water Pollution |
| <input type="checkbox"/> El Nino | <input type="checkbox"/> Saving Water | <input type="checkbox"/> Water Purification |
| <input type="checkbox"/> Filter | <input type="checkbox"/> Smart Water | <input type="checkbox"/> Water Quality |
| <input type="checkbox"/> Global Warming | <input type="checkbox"/> Surface Water | <input type="checkbox"/> Water Softener |
| <input type="checkbox"/> Ground Water | <input type="checkbox"/> Sweet Water | <input type="checkbox"/> Water Treatment |
| <input type="checkbox"/> Healthy Water | <input type="checkbox"/> Terrestrial Water | <input type="checkbox"/> WaterShed |
| <input type="checkbox"/> Hydraulic | <input type="checkbox"/> Wastewater | |