DEPARTMENT OF EARTH AND ENVIRONMENTAL SCIENCES

AquaCrop-Hydro

Manual for the MATLAB model

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The AquaCrop-Hydro MATLAB model is available for download from:
https://github.com/HanneVG/AquaCrop-Hydro , and can be freely used, provided that following source is acknowledged:

Van Gaelen, H., Willems, P., Diels, J., Raes, D. 2016. Bridging rigorous assessment of water availability from field to catchment scale with a parsimonious agro-hydrological model. Environmental Modelling and Software [submitted]

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1 Introduction

The AquaCrop-Hydro model was developed to fill the need for a parsimonious agro-hydrological model with low data and calibration requirements, that can be used to study the impact of agronomic and environmental changes on both crop productivity and catchment hydrology. AquaCrop-Hydro was developed as a combination of the process based AquaCrop crop water productivity model (Hsiao et al., 2009; Raes et al., 2009; Steduto et al., 2009; Vanuytrecht et al., 2014) and a lumped conceptual hydrological model (Willems, 2014; Willems et al., 2014) .

Model development and evaluation for the Plankbeek catchment in Flanders (Belgium) has been published by Van Gaelen et al. (2016). Moreover, the model has been applied to study the impact of climate change and related agricultural management adaptations on crop production and catchment water availability for the same catchment (Van Gaelen et al., n.d.).

2 The AquaCrop-Hydro model

AquaCrop-Hydro simulates the daily soil water balance, crop development and production, based on limited inputs of weather data (daily rainfall, reference evapotranspiration (ET_0), minimum and maximum temperature), crop characteristics (e.g. sowing date, length of the growing period, harvest index, rooting depth, sensitivity to abiotic stresses), soil and groundwater table characteristics (hydraulic properties and saturated hydraulic conductivity, ground water table depth), and agricultural management practices for each land unit of the catchment. Furthermore, based on few hydrological parameters, AquaCrop-Hydro enables simulation of average daily discharge at the catchment outlet.

The model flow chart is presented in Figure 1. AquaCrop-Hydro operates at a **daily time step**. The model applies a **semi-distributed** approach, as it requires the catchment area to be divided into homogenous land units (LUs) with similar land use, soil and agro-climatological characteristics. Crop development, production and the soil water balance are simulated at the scale of a land unit. Next, the soil water balance at catchment scale is derived from simulated soil water balance components of all individual LUs. Subsequently, river discharge at the catchment outlet is simulated by means of a lumped conceptual hydrological model.

More detailed information on the model and simulation procedure can be consulted in Van Gaelen et al. (2016).

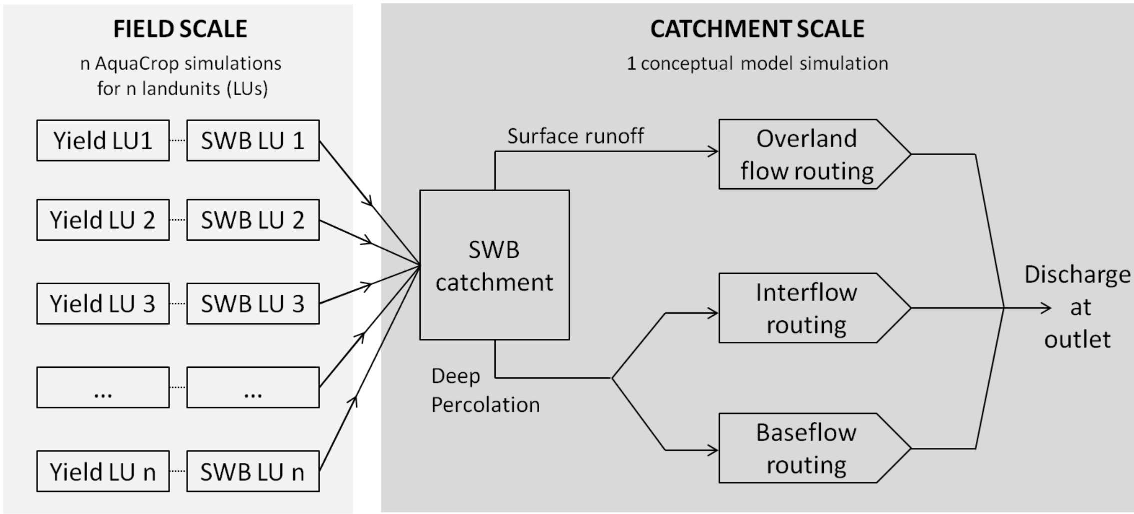

Figure 1 - Flow chart of the AquaCrop-Hydro model presenting how the AquaCrop soil water balance (SWB) simulations for each individual land unit (LU) are translated into different subflows, which after routing sum up to the total discharge at the catchment outlet.

3 Model limitations and applications

It should be noted that the model structure of AquaCrop-Hydro poses some limitations, in particular towards model application.

- **Type of catchments:** AquaCrop-Hydro simulations are most accurate for cropped fields and consequently agricultural catchments. Hence, it is not advised to use AquaCrop-Hydro for urban catchments with a large impervious areas.
- **Time step**: AquaCrop-Hydro can only simulate with a daily time step. This affects the accuracy to simulate surface runoff and overland flow. Since flood events and peak flows are mainly dominated by overland flow processes, the model should not be used for flood forecasting or design of flood control measures.
- **Semi-distributed approach**: With the semi-distributed approach, spatial distribution and patterns of land use within the catchment are not considered. Consequently, AquaCrop-Hydro can only be used to assess the quantitative but not the spatial aspect of land use changes.

Despite these limitations, potential model applications are numerous, for example:

- **Climate change impact assessment**: AquaCrop-Hydro can be used to study the impact of climate change on both crop (water) productivity and water availability.
- **Agricultural management assessment**: AquaCrop-Hydro can be used to assess the effect of agricultural management on both crop (water) productivity and water availability. This might include studying the impact of soil and water conservation practices, soil fertility management, weed management, irrigation management, crop choice, sowing and harvest dates of crops, ...

More discussion on model limitations and applications can be consulted in Van Gaelen et al. (2016).

4 Running AquaCrop-Hydro in MATLAB

A package of MATLAB scripts, compatible with MATLAB version 2015a, was developed to run AquaCrop-Hydro. The package contains three main options to run AquaCrop-Hydro, which are discussed below.

4.1 Simple simulation (AquaCropHydro.m)

The ***AquaCropHydro.m*** file is the script to run one basic AquaCrop-Hydro simulation. The script proceeds according to the steps highlighted in Figure 2.

In a first step, the user manually runs AquaCrop (version 5.0) outside MATLAB for each land unit (LU) of the catchment. A model user can describe an LU as small as an individual field if detailed field observations are available, but it can be larger when its characteristics originate from basic information from literature, maps, agricultural statistics or farmer knowledge.

In a second step, all AquaCrop output variables of interest will be read and extracted. These variables include both values at daily time step (e.g. daily values of transpiration, crop biomass build up etc.), as well as seasonal values (e.g. seasonal crop yield). Values are extracted for each land unit of the catchment. The script is only compatible with files originating from AquaCrop version 5.0. However, both the normal interface and the plugin version of AquaCrop version 5.0 can be used. The user should pay attention to request the correct output files when running the AquaCrop simulations (see section 5).

In a third step, the AquaCrop output variables at land units scale are scaled up to calculate values for the whole catchment. This is done by taking the weighted average based on the relative area of each land unit within the catchment. This part of the script needs additional information on the characteristics of all land units of the catchment (*SimInfo.txt*), the soil parameters of each soil in the catchment (*SoilPar.txt*), the reference harvest index of each crop in the catchment (*HIo.txt*), and maximum rooting depth of the crops in each run for each simulation unit (*Zrx.txt*).

In the final step, the simulated surface runoff, deep percolation and soil water content (0-2 m depth) for the whole catchment are used as input for the hydrological routing model. This model needs parameters that are specified in *Parameters.txt.*

The script is set up as a function and hence requires input of the datapaths were the input files are stored as well as the AquaCrop mode that was used (1= normal version, 2= plugin version). The output of the script contains amongst others the simulated total river flow at the catchment outlet and its subflows (baseflow, interflow, overland flow), crop development and crop production variables as well as the soil water balance components at land unit scale as well as catchment scale.

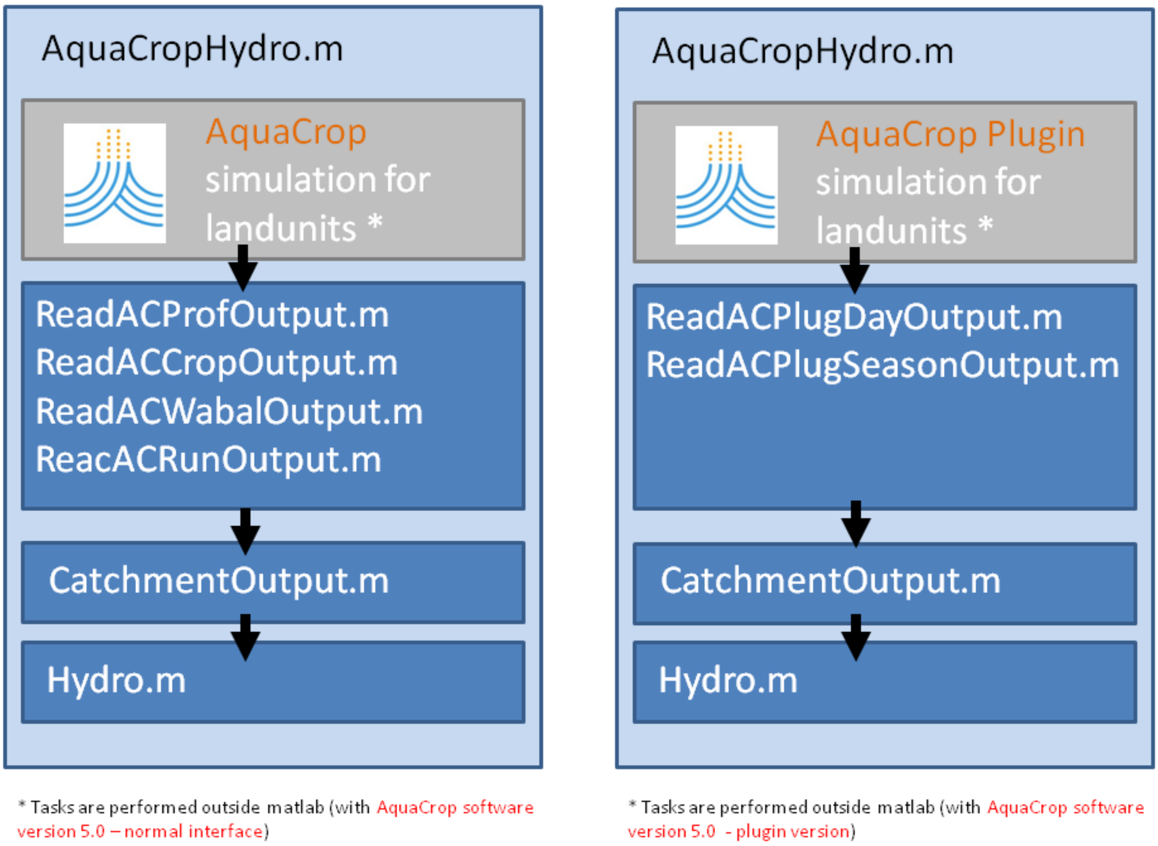

Figure 2 – Flowchart of the AquacropHydro.m script. The left side presents the flowchart if the normal AquaCrop interface is used, the right side presents the flowchart when using the AquaCrop plugin version.

4.2 Model evaluation (Main_ACHydro_Evaluation.m)

The ***Main_ACHydro_Evaluation.m*** file is the script to run a single AquaCrop-Hydro simulation and compare results to observations of river flow at the catchment outlet. That way model performance can be evaluated. The script proceeds according to the steps highlighted in Figure 3.

In a first step, observations of river flow (*Flow.txt*) and weather data (*Climate.txt*) are loaded. Flow observations include observations of total river discharge (average daily value), as well a filter values for the corresponding subflows (baseflow, interflow, overland flow) for each time step of the simulation period.

Next, AquaCrop-Hydro is ran according to the procedure explained in section 4.1, and data are processed. In a fourth step, model performance is evaluated by comparing modelled and observed flow values, using performance statistics. Model performance is also visualized in graphs. Finally, some summary output excel files of the performance assessment and crop yield simulations are created. The latter can be used to compare crop yield simulations to field observations outside MATLAB .

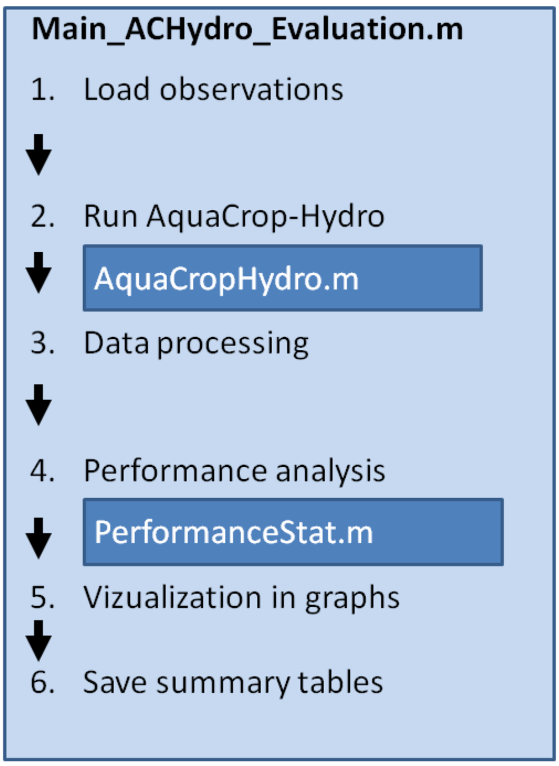

Figure 3 – Flowchart of the Main_ACHydro_Evaluation.m script.

4.3 Scenario analysis (Main_ACHydro_Scenario.m)

The ***Main_ACHydro_Scenario.m*** file is the script to run several AquaCrop-Hydro simulations for the same catchment to compare various scenarios. This could be climate scenarios, crop management scenarios, land use scenarios, etc. The script proceeds according to the steps highlighted in Figure 3.

After defining all datapaths, extra information on the scenarios (*Scenario.txt*) and the simulation units (*SimInfo.txt*) is loaded. Next, AquaCrop-Hydro is ran for each scenario.

In steps 4 to 10, the difference between scenarios is analyzed. Results of all scenarios are compared to results of the first scenario (the reference or baseline scenario). The scenarios are analyzed with respect to seasonal crop yield, seasonal crop water productivity (WP_{ET}), the seasonal drought stress index (DSI) and temperature stress index (TSI), seasonal length of the growing period (potential and actual LGP), annual flow at the catchment outlet (including sublfows) and monthly total flow at the catchment outlet.

Finally, some summarizing tables are saved in an excelfile.

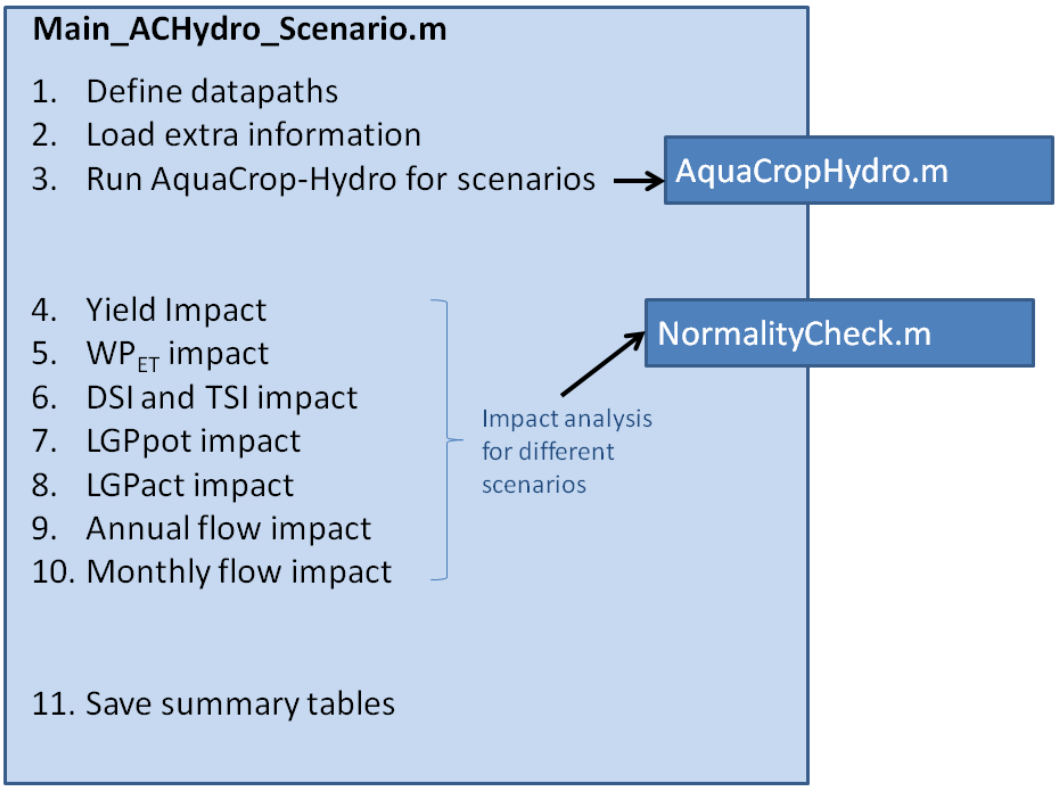

Figure 4 – Flowchart of the Main_ACHydro_Scenario.m script.

<u>Note:</u> If scenario analysis consists of comparing various climate scenarios, as in climate change impact assessment, weather characteristics (rainfall, ET_0, T_{min}, T_{max}) under the different scenarios can be analyzed using the script ***AnalyseClimateScen.m*** in the 'Climate_Processing' package by Hanne Van Gaelen (available on GitHub).

5 Required input files

An example of all required input files can be found in the folder 'AquaCrop-Hydro/Information/ExampleInput'. Table 1 lists all required files for each of the main scripts presented above. The input files are either input or output files of AquaCrop, or txt files that are created by the user on beforehand. Input files can be stored anywhere on the computer, because the user will be asked to select the datapath(s) when running the main AquaCrop-Hydro scripts.

Table 1 - Overview of required input files for the three main AquaCrop-Hydro scripts. Input files are either AquaCrop input/output files, or created by the AquaCrop-Hydro user.

	Simple simulation	Model evaluation	Scenario analysis
AquaCrop files			
for each land unit & scenario			
.Tnx or .TMP			x
.PLU			x
.ETO			x
*Prof.OUT	x (normal AC)	x (normal AC)	x (normal AC)
*Crop.OUT	x (normal AC)	x (normal AC)	x (normal AC)
*Run.OUT	x (normal AC)	x (normal AC)	x (normal AC)
*Wabal.OUT	x (normal AC)	x (normal AC)	x (normal AC)
* Day.OUT[1]	x (plugin AC)	x (plugin AC)	x (plugin AC)
*Season.OUT[1]	x (plugin AC)	x (plugin AC)	x (plugin AC)
User created files			
SoilPar.txt	x	x	x
SimInfo.txt	x	x	x
Hio.txt	x	x	x
Zrx.txt	x	x	x
Parameters.txt	x	x	x
Scenario.txt			x

[1] These files should contain following sets of output variables (to be determined in simulation set up): '1: Various parameters of the soil water balance', '2 : Crop development and production' and '3 : Soil water content in the soil profile and root zone'.

6 References

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