A Site-sPecific Agricultural water Requirement and footprint Estimator (SPARE:WATER)

- Manual –

Version 1.0

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This manual is a short introduction and hands-on-model training guideline for the new Site-sPecific Agricultural water Requirement and footprint Estimator (SPARE:WATER).

Links in the manual are connected with background information from the online FAO guidelines for computation of crop evapotranspiration (Allen RG, Pereira LS, Rase D, Smith M, 1998. Crop evapotranspiration - Guidelines for computing crop water requirements - FAO Irrigation and drainage paper 56. FAO Rome).

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Background

The **S**ite-s**P**ecific **A**gricultural water **R**equirement and footprint **E**stimator (SPARE:WATER 1.0) is a tool for estimating the fate of water use in agricultural production systems. SPARE:WATER enables the spatial explicit calculation of the crop specific water footprint, the national water footprint and alternative production scenarios, considering all water resources required to produce food and feed, including green (precipitation), blue (irrigation) and grey (de-salinization) water. SPARE:WATER is based on the virtual water concept originally introduced by Allan in the 1990s, and further developed to the water footprint concept by Hoekstra in the past years. Equipped with a graphical user interface SPARE:WATER calculates crop water requirement according to the Food and Agricultural Organization FAO56 crop water guidelines. User defined parameters allow to set crop types, irrigation efficiencies, salinity of irrigation water or depression of yields due to salinization. A SPARE:WATER scenario manager allows to rapidly investigate the effect of introducing different cropping regimes on site specific water resources. All model data are saved in the working directory of the session, including soil and climate information as well as data on yields to calculate crop water requirements for each spatial entity.

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1 Installation and start program

Note: SPARE:WATER is only working on windows.

Install SPARE:WATER on your computer by running SPARE:WATER.msi. Windows 7 users should install the software with a right-click and run the installation as administrator. You need to have administrator rights to run SPARE:WATER. Please take a look at the section trouble shooting (Appendix 3) if the installation does not work out.

You will now find a new folder on your system hard drive named SPARE:WATER and a SPARE:WATER icon in your start menu of Windows.

All other relevant input data (contained in the folder *Final data – Saudi Arabia*) must be copied manually to a folder of your choice. These input data have been prepared in agreement with the description of data pre-processing in the appendix. If you plan to set up SPARE:WATER for a new area of investigation or in other spatial resolutions you need to prepare the input data files accordingly.Open the program by clicking SPARE:WATER in the new folder of your system hard drive or click the icon in the start menu.

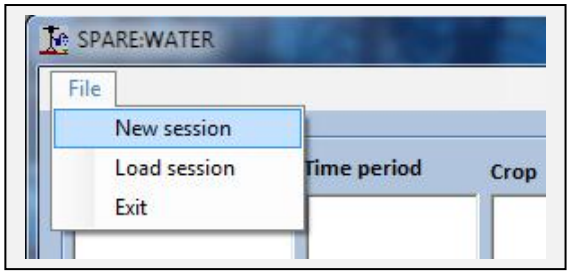
The program starts with the user interface. Here, the results for the Crop Specific Water Footprint (Statistics and Histograms), the National Water Footprint and the Production Scenarios will be displayed. But before this, you need to work through the following steps and create a baseline scenario. These steps are needed to read in data and calculate relevant equations before finally evaluating the water footprint.

2 Set up of baseline scenario

Data of current water use and crop production as well as environmental boundary conditions (soils, topography, climate) are used to calculate the current water footprint of a given area. This calculation is also referred to the baseline scenario which is being used as a reference in later scenario analyses. The calculation of the baseline scenario involves a data pre-processing that consists of 8 steps which need to be sequentially worked on.

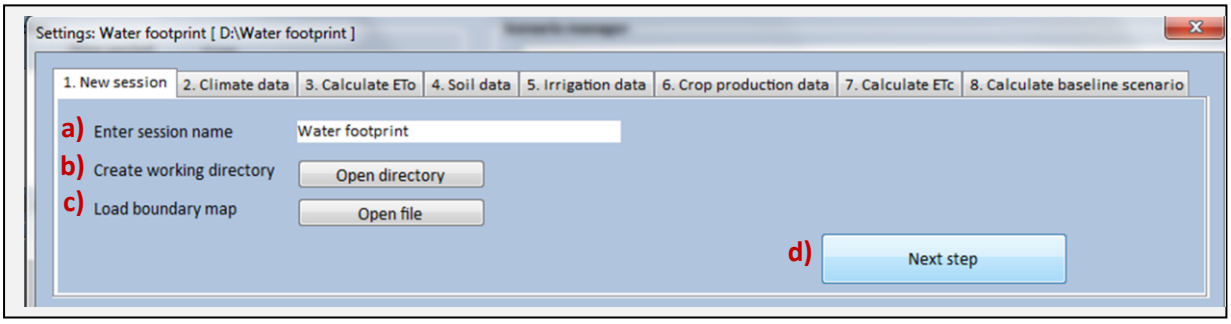
File > New Session

Starts a new session for loading all data for the calculation of the water footprint. Opens **Settings** in a new window, in which all steps are carried out. **Settings** consist of 8 steps that are needed to be calculated in sequence. Do not mix steps or try to work on steps without finishing the previous ones.



2.1 Create new session

This first step creates a new session on the computer necessary to conduct a water footprint analysis.



a) Enter session name
Choose and enter a name for the current session (it is always a good idea not to use excessively long file names).

b) *Create working directory → Open directory*
Determine a location on your computer where the current session should be saved. This folder is used to store all model input and forcing data as well as model output (results). It consists of the following subfolders

- Forcing data
- Input data
- Input parameter
- Output files

The file info.txt contains general information about the current project, such as name of the project and projection.

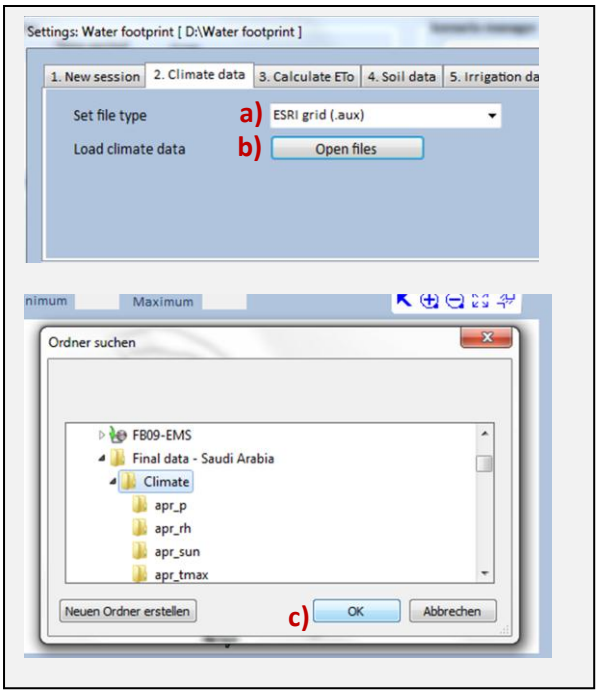
c) *Load boundary map → Open file*
Load map with political boundaries. This map is a shapefile (.shp) created for example in ESRI. Loaded data are shown at the bottom left. The prevailing data are concealed by removing the tick. The map is displayed at the bottom right.

d) Next step

At the end of each step, the button *Next step* leads to the following step. This button can only be clicked, if the current step is completely finished.

2.2 Climate data

This second step is relevant to read in climate data (model forcing data), relevant for estimating potential crop evapotranspiration.



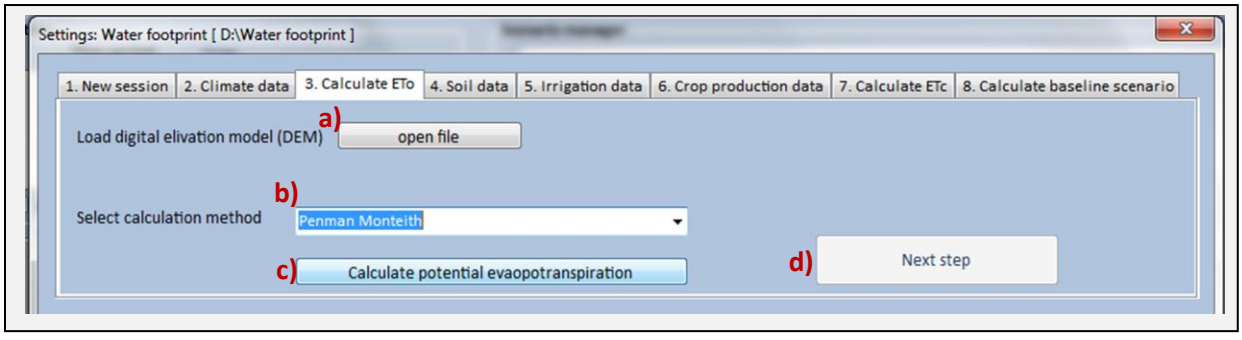
a) Set file type
Select the format for the data that will be loaded: *ESRI grid (.aux)* or *ASCII (.asc)*

b) Load climate data → Open files

c) Select the folder where all climate data are stored. Following, all climate data (average values for each month) are loaded: rainfall, sunshine hours, wind speed, humidity, minimum and maximum temperature.
The loading has finished as soon as *Next step* can be clicked.

2.3 Calculate potential evapotranspiration ET_0

In this step, SPARE:WATER calculates solar radiation and potential evapotranspiration ET_0. Calculated maps are displayed in the map section of SPARE:WATER and are stored in the project folder. To calculate ET_0 the following steps are required:



a) *Load digital elevation model (DEM) → Open file*
First, select the format *ESRI grid (.aux)*, then select *DEM.aux*

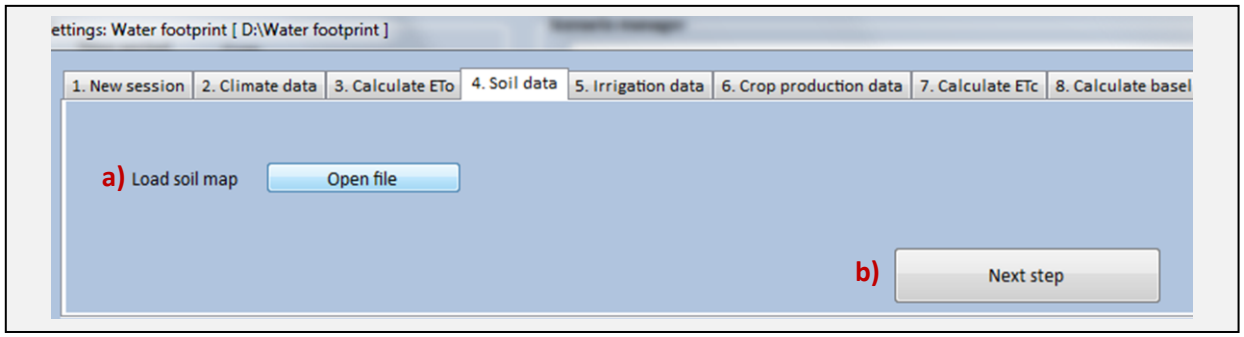
b) *Select Calculation method* → e.g. *Penman Monteith*
Selects the calculation method for ET_0.
Note: Check plausibility of calculated ET_0 values. Penman Monteith does not necessarily lead to the best ET_p estimation in some ecosystems. However, it is the suggested method by FAO.

c) *Calculate potential evapotranspiration*
Start calculation of ET_o: monthly average data on *potential evapotranspiration* and *solar radiation* are calculated.

d) *Next step*

2.4 Soil data

During step 4 the soil digital data are loaded that are required to calculate the soil water balance.

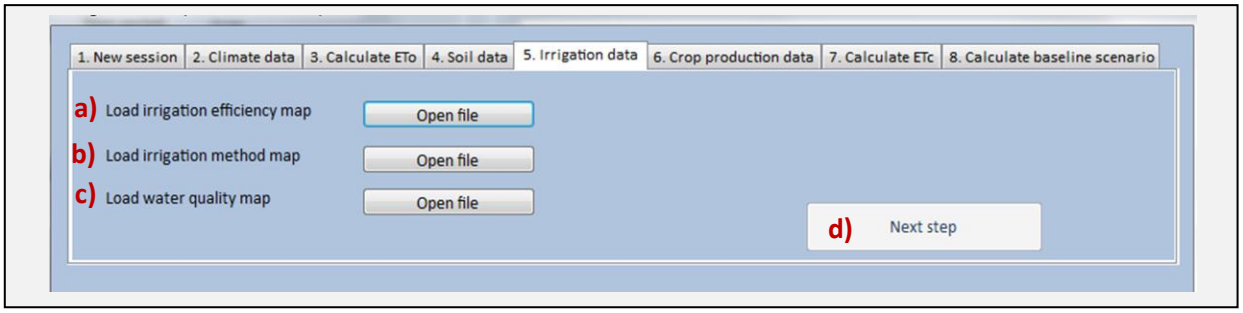


a) *Load digital soil data → Open file*
First, select the format *ESRI grid (.aux)*, then select *DEM.aux*

b) *Next step*

2.5 Irrigation data

Data for irrigation are uploaded to SPARE:WATER during this step.



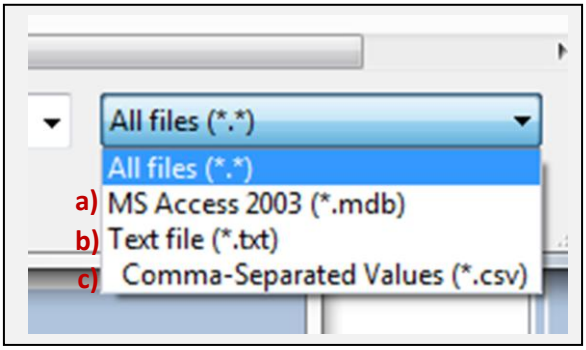
Three maps concerning Irrigation are loaded: Efficiency, Method and Quality of Irrigation
Select the correct format (*ESRI grid (.aux)* or *ASCI (.asc)*) when loading the maps

a) *Load irrigation efficiency map*
b) *Load irrigation method map*
c) *Load water quality map*
d) *Next step*

2.6 Crop production data

This step is relevant to upload production data. The following formats are allowed to be used:

a) Microsoft Access 2003 files .mdb
b) Tab-stop text files .txt
c) Comma separated files .csv



2.7 Calculate crop specific evapotranspiration ET_c

Step 7 calculates the crop specific evapotranspiration ET_c based on ET_0 and crop specific parameters.

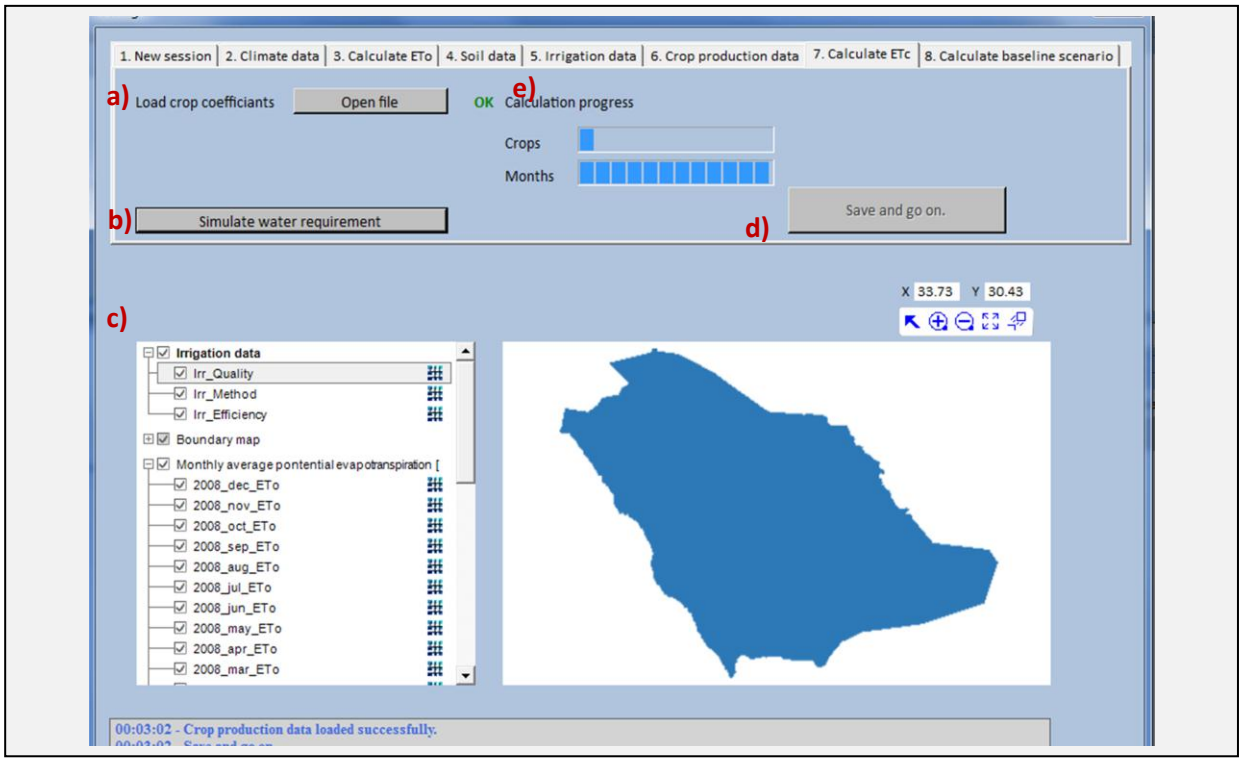
a) *Load crop coefficients → Open file*
Crop coefficients are given as text files (.txt).

b) Click the button to *Calculate crop specific evapotranspiration.*

c) Calculated maps will be displayed in the map viewer. Calculation of crop water, irrigation and leaching requirement takes place and results are stored for each crop in the project folder under Output files.

d) The calculation of ET_c takes several minutes. Two moving bars indicate the calculation progress.

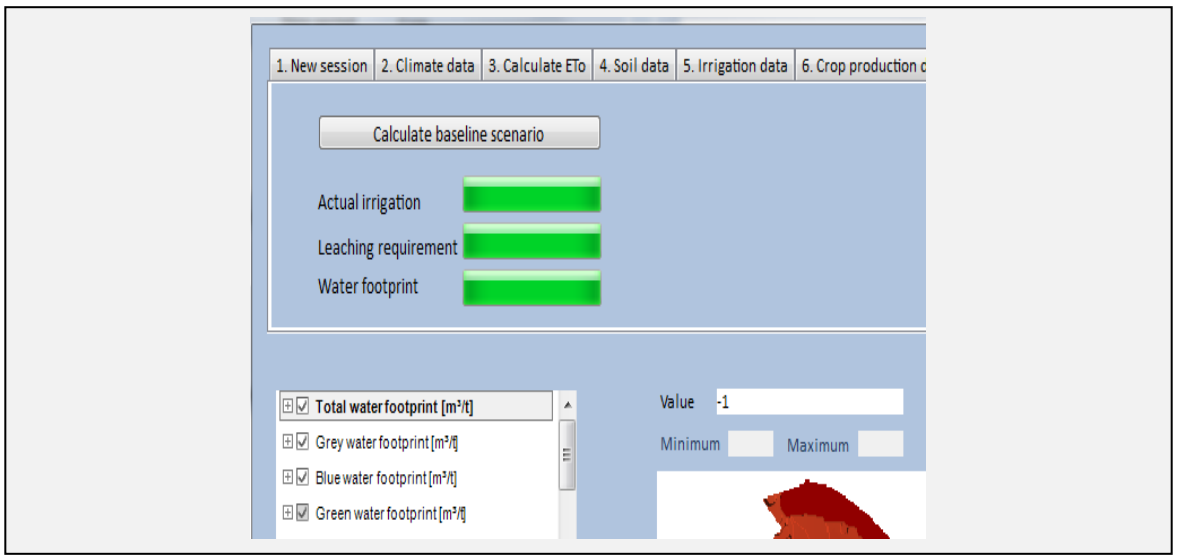
e) Once loading of ET_c has finished, *Next step* can be clicked.



2.8 Calculate baseline scenario

This final step 8 of data pre-processing will estimate the baseline scenario, i.e. the water footprint under current conditions. During this step the calculation of green, blue and grey water footprint take place (c). After the baseline scenario has been calculated raster maps with crop specific green, blue and grey water footprint are stored in the project folder under Output files.

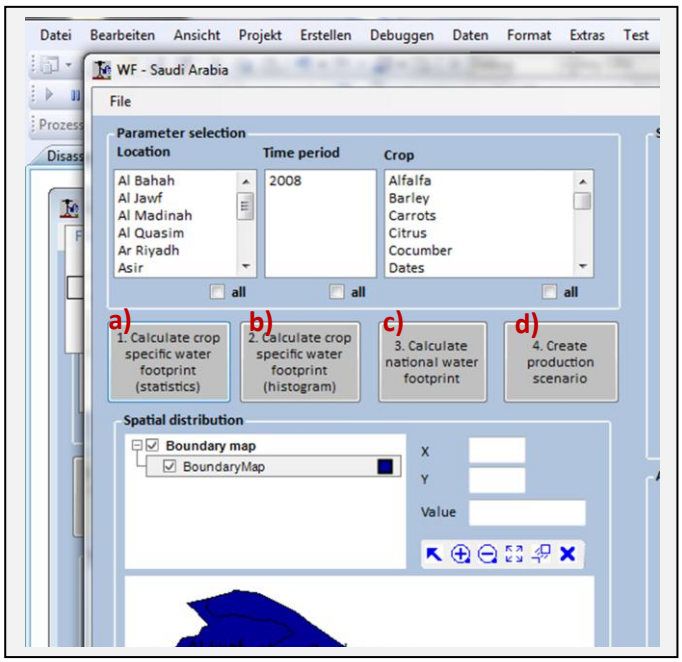
Calculation is finished as soon as all three indicator bars are filled and the button *Finish setup* needs to be clicked.



3 National water footprint assessment

After going through these 8 steps of data pre-processing, results will be shown in the *Setup* window. For this, the raster based crop specific water footprint calculations need to be evaluated.

a) *Calculate crop specific water footprint (statistics)*
b) *Calculate crop specific water footprint (histogram)*



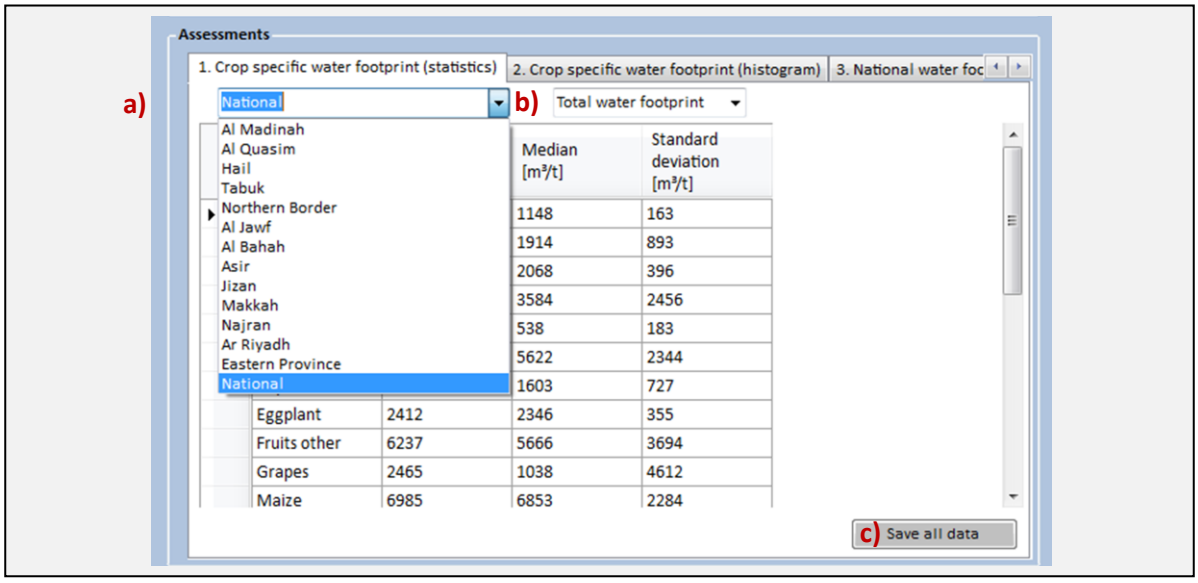
In the subsequent two steps users calculate the national water footprint as well as a set of self-defined production scenarios. For doing this, the used has to click the following two buttons

c) *Calculate national water footprint*
d) *Create production scenario*

3.1 Crop specific water footprint (statistics)

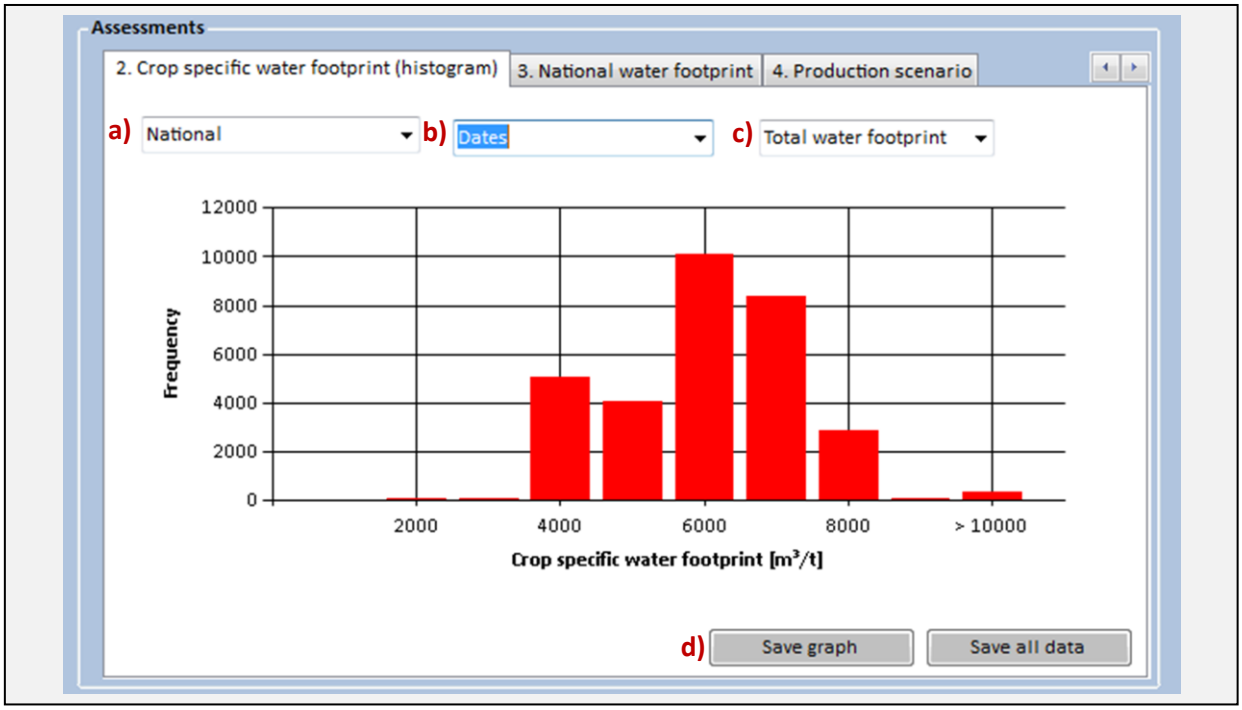
Results can be shown on the level of emirates or for the entire nation (a).

Users can also choose between green, blue grey and total water footprint statistics (b). In each table, median, average and standard deviation of calculated water footprint for each crop are shown. By clicking in the header of each column, columns are sorted by size. The button *Save all data* (c) allows to save data as .csv files.



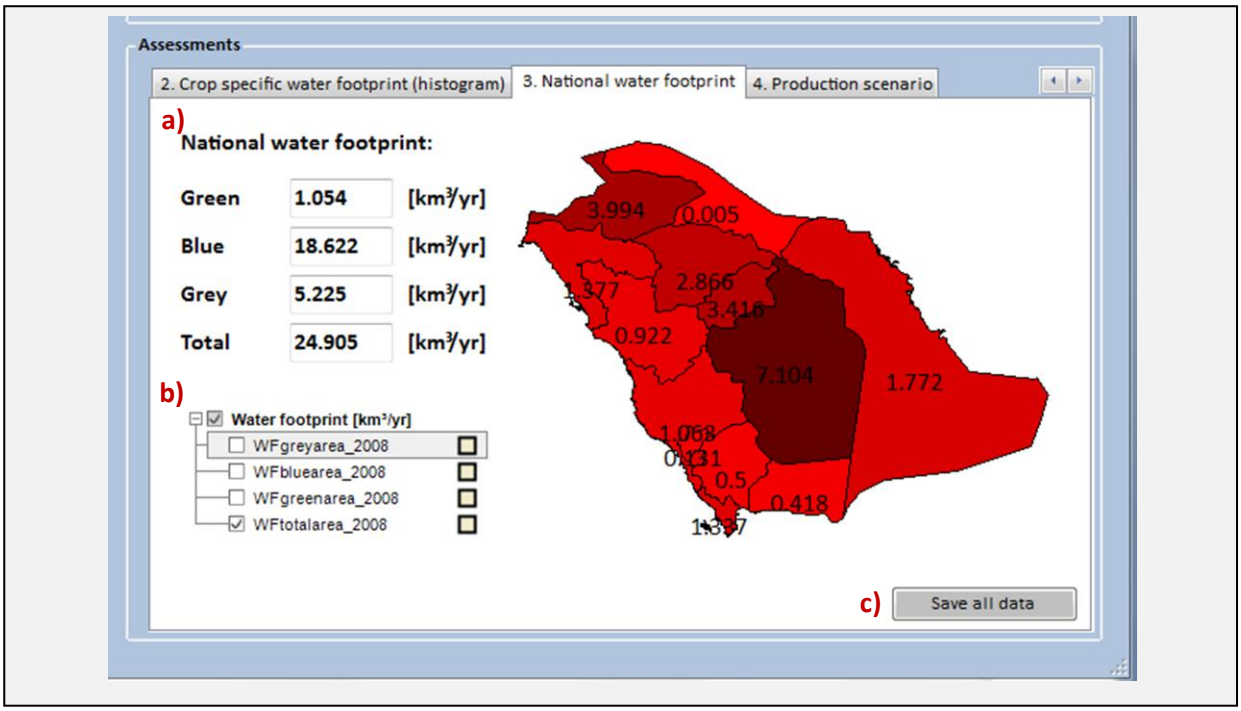
3.2 Crop specific water footprint (histogram)

Histograms are displayed in the second worksheet. They display the histogram for each crop specific water footprint. Results can be selected for emirates or the entire nation (a). Users can also select between specific crops (b) and green, blue grey and total water footprint (c). Results of histograms can be saved as graphs or .csv files by clicking the respective button (d).



3.3 National water footprint

The national water footprint consists of a green, blue and grey water component. The total sum of each component is shown in the third worksheet to the upper left (a). The map displays spatially distributed water footprints for each emirate are shown on the map. Depending on selection criteria (b) the different water footprint components can be selected. Data and maps can be saved by clicking the *Save all data* button (c).



3.4 Production scenario

The last of the 4 buttons on the top left of the panel allows creating alternative production scenarios by assuming new crop production data (e.g. reducing the production of wheat in a certain emirate, or increasing the production of another fruit for the entire country). By clicking the button one has to define a name for the new scenario. For the calculation of the scenario the following steps are required.

a) Create a new production scenario

b) *Selection* of parameters to be varied in the scenario.
Select the parameters that should be changed in the scenario. (*Location*: mark several counties while holding the Strg button. *Crop*: mark several crops by clicking while holding the Strg button).

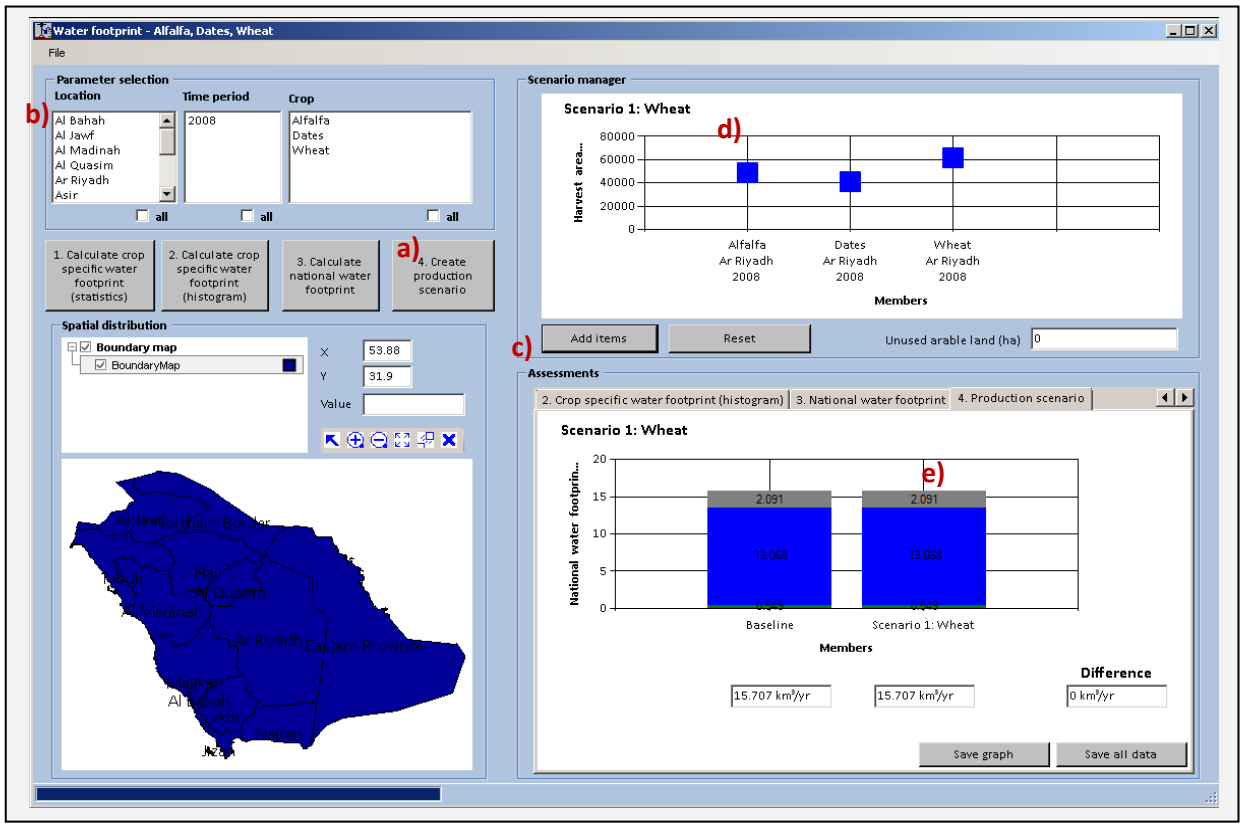
c) *Add items for parameter selection*
The production data for the prior selected parameters (location, crops) are displayed.

d) *Variation* of cropping area by moving bars. One can also change the current cropping area with a double click on the bars and by typing in the new cropping area.

In case, a specific crop is not grown in a selected location, enter a value for the potential crop yield (t/ha) for this location. Because of the increase in production, the value for unused arable land becomes negative. To balance this, you can reduce the cropping area elsewhere or reduce the cropping area of other crops.

e) The resulting water footprint will be shown as a new graph

The diagrams in the scenario manager show the prevailing harvest area of each crop in each emirate. The left diagram shows the total water footprint of the baseline scenario, whereas the diagram on the right displays the water footprint according to the prevailing change in the new production scenario.



Appendix 1: Project working space

When starting a new session, SPARE:WATER automatically creates a new project folder. This folder is subdivided in 4 sub-folders and a text file. The text file *info.txt contains project name, geographic projection information and further details relevant for this session*. All folders will be filled with input and output (results) data during the session. The 4 sub-folders are structured as follows:

Forcing data\ contains climate input data, stored in ASCII (.asc) format. Climate data consist of 12 maps for each climate parameter and month. Further, the folder contains a table with crop specific production data (*CropProduction.txt).*

Input data\ contains a map of all locations (provinces, emirates) as a shapefile and a raster file. Further data on elevation, soil and 3 maps with irrigation data are stored here. Irrigation data contain irrigation efficiency, irrigation technique and irrigation water quality (salinity).

Input parameter\ contains two text files on soil and crop specific coefficients.

Output files\ *contains* 8 sub-folders for storing results. Results are saved in ASCII (.asc) format. The following results are stored during a session:

- *Actual evapotranspiration*\ contain raster maps with the sum of crop specific evapotranspiration rates (per crop and vegetation period).
- *Actual irrigation*\ store raster maps with sum of actual irrigation requirement per crop and vegetation period.
- *Irrigation*\ holds raster maps with net irrigation amount per crop and vegetation period.
- *Leaching requirement*\ contains raster maps with required water to leach salts from soil per crop and vegetation period.
- *Potential evapotranspiration*\ presents 12 raster files with potential evapotranspiration (per months).
- *Solar radiation*\ stores 12 raster maps on solar radiation.
- *Water footprint*\ contains raster maps for each crop on green, blue, grey and total water footprint.

Appendix 2: Data pre-processing and required formats

Input data for SPARE:WATER will be imported during a session step by step and will be stored in the project folder. Input data require a specific pre-processing and format described in the following:

Boundary map: A shapefile (*.shp*) delineating the entire project into provinces, emirates or any other entities area is required. The title *province* must be stored in the column *"Name"* of the shapefile. The names of provinces must be in agreement with names of provinces in the production table.

Climate data: Climate data comprise 12 maps with precipitation and 12 maps with those data that are requested for method to calculate evapotranspiration (note that the different methods to calculate evapotranspiration depend on a varying number of climate input data. The user needs to check which methods suits best to the area of investigation). Maps must be provided as raster files ESRI-grid (.aux) or as ASCII format (.asc). The name of each file must start with the first three letters of a given months (e.g. jan*.asc for January or aug*.aux for August). The following acronyms after the underscore present the respective climate variable. Take care for providing the correct units:

- Precipitation is abbreviated with *"p"* and is stored as monthly sums [mm].
- Minimum and maximum air temperature is abbreviated with „tmin" and „tmax" and presents the mean monthly minimum/maximum temperature [°C].
- Wind speed „wind" is the wind speed measured in 2 m height [km/day]. Depending on the height level where wind speed data are available for they might need to be corrected using the logarithmic wind profile corrections.
- Mean monthly relative humidity is abbreviated with „rh" [%].
- The mean monthly sunshine duration is abbreviated as „sun" and given in hours [h].

The **digital elevation model (DEM)** as well as **irrigation data** must be provided as ESRI-grid (.aux) or in ASCII format (.asc). The DEM represents elevation above sea level [m]. The irrigation maps must be presented in the following way:

- Irrigation efficiency describes the efficiency of the irrigation system with values between 0.0-1.0.
- The map on irrigation technique depicts the prevailing technique in a given raster by surface irrigation = 1, sprinkler irrigation = 2 and drip irrigation = 3.

Production data must be provided as Microsoft Access Database (.mdb), text files (.txt) or as csv files (.csv). In case of text and csv files columns must be separated by tabs. The files contain 5 columns for each crop:

- *„Commodity“*: crop type;
- *„Province“*: region of production;
- *„Year“*: year of production;
- *„Yield [t/ha]“*: yield of production in a given region and year [t/ha];
- *„Harvest area [ha]“:* area of production in a given year [ha/year].

Appendix 3: Trouble shooting

The installation does not work if the installer cannot register the Active-X components of the MapWinGIS library on your machine. In this case, please visit the MapWinGIS homepage and download the full installer of MapWindow to make sure, that all Active-X components are registered correctly (http://www.mapwindow.org/apps/wiki/doku.php?id=mapwindow4). After installation of MapWindow full version try again to install SPARE:WATER.