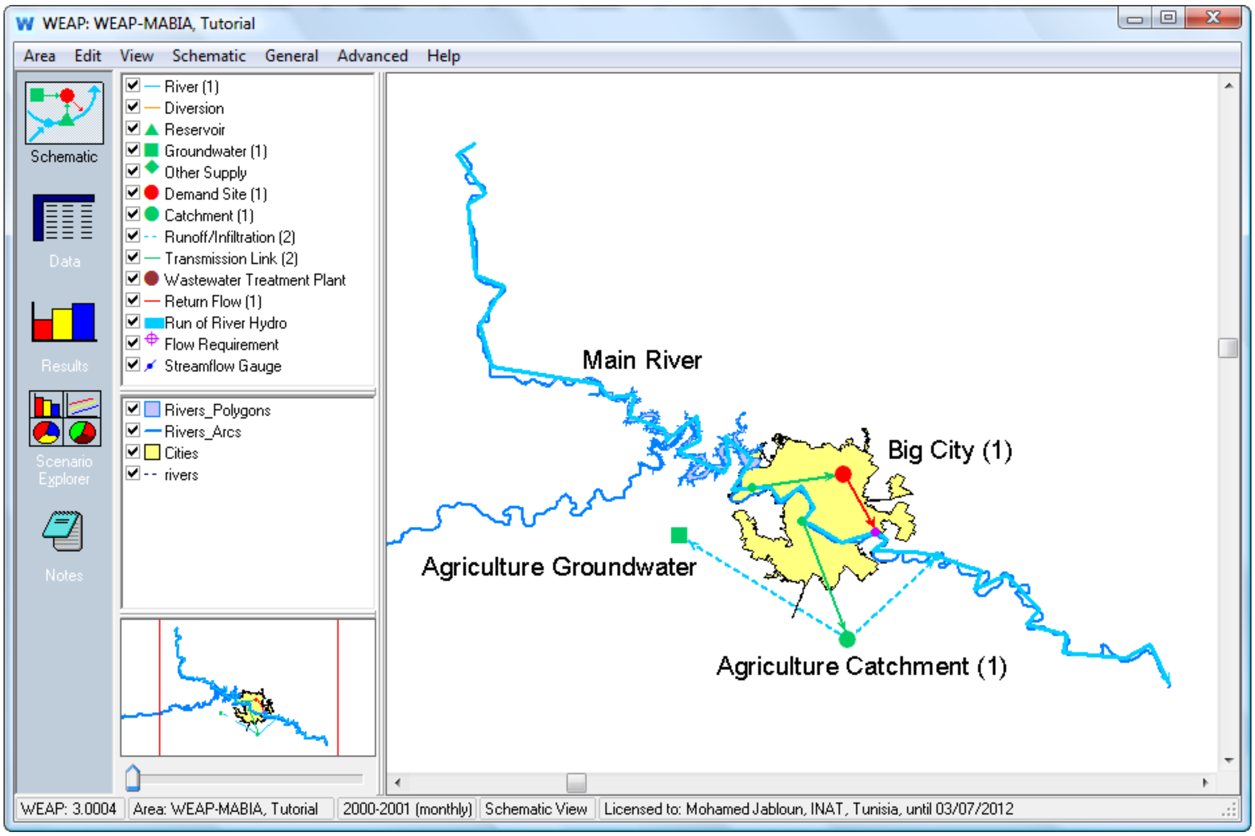
WEAP-MABIA Tutorial

A collection of stand-alone chapters to aid in learning the WEAP-MABIA module



by

Jabloun, Mohamed and Sahli, Ali

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Introduction to Tutorials

WEAP-MABIA is a complete software package for modeling crop water requirements and the different water balance components. It is used by scientists, engineers and resource and asset managers to simulate runoff, infiltration and percolation processes resulting from natural rainfall, irrigation scheduling, crop yield reduction and the performance of engineered systems that manage our water resources, WEAP-MABIA is used to develop link-node and spatially distributed models that are used for the analysis and simulation of agricultural water demands, WEAP-MABIA also models flow and recharge in natural systems including rivers and lakes with groundwater interaction.

This document contains four self-guided tutorials that demonstrate basic tasks required to build and solve different scenarios and to analyze simulation results. A list of data files required to start each tutorial is presented on the first page of each module. These files can be downloaded from http://www.bgr.bund.de/IWRM-DSS .

The tutorials are intended to be run on WEAP-MABIA Release 2010.

The tutorials and the demo files are updated from time to time. It is suggested that customers visit our web site http://www.bgr.bund.de/IWRM-DSS to obtain the latest version of the tutorials and the demo files. The latest version of WEAP can be downloaded from www.WEAP21.org .

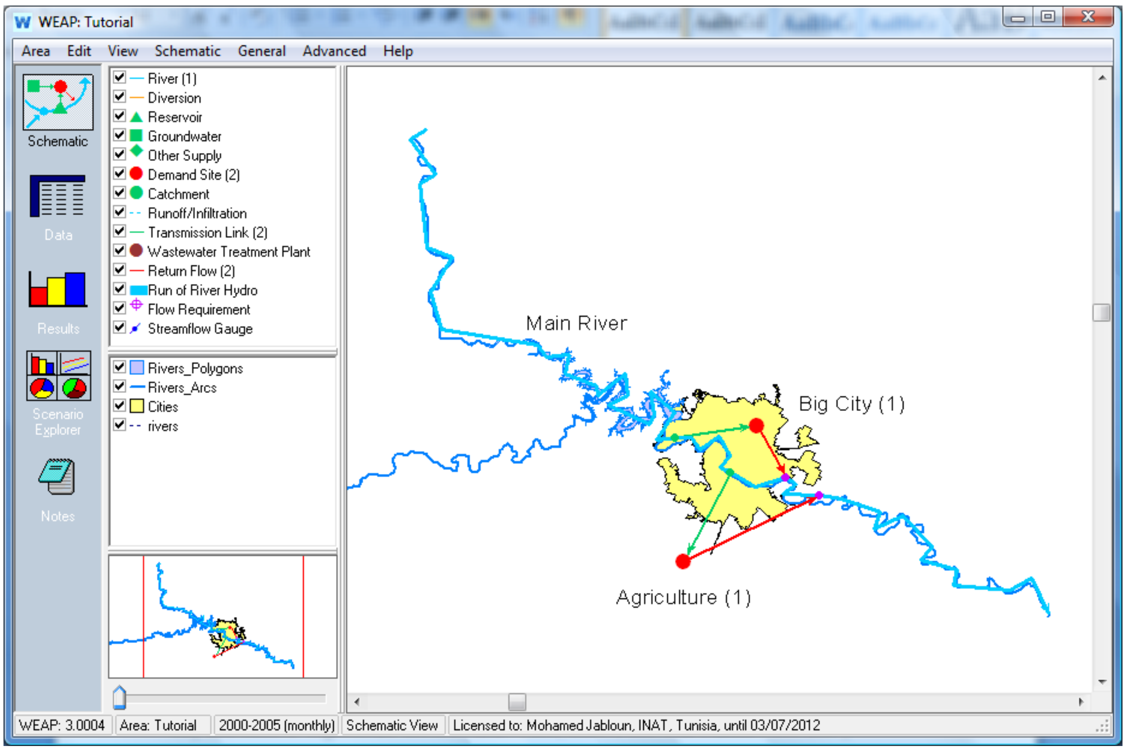
The tutorials are available in PDF format. Users may download the files and print selected pages on their local color printer to enhance visibility.

Each tutorial demonstrates a defined skill set. The tutorials are self contained and may be followed in any order. The required skill level is to have a basic knowledge of WEAP (creating an area, drawing a model, entering basic data, obtaining first results).

The purpose of these tutorials is to demonstrate software features and the typical work flow for common applications. The values and examples used in these tutorials represent real and experimental cases that help users define their own modeling needs. The end user is obliged to judge the scientific validity of the specific parameter values within the given scenario.

Building the basic model

The WEAP-MABIA models in this guide utilize the "Starting Point for 'Basic Tools' module". To begin this module, on the Main Menu, go to Area and select "Open". You should see a list of Areas that includes "Tutorial" - select this Area. Then, go to the Main Menu, select "Revert to Version" and choose the version named "Starting Point for 'Basic Tools' module". You should now see the Schematic as shown below.

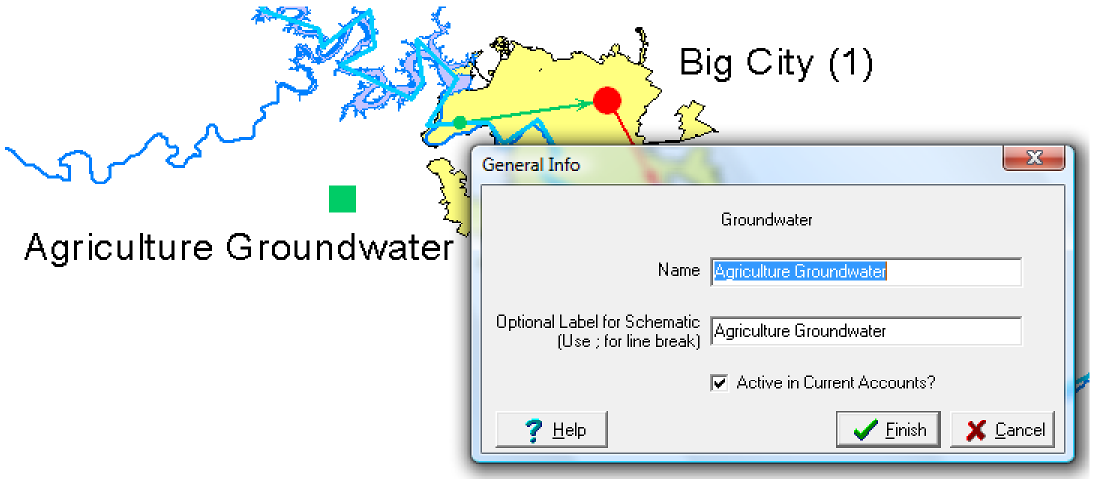


Create a Groundwater Resource

Create a Groundwater node on the other side of the Main River opposite and upstream of Big City and name it "Agriculture Groundwater". Also, make it active in Current Accounts.

Give Agriculture Groundwater the following properties (make sure you are in Current Accounts when entering the following data - you will realize you are not if there is no tab for Initial Storage):

Storage Capacity	*Unlimited (default, leave empty)*
Initial Storage	*100M* m^3



Replace the Agriculture Demand Site with a Catchment

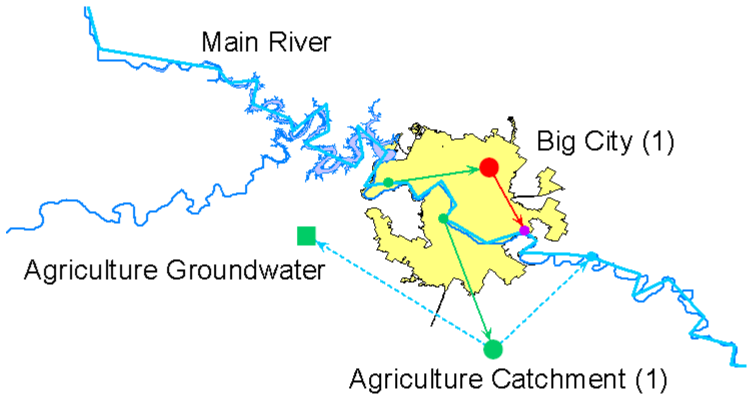
Delete the Agriculture demand site and create a Catchment in its place. Name it "Agriculture Catchment" and give it the following properties:

Runoff to	*Main River*
Represents Headflow	*No (check box)*
Infiltration to	*Agriculture Groundwater*
Includes Irrigated Areas	*Yes (check box)*
Demand Priority	*1 (default)*

Note that the Demand Priority data appears in the window only after selecting "Yes" to "Includes Irrigated Areas".

Connect the New Catchment

The new catchment should now already be connected to the Main River and to the Agriculture Groundwater with a Runoff/Infiltration Link. Add a Transmission Link from the Main River (same starting point as the former Agriculture demand site), with a Supply Preference of 1. Your model should now look similar to the figure below:



> The purpose of this transmission link is to allow supplying irrigated areas with water from the river in case rainfall is insufficient.

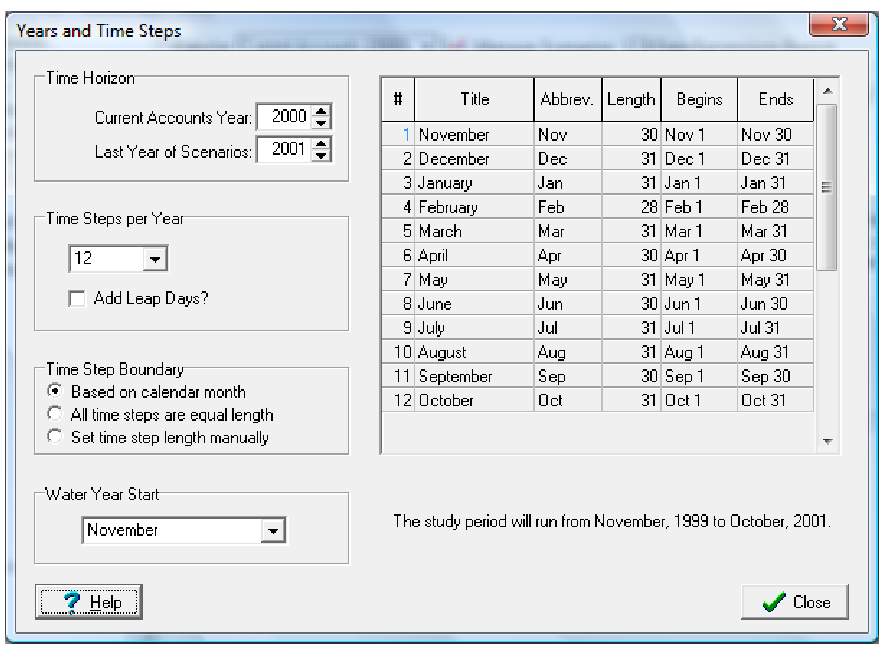
Change the Time Horizon for the Area

Under the General\Years and Time Steps menu, change the “Time Horizon” of the Area.

Current Accounts Year *2000 (unchanged)*

Last Year of Scenarios *2001*

Set the starting month of the “Water Year” to November



> The first month of the water year must be chosen so that the cropping cycle of all the chosen crops is within the so defined study period.

Modeling Catchments: The MABIA Dual K_c model

Objectives: Introduce the steps required to define:

- the climatic parameters
- the different crops cultivated in the catchment
- the soil characteristics for each sub-catchment
- the irrigation system characteristics and the irrigation schedule criteria for each crop

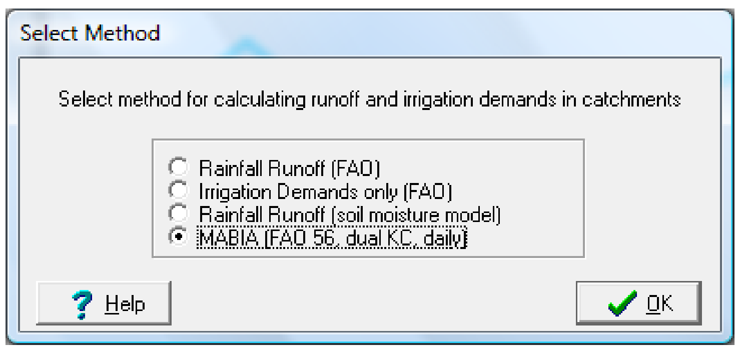
Data files:

- DailyClimate.csv
- Pepper&Wheat.csv

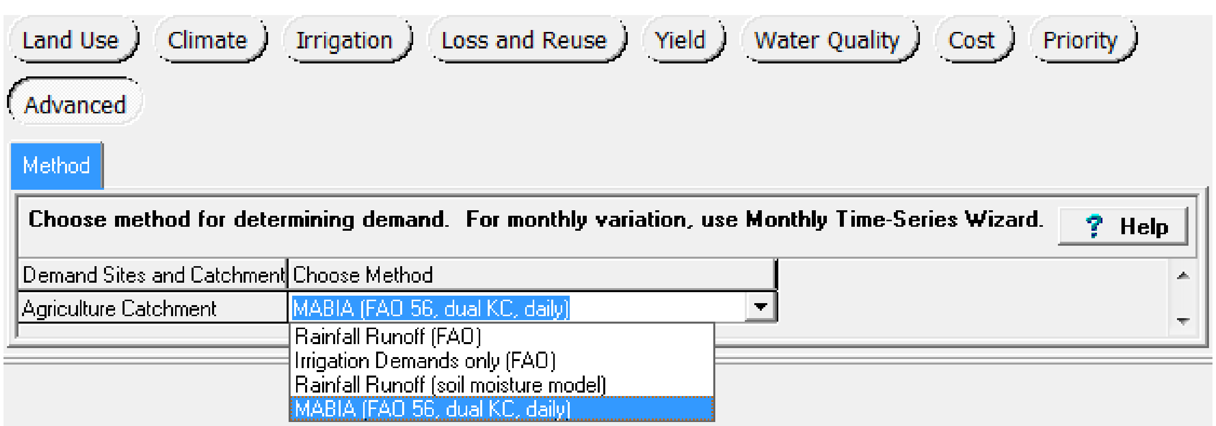
Create sub-structure in the Catchment

The first time you right click on the Agriculture Catchment or select it in the Data Tree, you will get a window that asks you to select a model for the Catchment:

Select the model MABIA (FAO 56, dual KC, daily) and click OK



There is also the opportunity to change this selection later by clicking on the "Advanced" tab in the Data view:

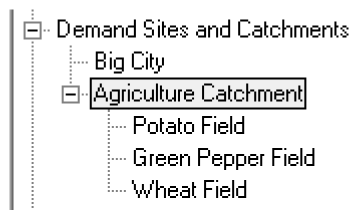


We will assume this catchment has three types of land use. In the Data View, add the following branches to your new catchment by right-clicking it in the data tree and selecting "Add". (If you select the catchment for editing by right clicking on the node in the schematic view rather than going through the Data view, you will be asked beforehand to choose a simulation method - pick the "MABIA (FAO 56, dual KC, daily)" method). Add the following branches:

Potato Field

Green Pepper Field

Wheat Field



Enter the Appropriate Land Use Data

Area

Select the Agriculture Catchment in the Data view and enter the following data after clicking on the "Land Use" button and on the "Area" tab:

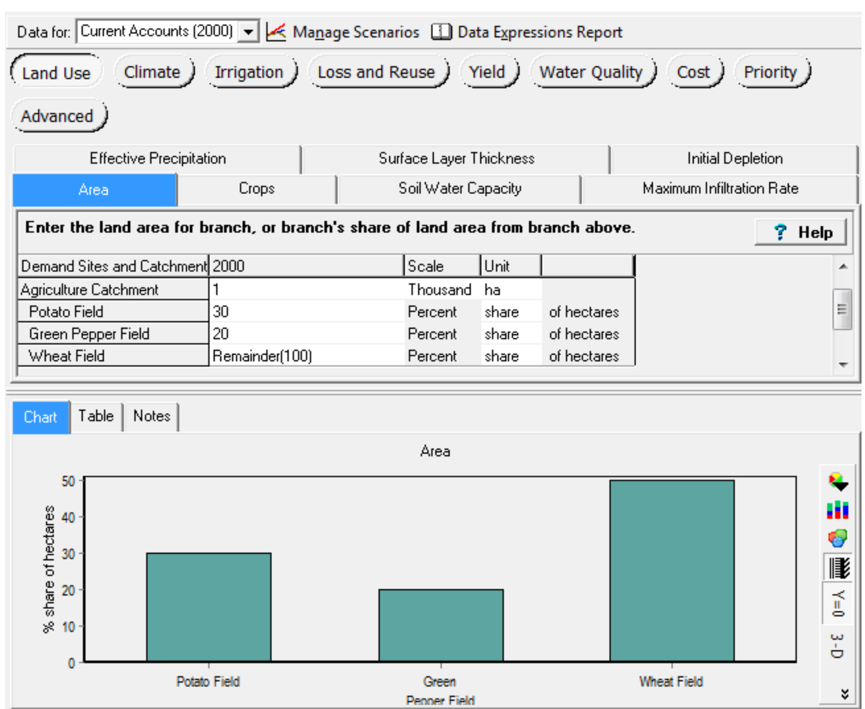
Total Land Area *1,000 ha (you will have to select units first)*

Share of Land Area

Potato: 30

Green Pepper: 20

Wheat: Remainder(100)

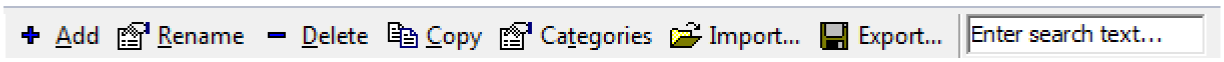


Crop

Click on the “Crops” tab to activate it.

The “Crops” tab is used to define the crop(s) and to set the planting date(s) for these chosen crop(s) to be used in the selected catchment.

WEAP-MABIA includes a “Crop Library” which provides the required parameters for over 100 crops, some with multiple entries for different climates or regions of the world. The end user can add, edit, remove, copy, export, import or search the “Crop Library” for a particular crop:



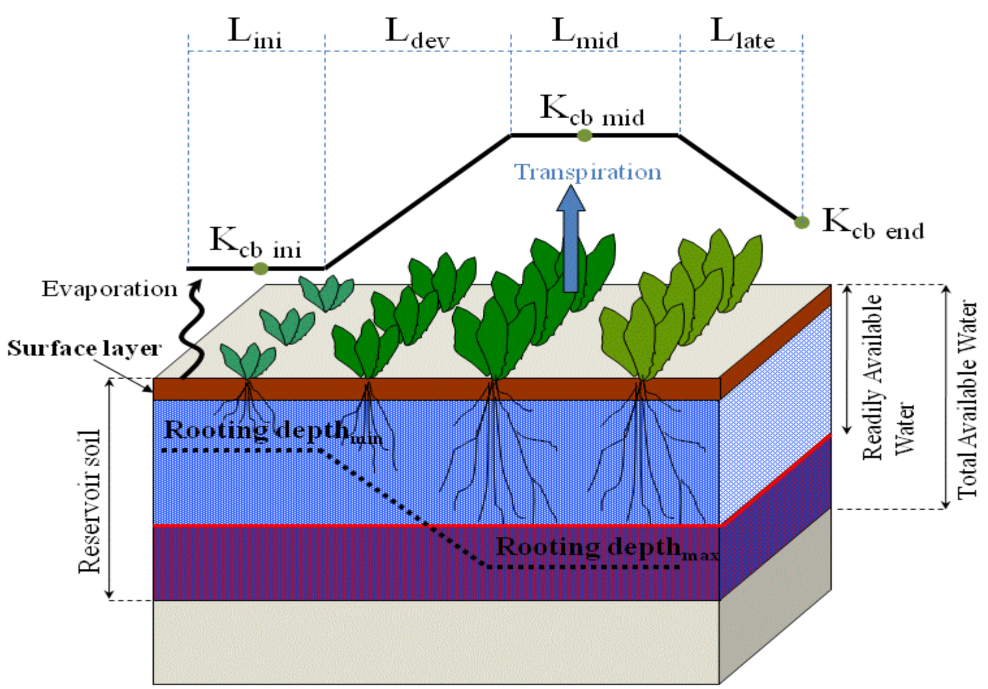
As showed in Graph, the parameters considered in the calculation algorithms of the WEAP-MABIA model are:

Crop or Land Cover	Stage Length [days]					Kcb			Depletion Factor [0-0.99]			Yield Response Factor, Ky					Maximum Height [m] (5)	Root Depth [m]	
	Initial (1)	Develop-ment	Mid-Season	Late	Total	Initial (2)	Mid-Season	Late	Initial (3)	Mid-Season	Late	Initial (4)	Develop-ment	Mid-Season	Late	Overall		Minimum	Maximum (6)
Fallow	365				365	0.01	0.01	0.01	0.99	0.99	0.99						0.15	1.00	1.00
Broccoli (Calif. Desert, USA)	35	45	40	15	135	0.15	0.95	0.85	0.45	0.45	0.45						0.30	0.15	0.50
Cabbage (Calif. Desert, USA)	40	60	50	15	165	0.15	0.95	0.85	0.45	0.45	0.45	0.40	0.40	0.50	0.50	0.95	0.40	0.15	0.65
Carrots (Arid climate)	20	30	40	20	110	0.15	0.95	0.85	0.35	0.35	0.35						0.30	0.15	0.75

- (1) The **lengths of growth stages** (L_{ini}, L_{dev}, L_{mid}, L_{late}) were computed according to the FAO-56 method as a function of vegetation cover f_c. The initial stage (L_{ini}) runs from sowing date to when f_c reach a value of 0.1, the development stage (L_{dev}) runs from f_c of 0.1 to full vegetation cover (f_c of 0.9), the mid-season stage (L_{mid}) runs from the end of development stage until canopy cover f_c drops back to the same value it had at the end of the development stage and the beginning of the mid-season period (f_c = 0.9). The late season stage (L_{late}) runs from end of the mid-season stage until the end of growing season.
- (2) The **basal crop coefficient** (K_{cb}) is defined as the ratio of the crop evapotranspiration ET_c over the reference evapotranspiration ETref when the soil surface is dry but transpiration is occurring at a potential rate. Therefore, K_{cb} represents primarily the transpiration component of ET_c. The K_{cb} coefficient serves as lumped parameter for the physical and physiological differences between crops. Variation in K_{cb} between the growth stages is mainly dependent on how the crop canopy develops. The values given in

the "crop library" represent a standard climate having mean daily minimum relative humidity (RH_{min}) equal to 45% and mean daily wind speed measured at 2 m (u_2) equal to 2 m s^{-1}.

- ❸ The **depletion factor** (p) is the fraction of the total available water (TAW) that can be depleted from the root zone before moisture stress occurs. You can define different values to express the variation of the crop sensitivity to water shortage over the different crop stages.
- ❹ The **yield response factor** (K_y) is a factor that describes the reduction in relative yield according to the reduction in the crop evapotranspiration (ET_c) caused by soil water shortage. K_y values are crop specific and may vary over the growing season. The values for K_y are given for the individual growth periods as well as for the complete growing season.



Graph illustrating the different parameters considered in the crop module.

- ❺ The **maximum height** of the crop
- ❻ The **rooting depth** for annual crops has three growth stages. The rooting depth is held constant at the minimum depth ($Z_{r\ min}$) throughout the initial crop growth stage. The root

zone increases linearly to a maximum depth ($Z_{r\ max}$) throughout the vegetative growth and development stages. The maximum root depth is attained at the beginning of the mid-season stage (peak growth) and is maintained throughout the mid and late season stage. However, the rooting depth for perennial crops is assumed to be constant.

Read the "Crop Library" help topic (under the "Data/Catchments/MABIA Method (FAO 56, dual Kc, daily)/Supporting screens" subheading in the Help Contents) for a more detailed description of the "Crop Library" screen.

Adding New Crops to the Library

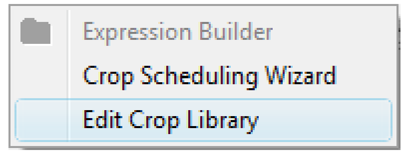
Now suppose you have your own experimental data and you want to use them instead of using the crops as defined in the "Crop Library". Therefore, you need to add them to the "Crop Library". For that you are going to use the data as described below:

Crop name	*Potato*
Category	*Roots and Tubers*

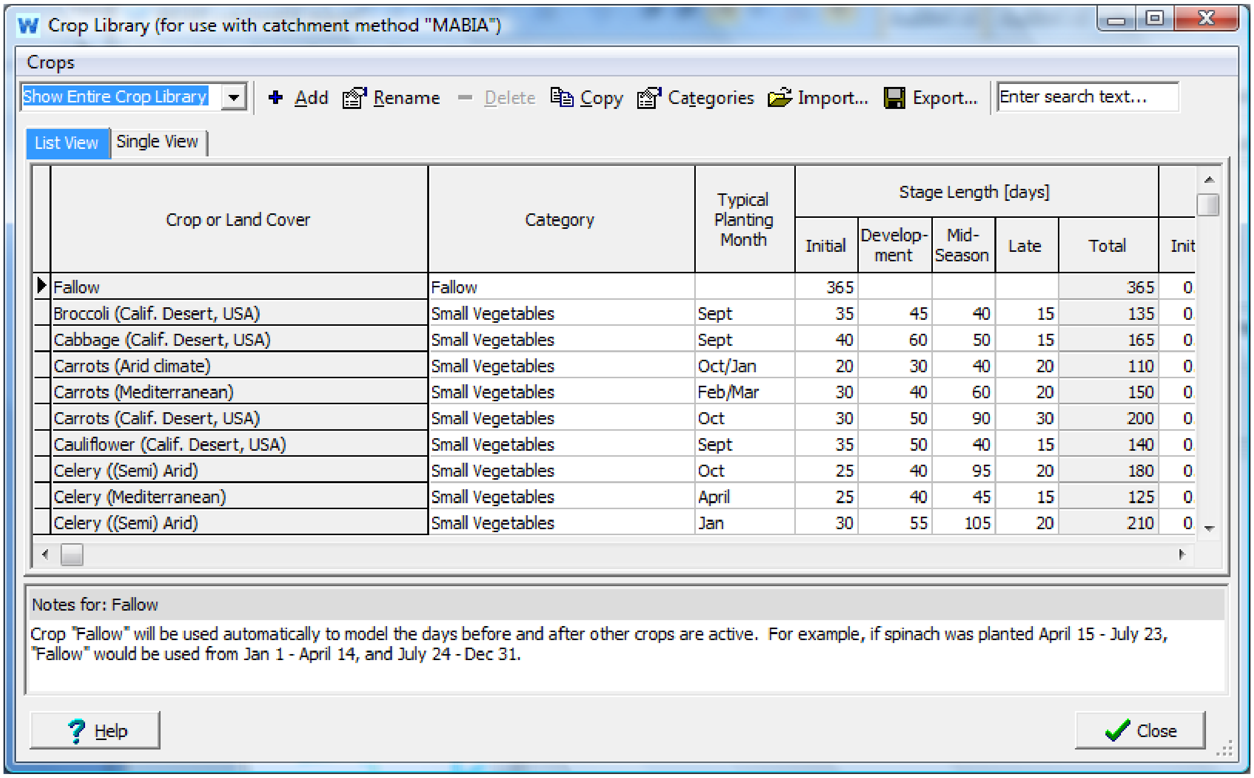
	Initial	*Development*	*Mid-season*	*Late-season*
Stage length	*20*	*25*	*35*	*25*
K_{cb}	*0.15*		*1.1*	*0.65*
K_y	*0.45*	*0.8*	*0.8*	*0.3*
K_y *(Overall)*	*1.1*			
Height (m)	*0.6*			
Depletion Factor	*0.35*		*0.35*	*0.35*

	Min	*Max*
Rooting Depth (m)	*0.15*	*0.6*

1. Click on the empty cell in front of the “Potato Field” of the “Crops” tab (in the “Land Use” window) and select the “Edit Crop Library” from the pull-down menu.

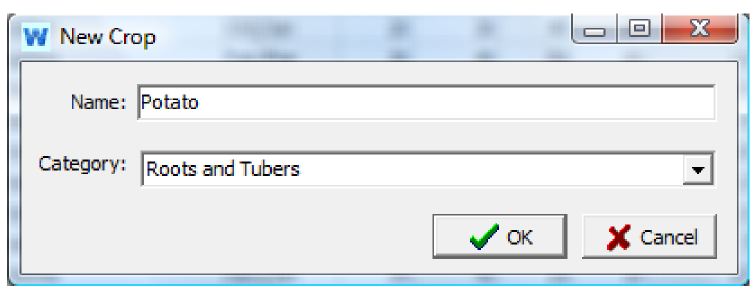


The “Crop Library” window will show up.



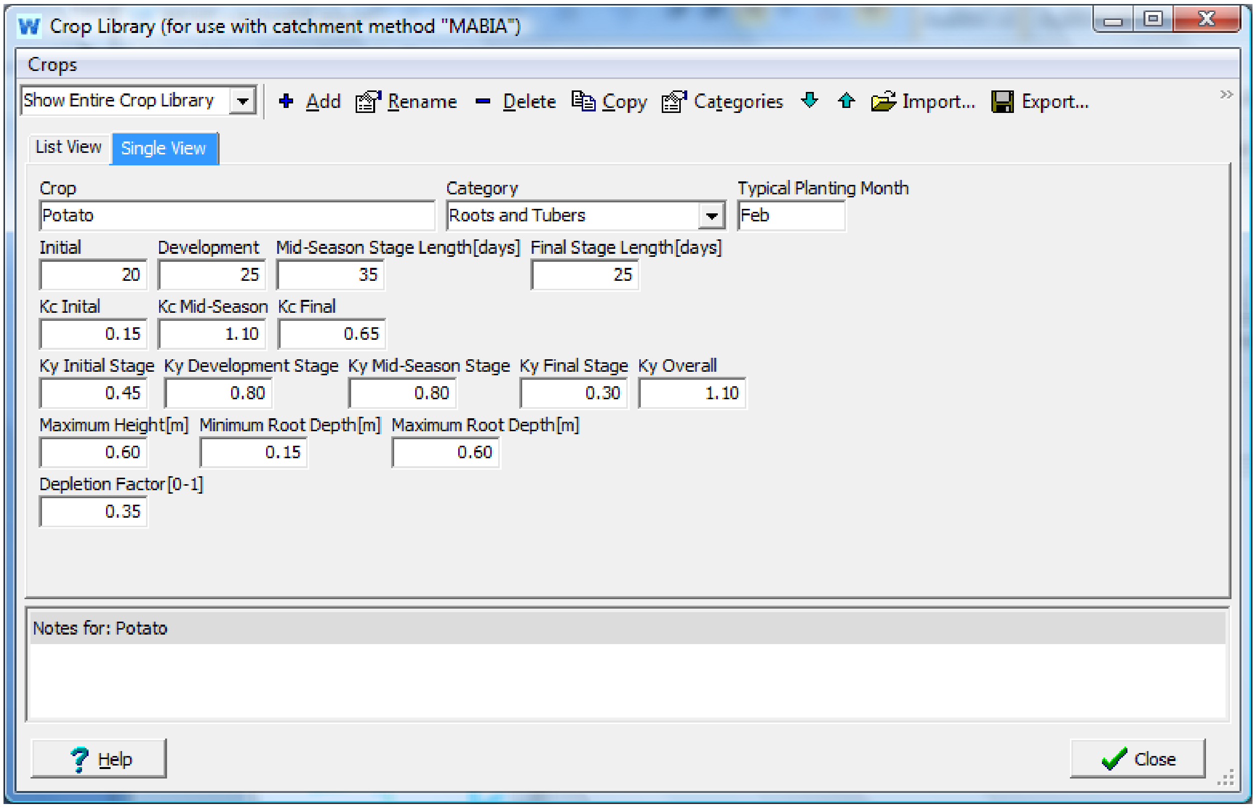
2. Click the **+ Add** button to add a new crop.

3. In the “New Crop” window enter the name and the category for Potato as shown in the figure. Then click **✔ OK**. The new crop will be added to the existing list.

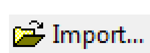


4. Now, click on the “Single View” and start entering the data for Potato **List View | Single View**

5. Once all the data are entered, click **✔ Close** to validate the data.



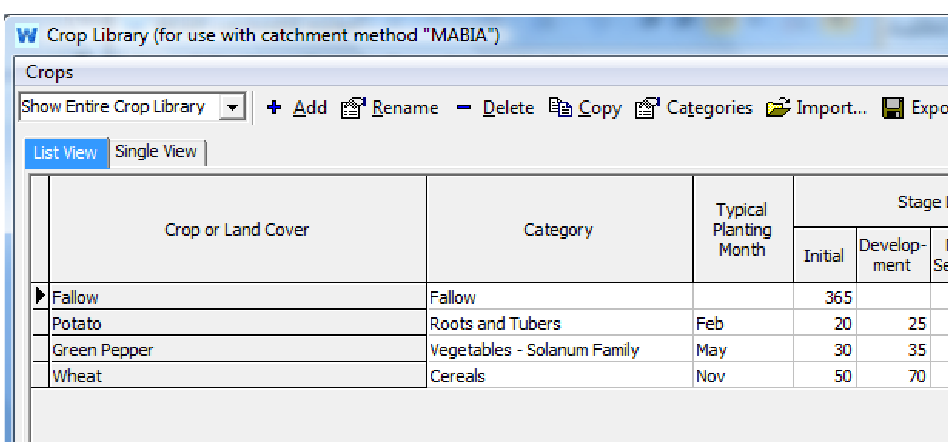
For the remaining crops (Green Pepper and Wheat) you will use the import functionality to add them to the list of crops. For that, you will need the file "Pepper&Wheat.csv". You need to download it from http://www.bgr.bund.de/IWRM-DSS WEAP-MABIA tutorial data.

1. In the "Crop Library", click the 

button

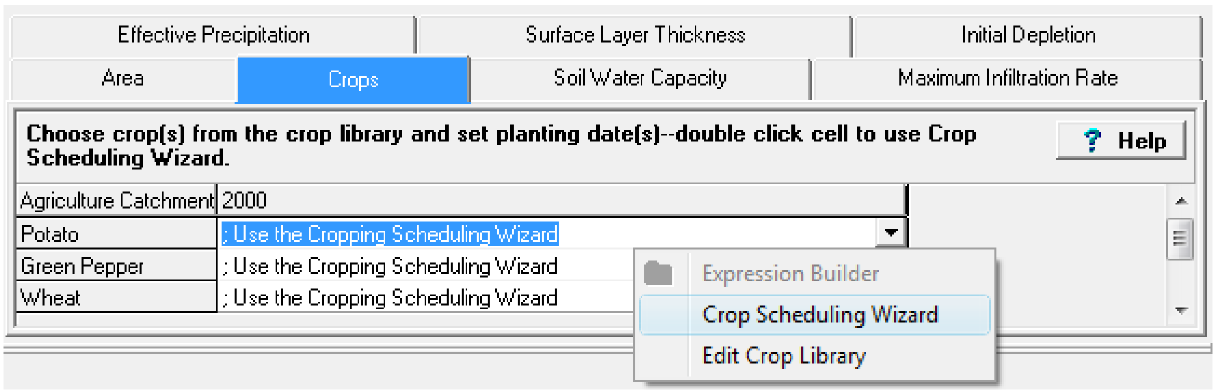
2. Tell WEAP where to find the file "Pepper&Wheat.csv", select it and click "Open"

3. The remaining crops will be added to the list. The "Crop Library" window will look like this:



Using the Cropping Scheduling Wizard

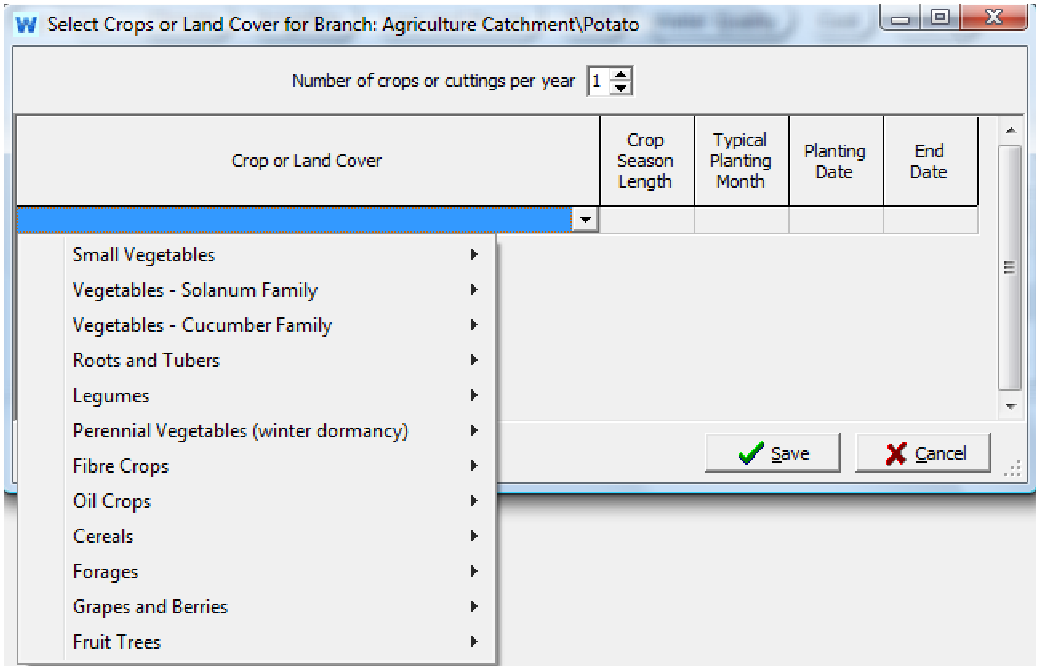
WEAP comes with a "Cropping Scheduling Wizard" to assist the user in defining the cropping pattern for the different catchment branches. It is accessible via the drop-down menu on the data grid for the "Crops" tab under "Land Use".



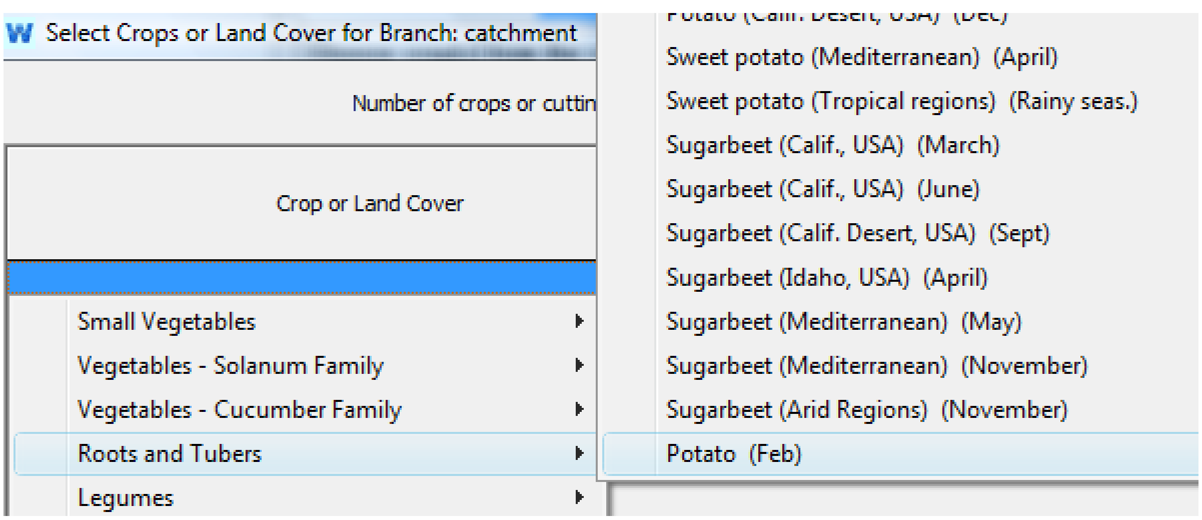
For each branch of the "Agriculture Catchment", use the Crop Scheduling Wizard to specify the crops (from the "Crop Library") and the planting date as described below:

Branch	*Crop Name*	*Planting Date*
Potato Field	*Potato*	*Feb 13*
Green Pepper Field	*Green Peppers*	*May 5*
Wheat Field	*Wheat*	*Nov 17*

1. Click on the empty cell in front of the "Potato Field" of the "Crops" tab (in the "Land Use" window) and select the "Crop Scheduling Wizard" from the pull-down menu in the data entry bar. The "Crop Scheduling Wizard" will show up.



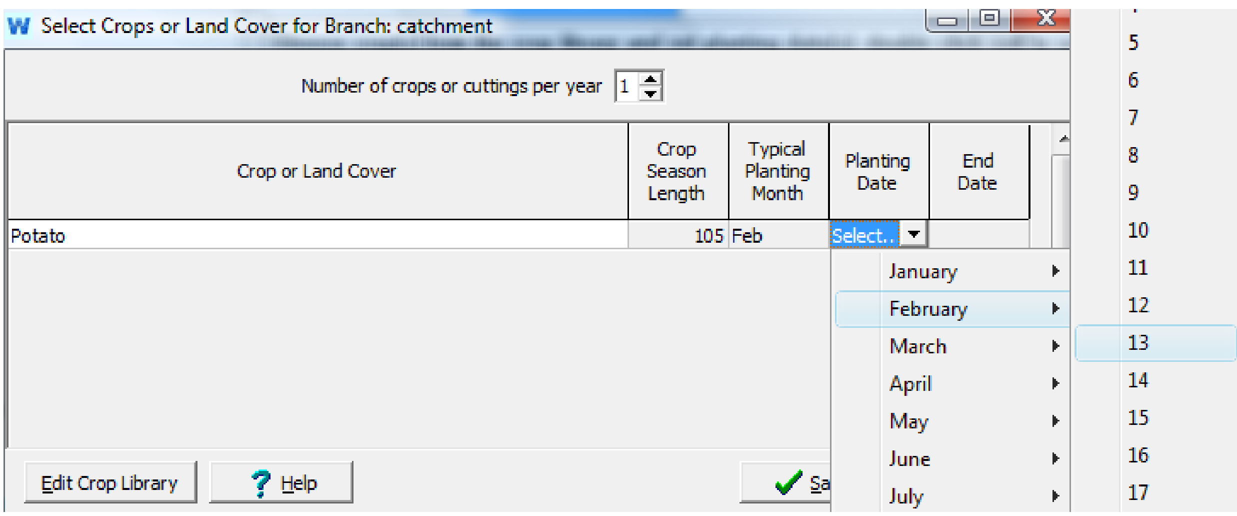
2. At the top of the wizard, select the number of crops or cuttings per year. For this example, leave it to default (1) as only potato is cultivated. Then, click on the empty data row and point to the "Roots and Tubers" category of the drop-down menu, another menu will show up with a list of the crops that belongs to this category, select *"Potato (Feb)"*.



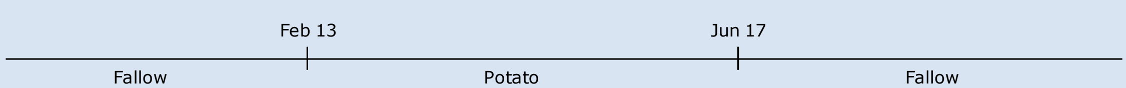
If you had potato followed by peanut for example, you would enter 2; or if you had instead an alfalfa crop with three subsequent cuttings, you would enter 3. Therefore, the crops would be defined as shown below:

Crop or Land Cover
Alfalfa (1st cutting cycle) (Calif., USA)
Alfalfa (other cutting cycles) (Calif., USA)
Alfalfa (other cutting cycles) (Calif., USA)

3. Then, click on the cell below the "Planting Date" and set the planting date to Feb 13 from the menu and click Save

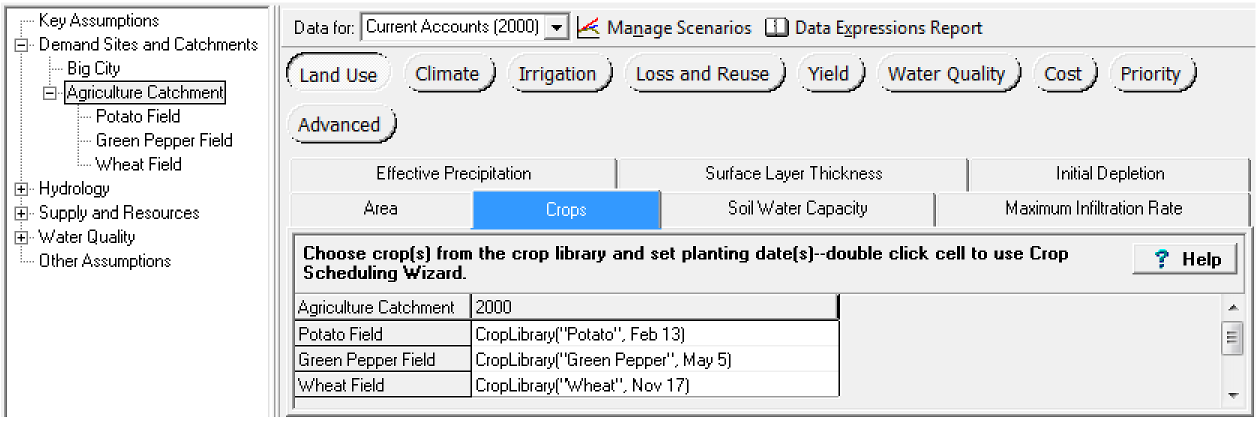


Note that any days not under cultivation by a crop will automatically use the characteristics of the crop named "Fallow" in the Crop Library. You do not need to add Fallow in the Crop Scheduling Wizard since it is automatically added. Then the cropping pattern will be as follow:



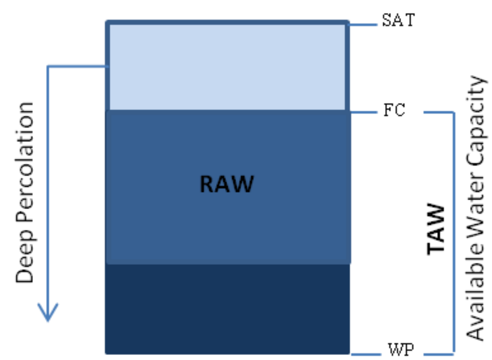
4. Repeat this procedure for the other two branches "Agriculture Catchment/Green Pepper Field" and "Agriculture Catchment/Wheat Field". The Green *Pepper* and the *Wheat* crop are under the categories "Vegetables - Solanum Family" and "Cereals", respectively.

Once you have completed all the tasks, the "Crops" tab should look like this:



Soil Water Capacity

In the WEAP-MABIA model, the most relevant soil hydrological property determining the soil water balance is the available water capacity. It is assumed that the soil profile as a whole is vertically homogeneous and characterized by identical water retention properties. The available water capacity or the total available water (TAW) can then be calculated by water content at field capacity point (FC) minus water content at wilting point (WP).



Available Soil Water Capacity refers to the capacity of a soil to retain water available to plants. After heavy rainfall or irrigation, the soil will drain until field capacity is reached. Field capacity is the amount of water that a well-drained soil should hold against gravitational forces, or the amount of water remaining when downward drainage has markedly decreased. In the absence of water supply, the water content in the root zone decreases as a result of water uptake by the crop. As water uptake progresses, the remaining water is held to the soil particles with greater force, lowering its potential energy and making it more difficult for the plant to extract it. Eventually, a point is reached where the crop can no longer extract the remaining water. The water uptake becomes zero when wilting point is reached. Wilting point is the water content at which plants will permanently wilt.

As the water content above field capacity cannot be held against the forces of gravity and will drain and as the water content below wilting point cannot be extracted by plant roots, the available water capacity or the total available water (TAW) in the root zone is the difference between the water content at field capacity and wilting point.

TAW is the amount of water that a crop can extract from its root zone. TAW of a soil depends on pore volume and pore size distribution and therefore vary with soil physical properties such as texture class and bulk density. Beside these influencing factors, its magnitude depends on the rooting depth.

Although water is theoretically available until wilting point, crop begins to experience stress well before the wilting point is reached. Readily available water (RAW) is the fraction of TAW that a crop can extract from the root zone without suffering stress and is expressed in the MABIA model as the product of TAW and the depletion factor, p (p is defined in the Crop Library).

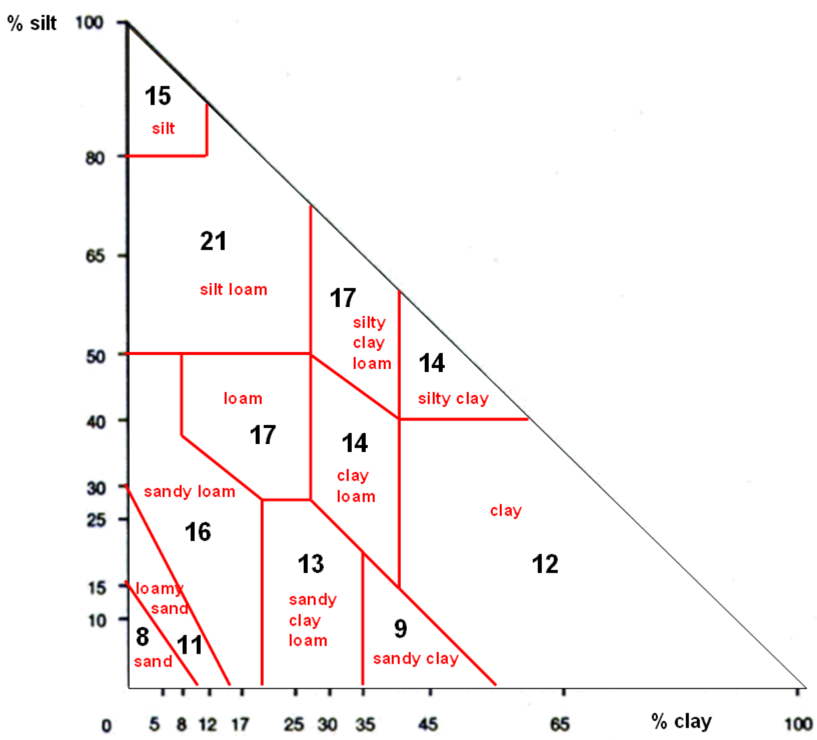


Figure: Available water capacity per FAO soil texture class.

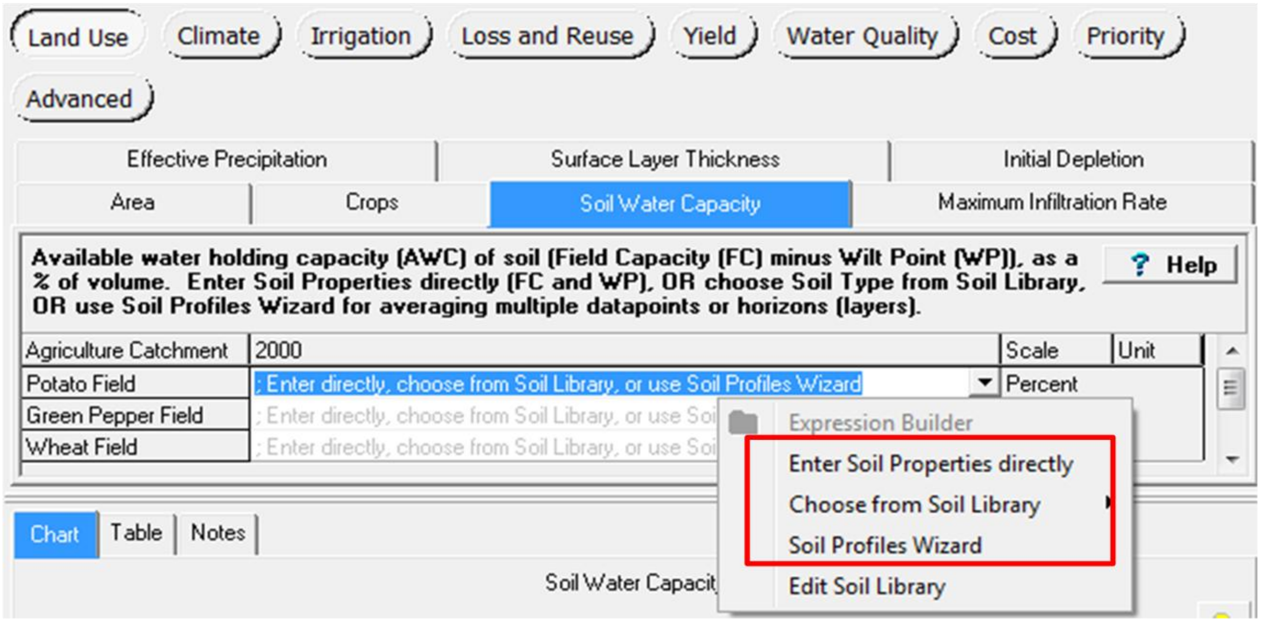
WEAP comes with a built-in “**Soil Library**” that provides typical values for SAT, FC, PWP and the Available Water Capacity for the 12 textural classes. You can edit this library or add to it.

Unfortunately, direct measurement of the water content at saturation (SAT), field capacity (FC) and wilting point (PWP) is labour intensive and impractical for most applications in research and management, generally cumbersome, expensive and time consuming, especially for relatively large-scale area.

Therefore, WEAP-MABIA comes with a built-in “**Soil Profiles Wizard**” which allows the estimation of the average soil water capacity (saturation, field capacity and wilt point) using one of seven available Pedotransfer Functions (PTF), in order to determine the Soil Water Capacity for catchment land use branches in the “Data View”, under “Land Use”. Using this wizard, you can average water content values over several soil profiles (sampling sites) and soil horizons (layers). This wizard is designed to average available water capacities from several soil and rock layers but does not allow to allocate awc values from individual soil horizons to rooting depths of a specific crop of a specific growth stage. The seven available PTFs are chosen so they can be used with different scenarios of basic soil data availability.

The basic soil data that can be used are: The particle size distribution (%Clay, %Silt and % coarse fragments) and/or the bulk density (BD) and/or the percentage of the soil organic matter (%OM). In a first step the available water capacity is derived from information on soil texture, bulk density and organic matter, afterwards the final result is calculated by subtracting the volume that is filled out by coarse fragments.

WEAP-MABIA offers three options to input SAT, FC and WP (all available on the drop-down menu in the data grid):



For this example you will be exercising on:

- Entering the soil properties directly
- Using the "Soil Library"

> The "Soil Profiles Wizard" will be discussed and described in details in a separate chapter. See the section titled "Using the Soil Profiles Wizard" for more details.

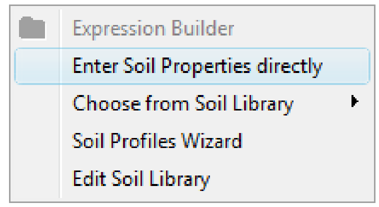
The soil data to use are as follows:

Branch	*Saturation*	*Field Capacity*	*Wilting Point*	Coarse Fragments
Potato Field	51.8	32.5	21.4	0
Green Pepper Field	47.8	36.2	21.8	0
Wheat Field	40.7	35.8	24.3	0

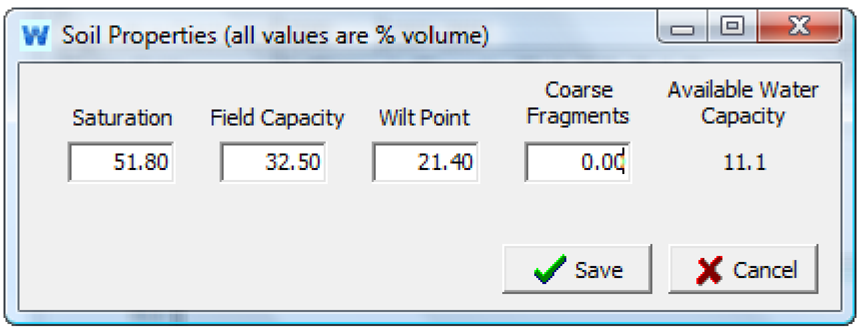
Enter the soil properties directly

1. Select the empty cell in front of the “Potato Field” heading.

2. Then select the “Enter Soil Properties directly” option from the drop-down menu in the data grid of the “Soil Water Capacity” tab.



3. A window will appear into which you enter the saturation, field capacity and wilt point of the Potato Field branch. Then click on “Save”.



4. Repeat the same steps to enter the soil properties for the “Green Pepper Field”.

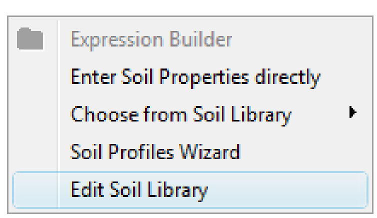
> If the soil properties of one branch are the same as those of another branch, you can copy and paste the expression from one branch to another.

Enter the soil properties from the “Soil Library”

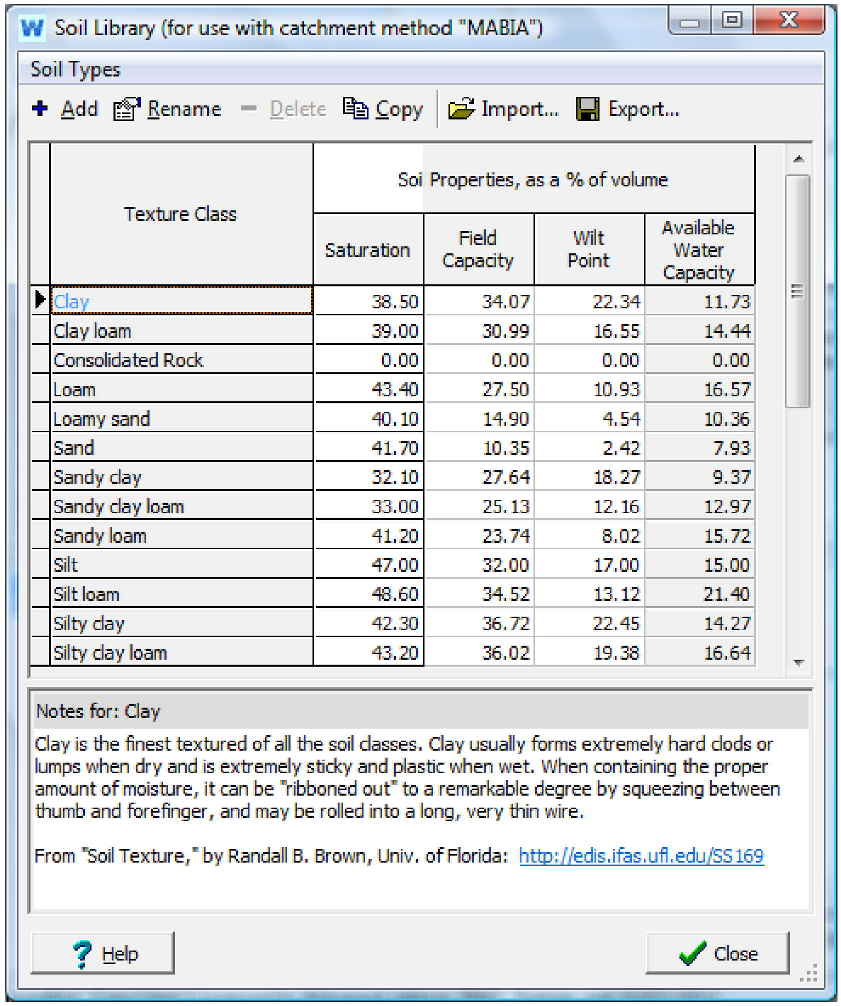
You are going to use the “Soil Library” to enter the soil properties for the “Wheat Field”.

1. Select the empty cell in front of the “Wheat Field” heading.

2. Then select the “Edit Soil Library” option from the drop-down menu in the data grid of the “Soil Water Capacity” tab.



A window will appear into which you have the typical values for the soil properties of the 12 soil classes.

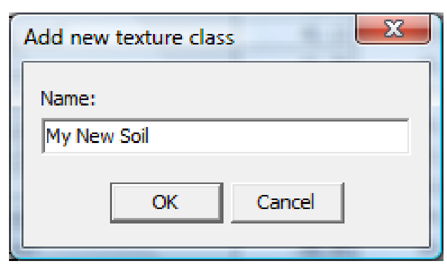


Texture Class	Soil Properties, as a % of volume			
	Saturation	Field Capacity	Wilt Point	Available Water Capacity
Clay	38.50	34.07	22.34	11.73
Clay loam	39.00	30.99	16.55	14.44
Consolidated Rock	0.00	0.00	0.00	0.00
Loam	43.40	27.50	10.93	16.57
Loamy sand	40.10	14.90	4.54	10.36
Sand	41.70	10.35	2.42	7.93
Sandy clay	32.10	27.64	18.27	9.37
Sandy clay loam	33.00	25.13	12.16	12.97
Sandy loam	41.20	23.74	8.02	15.72
Silt	47.00	32.00	17.00	15.00
Silt loam	48.60	34.52	13.12	21.40
Silty clay	42.30	36.72	22.45	14.27
Silty clay loam	43.20	36.02	19.38	16.64

Give a name to the soil of the "Wheat Field". Let it be "*My New Soil*".

3. Click on the button 

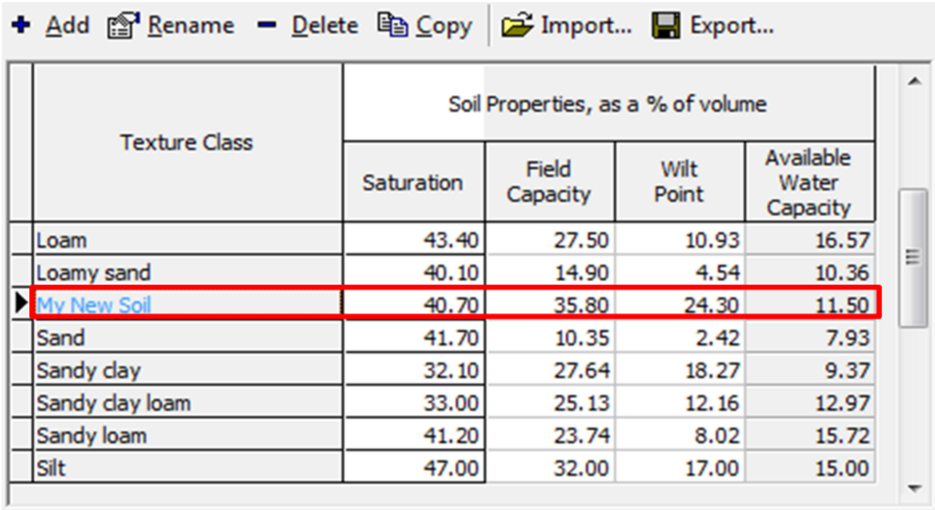
to add a new soil to the library.



4. In the "Add new texture class" window enter the name of your new soil as shown in the figure. Then click "OK". The new soil texture will be added to the existing list.

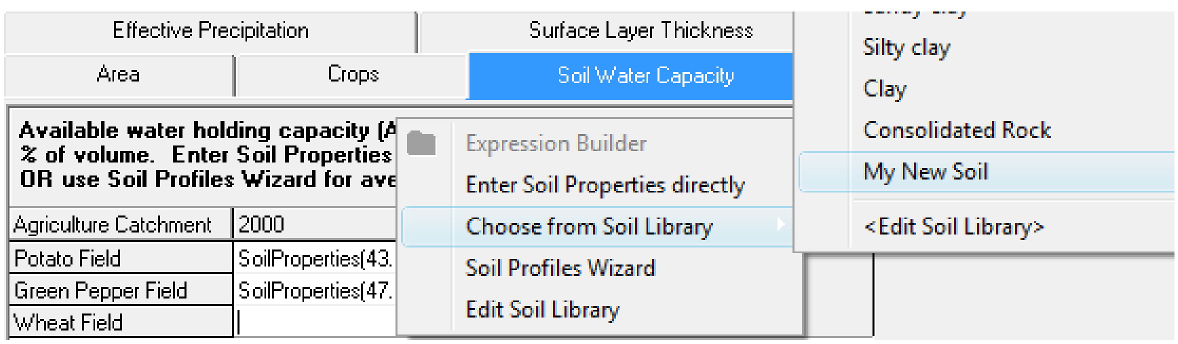
5. Enter the soil properties of your new soil as shown below then click 

to validate your data.

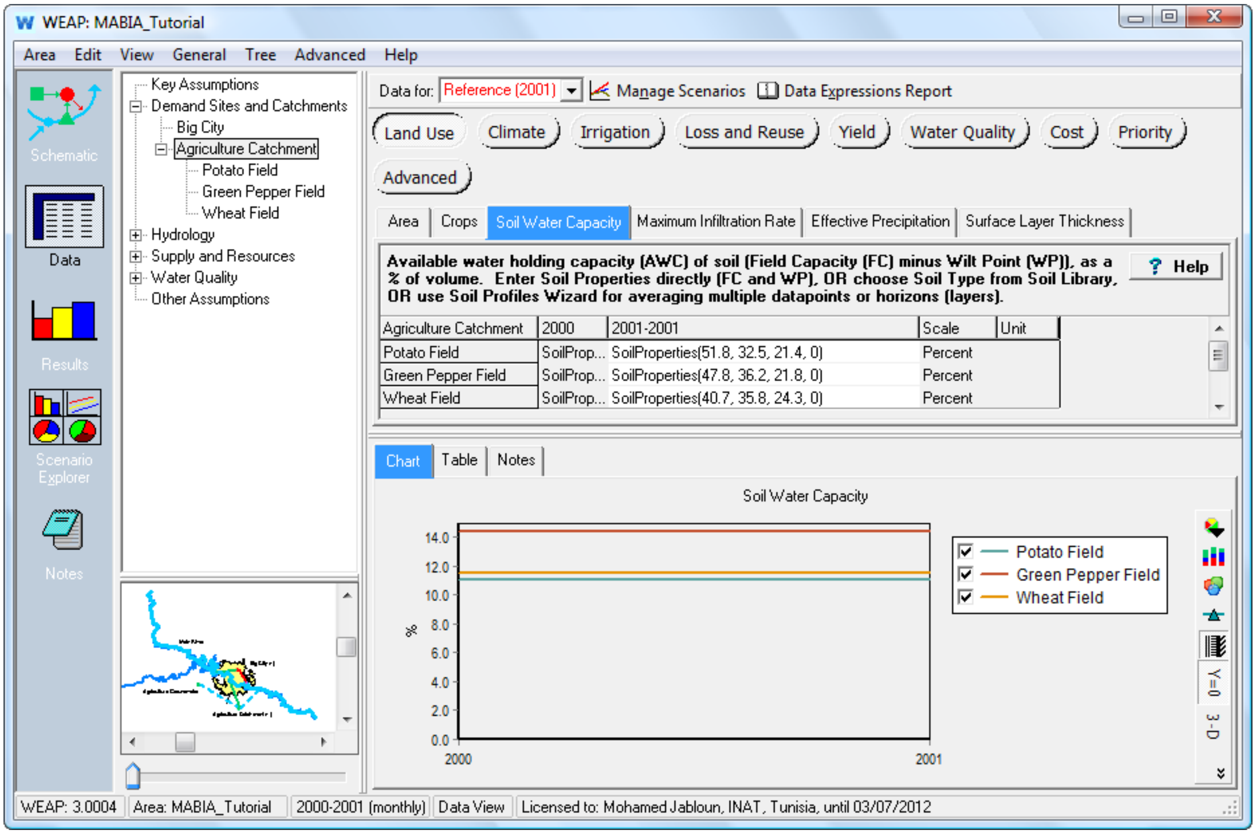


Texture Class	Soil Properties, as a % of volume			
	Saturation	Field Capacity	Wilt Point	Available Water Capacity
Loam	43.40	27.50	10.93	16.57
Loamy sand	40.10	14.90	4.54	10.36
My New Soil	40.70	35.80	24.30	11.50
Sand	41.70	10.35	2.42	7.93
Sandy clay	32.10	27.64	18.27	9.37
Sandy clay loam	33.00	25.13	12.16	12.97
Sandy loam	41.20	23.74	8.02	15.72
Silt	47.00	32.00	17.00	15.00

6. In the "*Data View*", under the "Soil Water Capacity" tab, click the empty cell in front of "Wheat Field" then point on "*Choose from Soil Library*" option of the drop-down menu. You should see a list of all the available soil textures in your library. Look for "*My New Soil*" and select it.



If you have completed all the above tasks, your screen should look like the one shown below:



Maximum Infiltration Rate

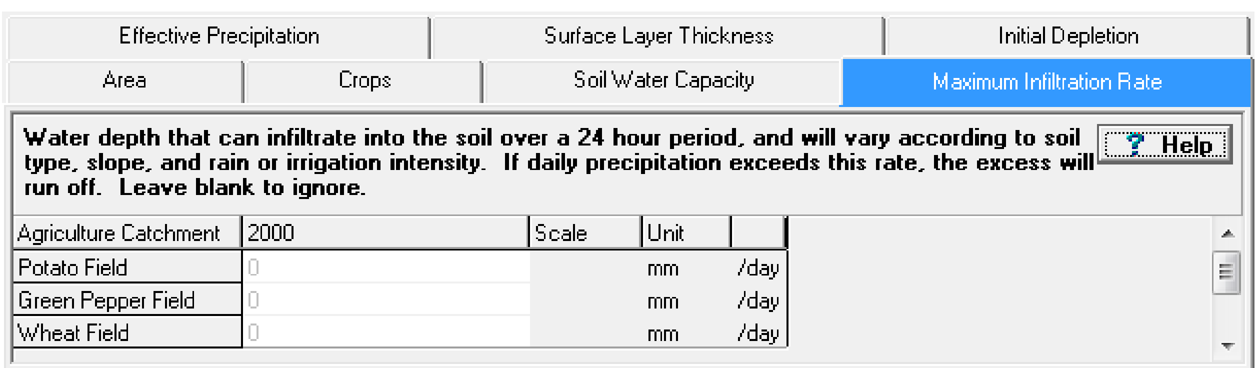
The Maximum Infiltration Rate is the water depth that can infiltrate into the soil over a 24 hour period. There are several factors affecting a soil's infiltration rate: in general sandy soils tend towards higher hydraulic conductivities while clayey soils are characterized by lower values. Soils with a crust have sealed pores that restrict water entry. Similarly, compacted soils will have lower infiltration. Soils with strong aggregates, like those with granular or blocky structures, have a higher infiltration rate than soils with weak structures. Infiltration rates are usually higher when soil is dry and decrease with wetter soil. If daily precipitation exceeds this rate, the excess will run off. The value entered here is not needed for calculations of the soil water balance and is only used to partition rainfall into surface runoff and infiltration. If no value is entered, gross precipitation equals net precipitation and all rainfall water is available for infiltration.

Typical values of the Maximum Infiltration Rate for the 12 textural classes are given in the table below (from "Davis , A. P. and McCuen, R. H. 2005. Stormwater Management for Smart Growth. Springer Ed.", 377p).

Soil Class	**Maximum Infiltration Rate**	
	(in./hr)	**(mm/day)***
Sand	5.0	3048.0
Loamy sand	1.5	914.4
Sandy loam	0.8	487.7
Sandy clay loam	0.4	243.8
Loam	0.4	243.8
Clay loam	0.25	152.4
Silty loam	0.20	121.9
Sandy clay	0.15	91.4
Silt	0.15	91.4
Silty clay loam	0.08	48.8
Silty clay	0.04	24.4
Clay	0.02	12.2

*converted by considering: 1 inch = 25.4 mm

Leave it blank for the three "Agriculture Catchment" branches.



Effective Precipitation

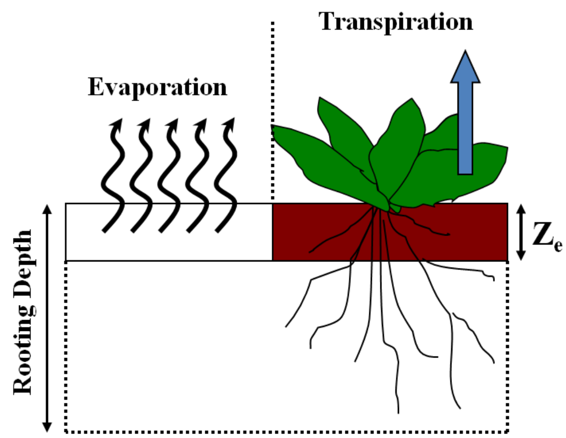
The effective precipitation is defined as the percentage of rainfall available for evapotranspiration. The remainder is direct runoff.

Suppose that only 80% of the rainfall is considered as effective. Therefore, 20% of this rainfall will be lost as direct runoff.

> *Leave it blank for the three "Agriculture Catchment" branches to consider that 100% of the rainfall is available for evapotranspiration.*

Surface Layer Thickness

In the MABIA model, the crop transpiration and the evaporation from the exposed soil layer are calculated separately. Thus, the surface layer thickness parameter (Ze) represents the depth of the surface soil layer that is subject to drying by way of evaporation. When no specific value for Ze is entered, an effective depth of the soil evaporation layer of 0.10 m assumed.



In some regions of the world, e.g. under climatic conditions of Central Europe, lower surface layer thicknesses of 0.02 – 0.03 m and resulting simulation results better fit to locally observed evaporation rates.

> *Leave it blank for the three "Agriculture Catchment" branches to consider that the surface soil layer is 0.1 m depth.*

Initial Depletion

The initial depletion is the initial value of the soil moisture depletion on the first day of the calculation period. Zero depletion means that the soil water content is close to soil water contents at field capacity. However, the maximum depletion value is the available water capacity, as specified under "Soil Water Capacity" and means that the soil was initially dry.

> *Leave it blank for the three "Agriculture Catchment" branches.*

Enter the Appropriate Climatic Data

The MABIA method requires **daily** information concerning the weather conditions. Those conditions determine the amount of water that can infiltrate into the soil profile and that can be extracted by the evaporation from the surface soil layer and the crop transpiration. The required daily climatic data are:

- Rainfall depth, which is the amount of water collected in rain gauges installed on the field or at a nearby weather station (mm);
- Evaporative demand of the atmosphere for the given weather conditions. It is given by the evapotranspiration of a reference surface, ETref (mm day^{-1}).

However, data on the reference evapotranspiration are most of the time unavailable. That's why the WEAP-MABIA model comes with different options to calculate ETref considering different scenarios of climatic data availability and using the Penman-Monteith equation as recommended by the FAO-56. Required climatic parameters to calculate ETref by the Penman-Monteith approach are:

- daily minimum and maximum temperature (^{o}C),
- daily average relative air humidity (%),
- daily wind speed measured at 2 m height (ms^{-1}),
- daily solar radiation (MJ m^{-2}) or alternatively daily duration of sunshine (h).

Daily wind speed is also used to correct the K_{cb} values during the mid-season and the late-season stage, and additionally daily minimum relative air humidity is required for the same purpose.

These different options to estimate ETref will be discussed and presented in a separate chapter. See the section titled "The Climate Calculation Module" for more details.

Because the MABIA method calculates on a daily time step, you will need daily data for most climate parameters (which will typically be read from a text file). However, if you only have monthly data, it can be disaggregated into daily data using several different methods. See the section titled "Disaggregating Monthly to Daily Data" for more details.

Import Climatic Data

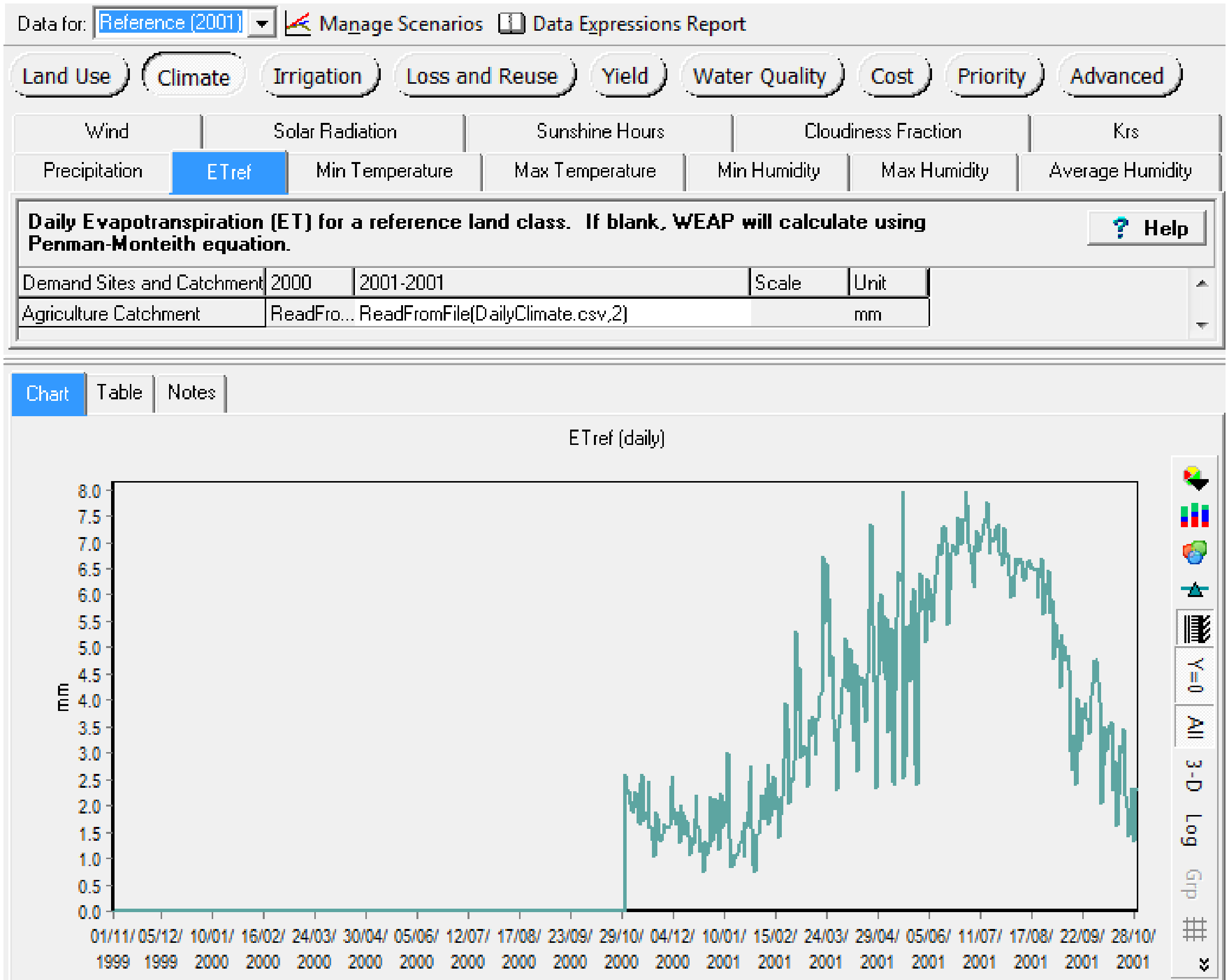
Import climatic data from a comma-separated text file containing all the required climatic parameters for the year 2001. For that, you need to have the file "DailyClimate.csv" under the folder "Tutorial" in your area's folder. You can download the file from http://www.bgr.bund.de/IWRM-DSS .

To import the climatic data, use the "ReadFromFile" function in the Climate's data tab in the "Demand Sites and Catchments\Agriculture Catchment" branch of the Data tree.

Type in the following expressions, which will read the file for each of the required climatic parameters:

Climatic Parameter	*Column Number*	*Function*
Precipitation	*1*	*ReadFromFile(*DailyClimate.*csv,1)*
ETref	*2*	*ReadFromFile(*DailyClimate.*csv,2)*
Min Humidity	*4*	*ReadFromFile(*DailyClimate.*csv,4)*
Wind	*3*	*ReadFromFile(*DailyClimate.*csv,3)*

Go under the "Reference" scenario and click on the "ETref" tab to check if you can see the following screen. Go back to the "Current Account" to fill the other parameters.



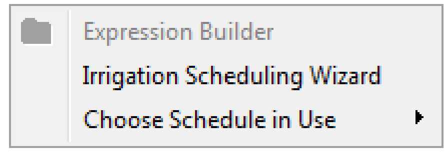
Enter the Appropriate Irrigation Data

Irrigation is required when rainfall is insufficient to compensate for the water lost by evapotranspiration. The primary objective of irrigation is to apply water at the right period and in the right amount. By calculating the soil water balance of the root zone on a daily basis, the timing and the depth of future irrigations can be planned. To avoid crop water stress, irrigations should be applied before or at the moment when the readily available soil water (RAW) is depleted (Depletion <= RAW).

Irrigation Schedule

The next step in using the "MABIA" model is to define the irrigation schedule. For each branch of the Agriculture Catchment" is assigned an *IrrigationSchedule* expression.

You can choose the irrigation schedule criteria and options, using the “Irrigation Scheduling Wizard”, or choosing a schedule already in use for the same crop. These two options are available on the drop-down menu in the data grid.

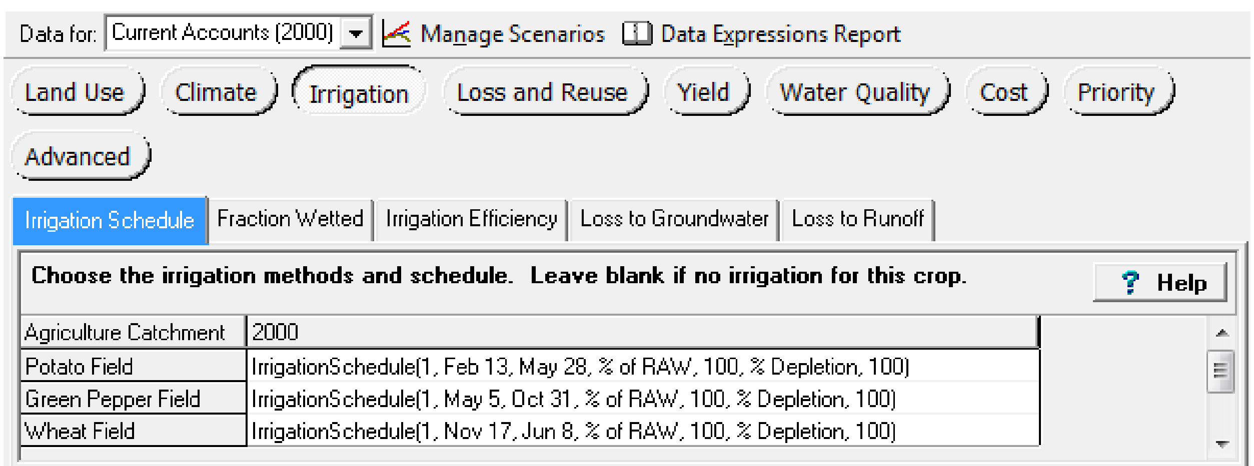


For the “Current Account”, we will assume the following expressions:

Branch	*Expression*
Potato Field	*IrrigationSchedule(1, Feb 13, May 28, % of RAW, 100, % Depletion, 100)*
Green Pepper Field	*IrrigationSchedule(1, May 5, Oct 31, % of RAW, 100, % Depletion, 100)*
Wheat Field	*IrrigationSchedule(1, Nov 17, Jun 8, % of RAW, 100, % Depletion, 100)*

These expressions will ensure that soil moisture depletion never goes below RAW so that no crop water stress will occur. Scheduling options in dependence of ‘Irrigation Trigger’ and ‘Irrigation Amount’ will be discussed and described in details in a separate chapter.

> *To input these expressions, select the “Irrigation Schedule” tab under the “Irrigation” variable. Then, input the expressions given above. Use Copy and Paste.*

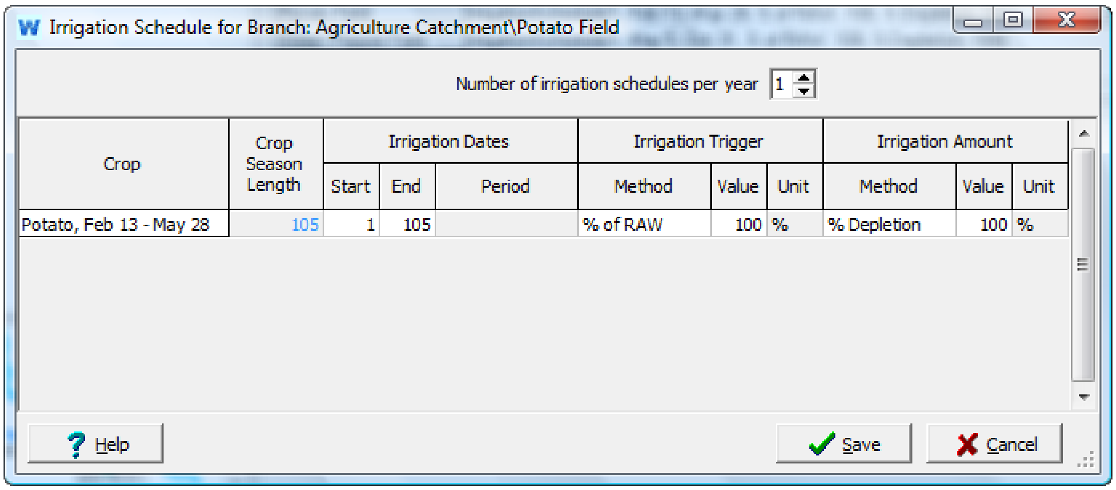


You can also define these expressions by

1. Select the “Irrigation Scheduling Wizard” from the drop down menu.

2. Then click on 

and WEAP will create the corresponding IrrigationSchedule expression that embodies the data already defined by WEAP as defaults.



3. Repeat these steps for each of the branches of the “Agriculture Catchment”.

> The “Irrigation Scheduling Wizard” will be discussed and described in details in a separate chapter. See the section titled "the Irrigation Scheduling and Crop Yield Module" for more details.

Fraction Wetted

Many types of irrigation systems wet only a fraction of the soil surface. For example, for a trickle irrigation system, the fraction of the surface wetted, F_w, may be only 0.4. For furrow irrigation systems, the fraction of the surface wetted may range from 0.3 to 0.8.

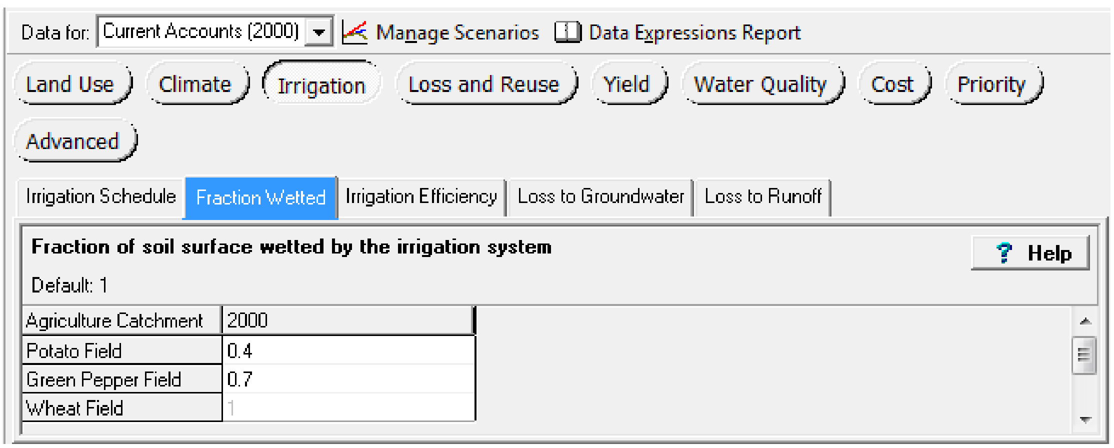
Below are common values of fraction F_w for some irrigation systems:

Irrigation System	*Fw*
Sprinkler irrigation	*1*
Basin irrigation	*1*
Border irrigation	*1*
Furrow irrigation (every furrow), narrow bed	*0.6 - 1.0*
Furrow irrigation (every furrow), wide bed	*0.4 - 0.6*

Furrow irrigation (alternated furrows)	*0.3 - 0.5*
Trickle irrigation	*0.3 - 0.4*

For this example, click on the "Fraction Wetted" tab and enter the following data:

Branch	*Irrigation system*	*Fw*
Potato Field	*Drip irrigation*	*0.4*
Green Pepper Field	*Furrow irrigation*	*0.7*
Wheat Field	*Sprinkler Irrigation*	*1*



Irrigation Efficiency

Not all water which is applied to the field can indeed be used by the plants. Part of the water is lost through evaporation, 'Loss to Runoff' (see page 33) and 'Loss to Groundwater' (see page 33). To reflect these water losses, the field application efficiency (E_a) has to be specified into WEAP and is determined by using the following formula:

$$E_a = \frac{d_{net} \times 100}{d_{gross}}$$

d_{gross}: gross irrigation depth in mm

d_{net}: net irrigation depth in mm = gross irrigation minus water losses

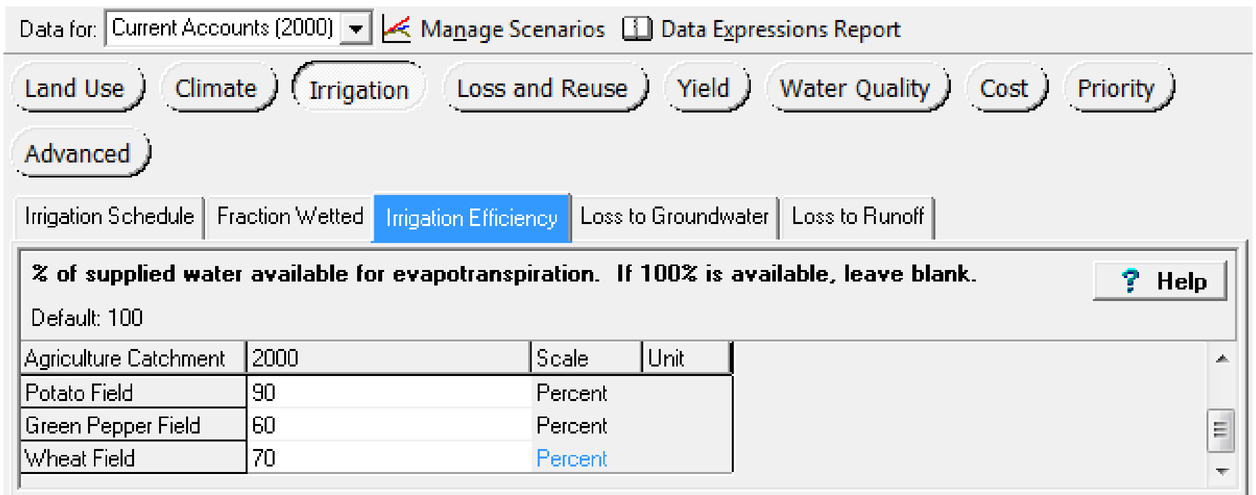
E_a: field application efficiency in percent

If reliable local data are available on the field application efficiency, these should be used. If such data are not available, the following empirical values from FAO recommendations for the field application efficiency (E_a) can be used:

System Type	***Application Efficiencies, Ea (%)***
Pressurized systems	
Sprinkler irrigation systems	
Fixed set systems	*70-80*
Guns	
Portable guns	*60-70*
Traveling guns	*65-75*
Center pivot and lateral move systems	*70-85*
Periodic move lateral	*65-75*
Microirrigation systems	
Drip or line source systems	
Surface	*70-90*
Subsurface	*70-90*
Spray systems	*70-85*
Bubbler systems	*70-85*
Gravity flow irrigation system	
Open field ditch systems	
Open ditch conveyance systems	
Flow through	*20-70*
Tailwater recycle	*30-80*
Semi-closed conveyance	
Flow through	*30-70*
Tailwater recycle	*40-80*
Subsurface conduit systems	*40-80*
Surface (flood) systems	
Crown flood systems	*25-75*
Continuous flood (paddy) systems	*25-75*

For this example, click on the "Irrigation Efficiency" tab and enter the following data:

Branch	*Irrigation system*	*Irrigation Efficiency*
Potato Field	*Drip irrigation*	*90*
Green Pepper Field	*Furrow irrigation*	*60*
Wheat Field	*Sprinkler Irrigation*	*70*



By entering an estimated value for "Irrigation Efficiency", only the total amount of irrigation water not available for evapotranspiration (100% - Irrigation Efficiency) is known. This water is partitioned into evaporation, direct runoff to surface water and deep percolation to groundwater (see flow chart on page 36). If these fractions are known, the user can specify them.

Loss to Groundwater

The "Loss to Groundwater" is defined as the percentage of the supplied water NOT available for evapotranspiration (100% - Irrigation Efficiency), that percolates to groundwater.

Loss to Runoff

The "Loss to Runoff" is defined as the percentage of the supplied water NOT available for evapotranspiration (100% - Irrigation Efficiency), that runs off to surface water.

> The amount of irrigation water which does not infiltrate or run off is assumed to evaporate.

For this example, the following partitioning is assumed:

Branch	*Loss to Groundwater*	*Loss to Runoff*
Potato Field	*80*	*0*
Green Pepper Field	*70*	*0*
Wheat Field	*70*	*0*

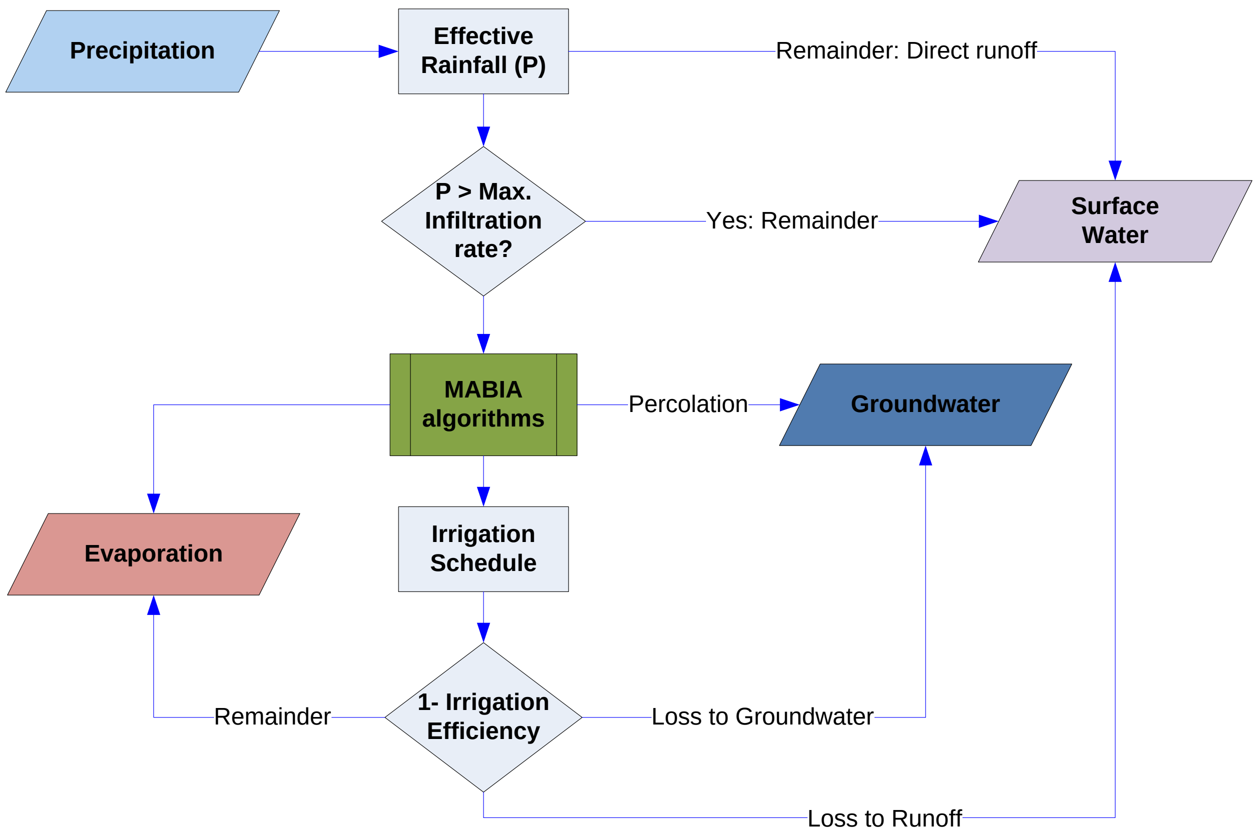


Figure: Flow chart illustrating the calculation procedures of the different water Losses.

As visible from the above given flow chart, direct runoff to surface water is fed from three different sources: the remainder from effective precipitation, the amount of rainfall exceeding the maximum infiltration rate and one of three fractions diminishing irrigation efficiency. By this way in WEAP the user can three-foldly influence the amount of surface runoff. Please notice that surface runoff in WEAP is not determined by applying a process-based rainfall-runoff-model.

Enter the Appropriate Yield Data

In irrigation schemes, crops, ideally, do not suffer from water shortages: irrigation water is applied before the crops are under drought stress.

However, it may not be possible to apply the irrigation water exactly when it would be best; for example, in a dry year the river may not have enough water to irrigate all the fields on time; the farmers may be badly organized and lose too much water at the upstream end of the scheme, thus causing problems downstream; the scheme management may decide to spread the available water over a large area, thus allowing more farmers to irrigate, although less than the optimal amount.

In such cases of unexpected - or sometimes even planned - water shortages, crop yields are presumed to decrease according to a simple, linear crop-water production function as defined by the FAO Irrigation and Drainage Paper No 33. The yield response of the crop to the reduction in evapotranspiration caused by soil water shortage is crop specific and may vary over the growing season. Empirical coefficients to assess this yield response are given by FAO and are part of the WEAP-internal “Crop Library” (see page 9).

> Read the “Yield” help topic (under the “Calculation Algorithms/Evapotranspiration, Runoff, Infiltration and Irrigation/MABIA Method” subheading in the Help Contents) for a more detailed description on the yield reduction calculation.

Potential Yield

The “Potential Yield” is the maximum yield of the selected crop assuming an optimal supply of water. This value will be used to estimate the actual yield using the crop-water production function.

For this example, click on the “Yield” tab and enter the following data:

Branch	*Potential Yield (kg/hectare)*
Potato Field	*90*
Green Pepper Field	*60*
Wheat Field	*70*

Market Price

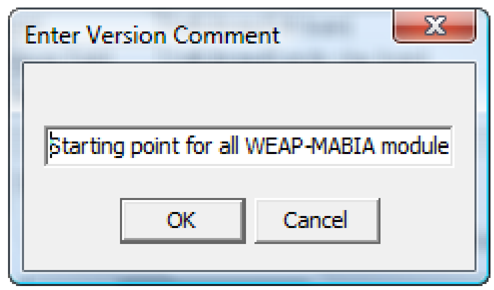
This parameter defines the market price of the crops.

For this example, use the following data:

Branch	*Market Price ($/kg)*
Potato Field	*90*
Green Pepper Field	*60*
Wheat Field	*70*

Save a version of your Area

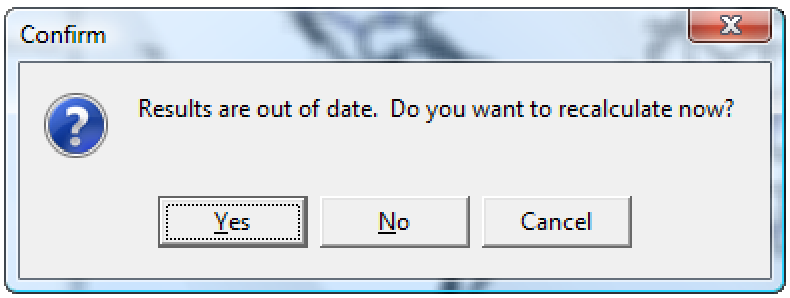
Select “Save Version” under the “Area” menu. A window will appear asking for a comment to describe this version. Type “Starting point for all WEAP-MABIA modules”. This version will be used for the remaining modules.



Getting first Results

Run the Model

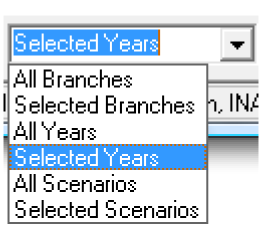
Click on the "Results" view to start the computation. When asked whether to recalculate, click yes. This will compute the entire model for the Reference Scenario - the default scenario that is generated using Current Accounts information for the period of time specified for the project (here, 2000 to 2001). When the computation is complete, the Results view will appear.

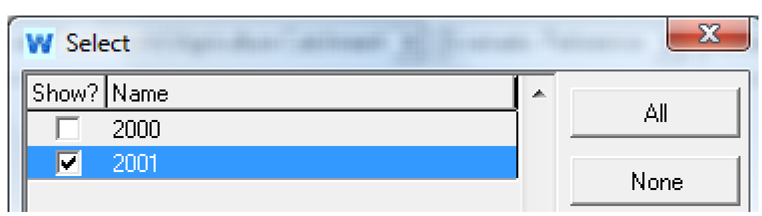


Check your Results

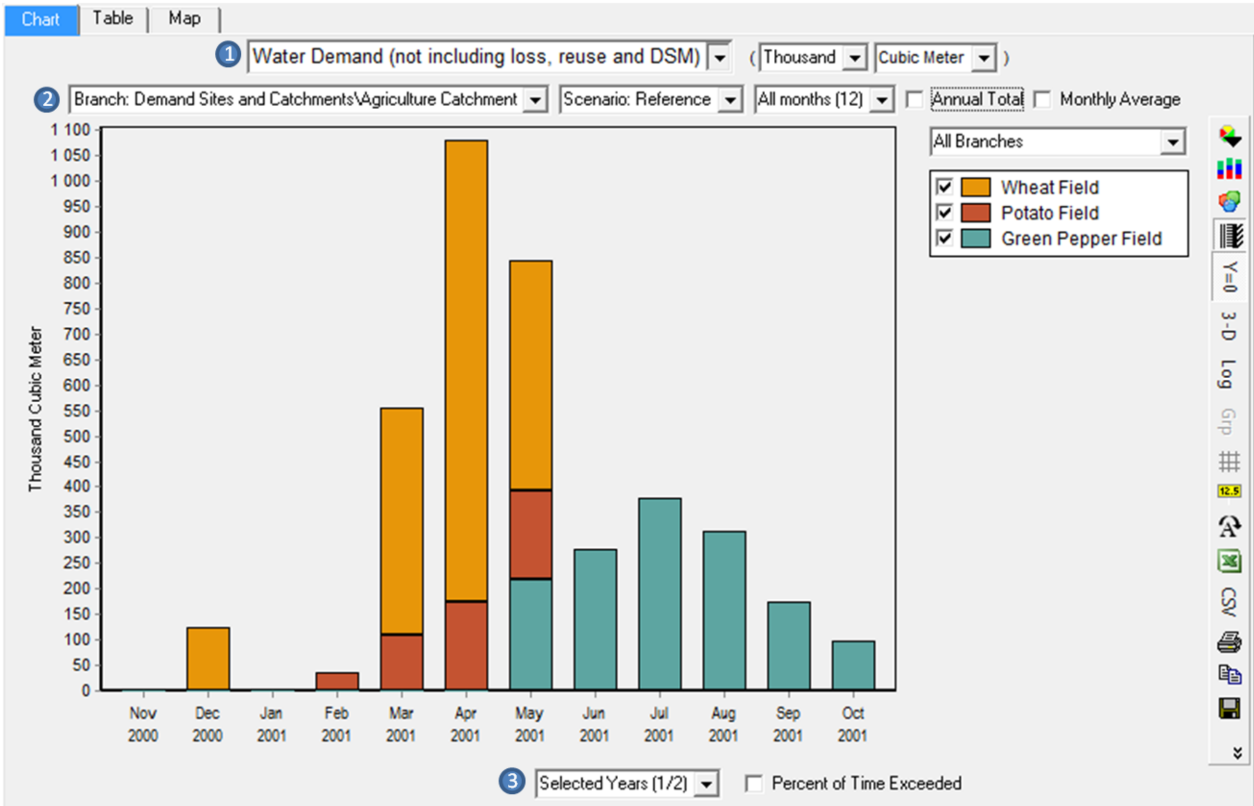
Click on the "Chart" tab and select "Demand" and "Water Demand" from the primary variable pull-down menu ❶ in the upper center of the window. Also, select the branch "Agriculture Catchment" of the "Demand Sites and Catchments" branch ❷ .

To show only the results for the year 2001, select "Selected Years" from the X-axis variable pull-down menu ❸ in the lower center of the window and select the 2001 box (see below) then click OK.





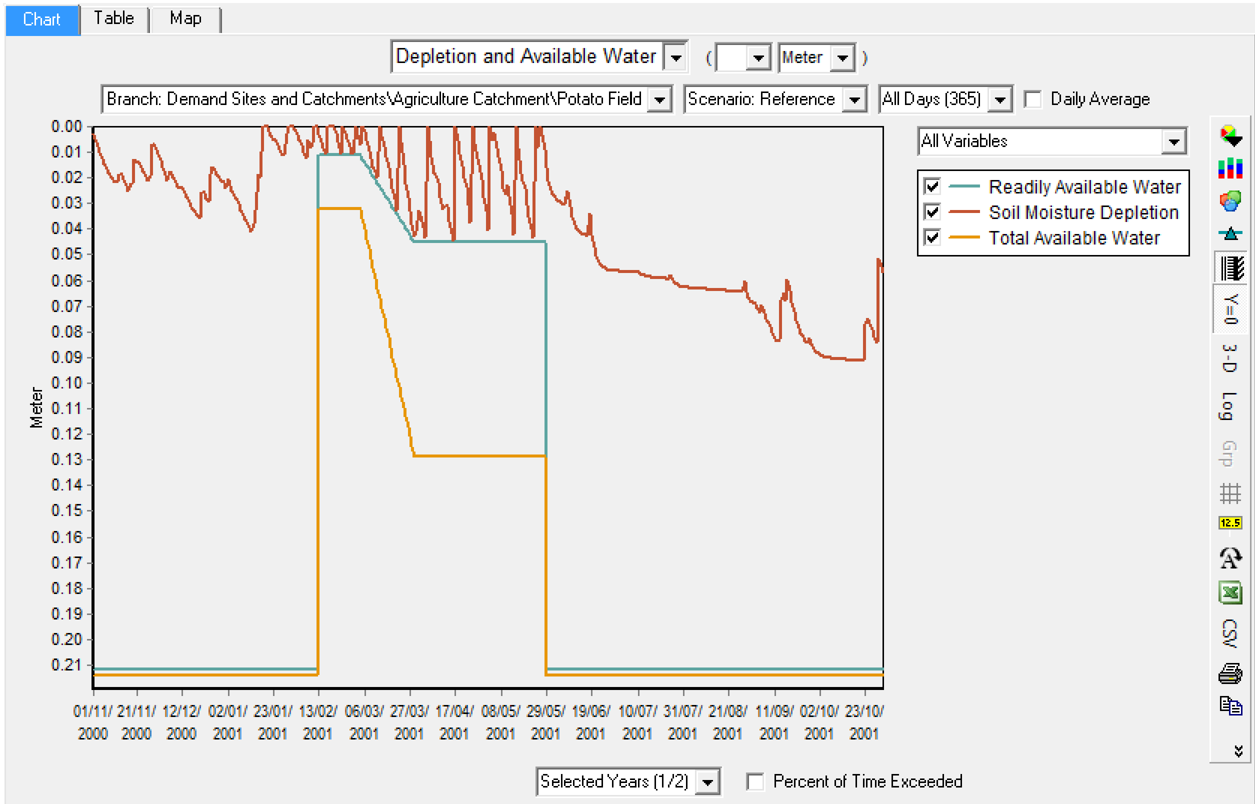
If you have entered all data as listed in previous steps, you should obtain the following monthly demand values for each branch of the "Agriculture Catchment" of the Reference scenario:



Note the higher demand during March, April and May especially for Wheat.

Look at Additional Results

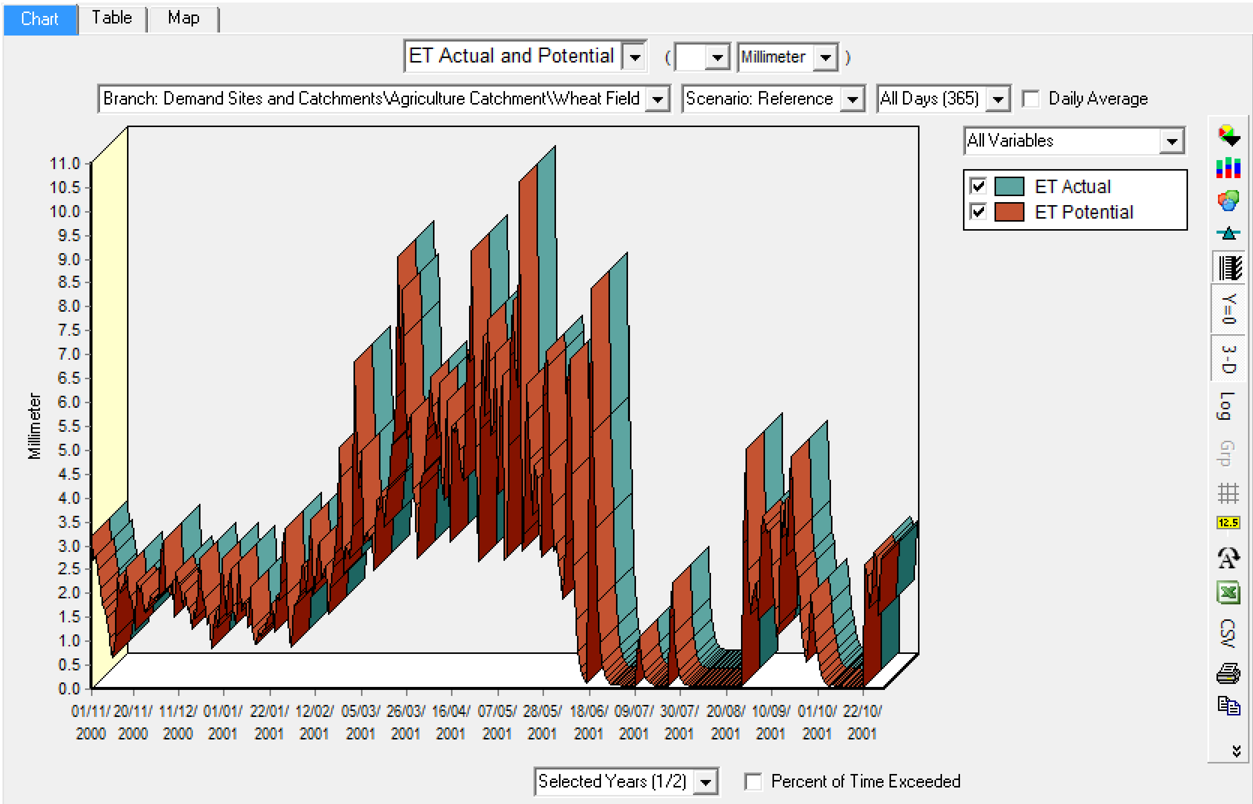
Now, look at the daily evolution of the soil water depletion for the "Potato Field" along with the daily evolution of Total Available Water (TAW) and Readily Available Water (RAW) in graphical form. Click on the "Chart" tab. Select "Catchments" and "Depletion and Available Water" from the primary variable pull-down menu in the upper center of the window.



Note that the available soil water doesn't go below RAW during the cropping cycle of the potato crop and therefore no water shortage occurred, as expected, since the irrigation scheduling options were chosen to ensure irrigating at the right period and in the right amount.

You can also verify if the crop had suffered or not from water shortage during the cropping cycle by looking at the "ET Actual and Potential" graph. Actually, "ET Potential" represents the amount of water that would be consumed by evapotranspiration in the catchment if no water limitations exist, while "ET Actual" represents the actual amount of water consumed by evapotranspiration in the catchment, including water supplied by irrigation, respectively. Hence, if any water shortage occurred you will notice that "ET Potential" would be greater than "ET Actual", for the period for which water limitation was registered.

Select "Catchments" and "ET Actual and Potential" from the primary variable pull-down menu. Format the graph by selecting the 3-D option on the left side-bar menu. The graph should look like the one below:



Note that ET Potential and ET Actual are equal because water is available for transpiration without limitations due to optimal water supply by irrigation.

Additional reports are available for catchments using the MABIA Method. You can read the "MABIA Method Results" help topic (under the "Results/Available Reports/Catchments Results" subheading in the Help Contents) for a more detailed description of the available reports.

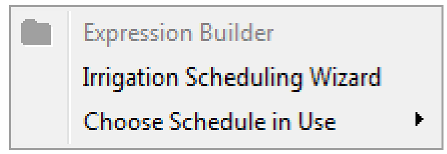
The Irrigation Scheduling and Crop Yield Module

Objectives: Present the steps required to input an irrigation schedule.

Data files: WEAP-MABIA, Tutorial.zip

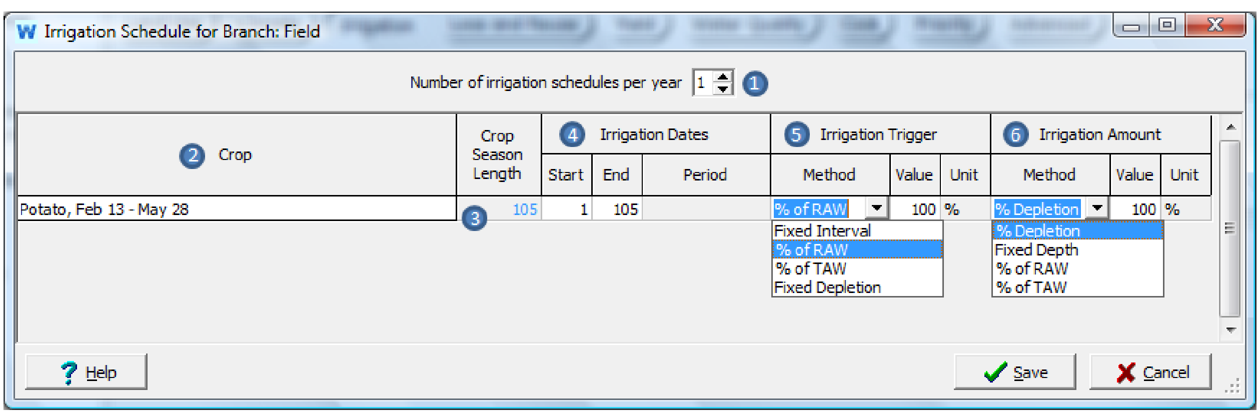
Description of the irrigation input options

You can choose the irrigation schedule criteria and options, using the "Irrigation Scheduling Wizard", or choosing a schedule already in use for the same crop. These two options are available on the drop-down menu in the data grid.



Leave the expression blank if there is no irrigation for this crop or land cover.

The "Irrigation Scheduling Wizard" is used in conjunction with the MABIA Method for catchment hydrology and crop water requirements. It is accessible via the drop-down menu on the data grid for the "Irrigation Schedule" variable under Irrigation.



At the top of the wizard 1, you can select the number of irrigation schedules per year for the crop in use. Leave it to 1 if the same irrigation criteria will be used for the whole cropping season.

If you want to set two different irrigation criteria for two different periods, then you would enter 2.

If the irrigation schedule expression is initially blank, then you will notice that WEAP will automatically add the crop name in use, and set the default irrigation schedule: triggered at 100% of RAW, with an application of 100 % of Depletion. This will ensure that soil moisture depletion never goes below RAW so that no crop water stress will occur.

The Irrigation schedule options

Of course, you can make changes to these defaults and here are short descriptions of the different options that WEAP-MABIA offers:

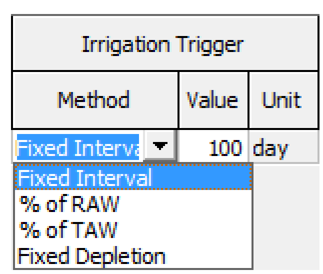
- 2 ***Crop***: Choose the crop for the irrigation schedule. Only the crops already chosen for this branch are available here for selection. For example, if you had Potato and Ray grass as chosen crops for this branch, then you can chose from the crop field to set the irrigation criteria only for potato and don't choose Ray grass. Therefore, Ray grass will be considered as a rainfed crop.

- 3 ***Crop Season Length***: The season length from the Crop Library for this crop (the sum of all four crop stages). It is displayed for information when you select a crop.

- 4 ***Irrigation Dates***: For the irrigation "Start Date", you have to enter the number of the day on which this irrigation schedule takes effect, counting from the first day of the crop season. To start on the first day, enter 1. And for the irrigation "End Date", you have to enter the number of the day on which this irrigation schedule ends, counting from the first day of the crop season. To end on the last day, enter the crop season length. Using this option, for the same crop you can define different criteria for different periods.

- 5 ***Irrigation Trigger***: WEAP-MABIA comes with 4 Irrigation Trigger Methods:

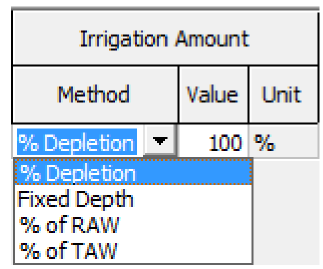
  - *Fixed Interval*: Irrigate every N days, where N is specified in the Irrigation Trigger Value.
  - *% of RAW*: Irrigate when soil moisture depletion is greater than or equal to a specified % of Readily Available Water (RAW). To prevent crop water stress, depletion should never exceed RAW.



- *% of TAW*: Irrigate when soil moisture depletion is greater than or equal to a specified % of Total Available Water (TAW). To prevent crop death (permanent wilt point), depletion should never equal or exceed TAW.
- *Fixed Depletion*: Irrigate when soil moisture depletion is equal to or exceeds a specified depth (in mm).

  The Irrigation Trigger Value is the value that goes with the *Irrigation Trigger Method*: days for the fixed interval method, % for the % of RAW or the % of TAW method and mm for the fixed depletion method.

- 6 ***Irrigation Amount***: WEAP-MABIA comes with 4 Irrigation Amount Methods. The method defines how much water to apply on days when irrigation occurs



- % Depletion: Apply a specified % of the current soil water depletion.
- Fixed Depth: Apply a specified depth of water.
- % of RAW: Apply a specified % of the Readily Available Water (RAW) level, regardless of the current soil water depletion.
- % of TAW: Apply a specified % of the Total Available Water (TAW) level, regardless of the current soil water depletion.

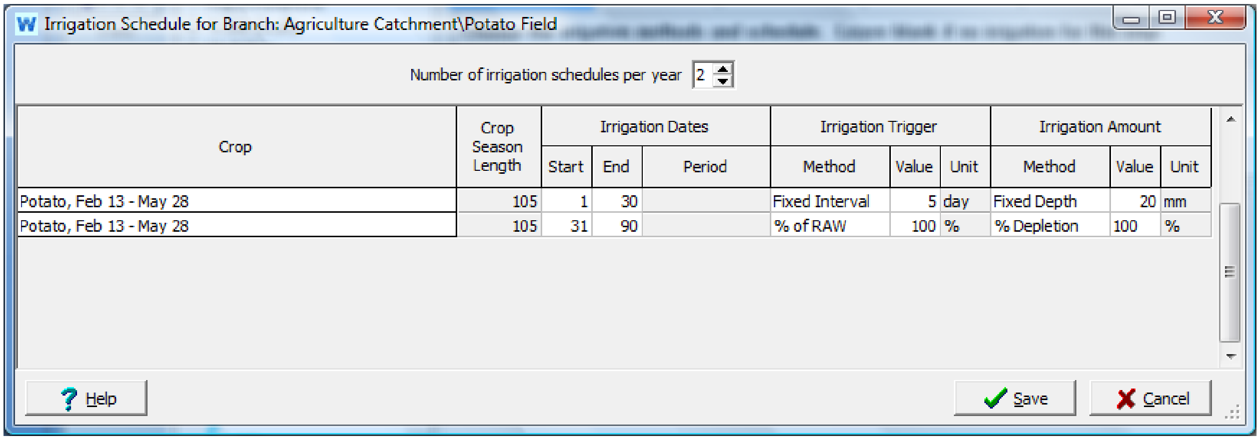
  The Irrigation Amount Value is the value that goes with the Irrigation Amount Method: % for the % Depletion, the % of RAW or the % of TAW method and finally mm for the fixed depth method.

  Let us now consider this example:

  You want to set three irrigation criteria for Potato:

  - *From day 1 to day 30 (vegetative establishment period) you want to irrigate every 5 days with a fixed water depth of 20 mm.*
  - *From day 31 to day 90 you want to irrigate when 90% of RAW is depleted and you want to irrigate with the same lost amount (that means 100% of the depletion)*
  - *From day 91 to the end of the cropping cycle, you don't want to irrigate.*

Therefore, the Irrigation Schedule Wizard should look like this:



Crop	Crop Season Length	Irrigation Dates			Irrigation Trigger			Irrigation Amount		
		Start	End	Period	Method	Value	Unit	Method	Value	Unit
Potato, Feb 13 - May 28	105	1	30		Fixed Interval	5	day	Fixed Depth	20	mm
Potato, Feb 13 - May 28	105	31	90		% of RAW	100	%	% Depletion	100	%

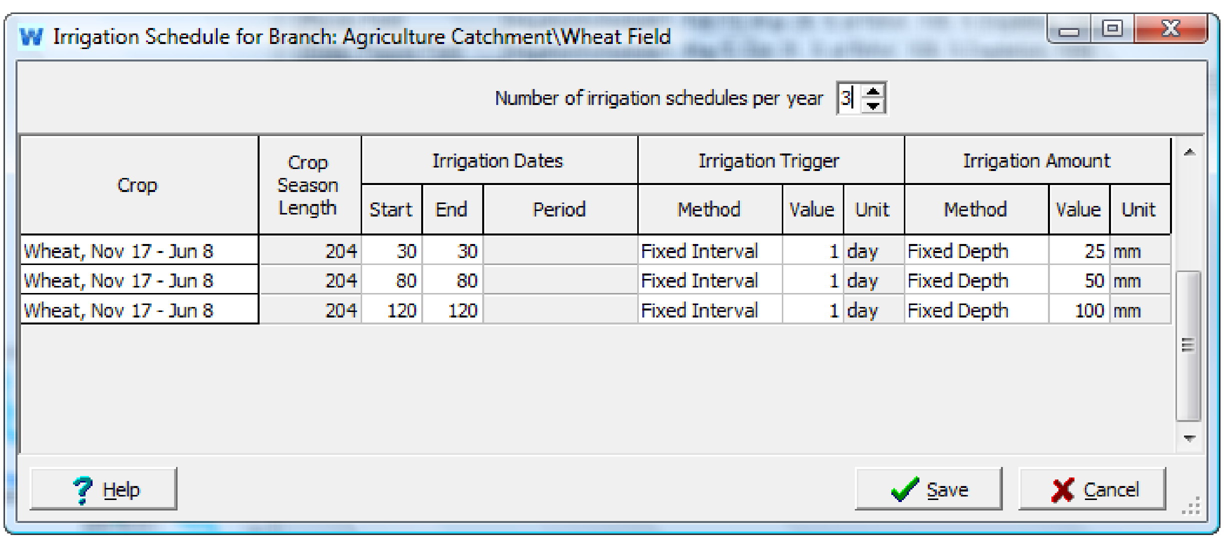
Each row of the table defines one irrigation schedule.

Now let us now consider this example:

You want to set three irrigations for Wheat:

- *Day 30, an irrigation of 25 mm.*
- *Day 80, an irrigation of 50 mm,*
- *And day 120, an irrigation of 100 mm*

Therefore, the Irrigation Schedule Wizard should look like this:



Crop	Crop Season Length	Irrigation Dates			Irrigation Trigger			Irrigation Amount		
		Start	End	Period	Method	Value	Unit	Method	Value	Unit
Wheat, Nov 17 - Jun 8	204	30	30		Fixed Interval	1	day	Fixed Depth	25	mm
Wheat, Nov 17 - Jun 8	204	80	80		Fixed Interval	1	day	Fixed Depth	50	mm
Wheat, Nov 17 - Jun 8	204	120	120		Fixed Interval	1	day	Fixed Depth	100	mm

Note that if there is not enough water to satisfy the irrigation water needs as calculated by MABIA using the specified irrigation schedule, then WEAP will reduce each calculated irrigation within the defined time step by the percentage of irrigation water requirements that are not met. This percentage of unmet demand goes from 0% (delivery of full requirement) to 100% (no water delivered).

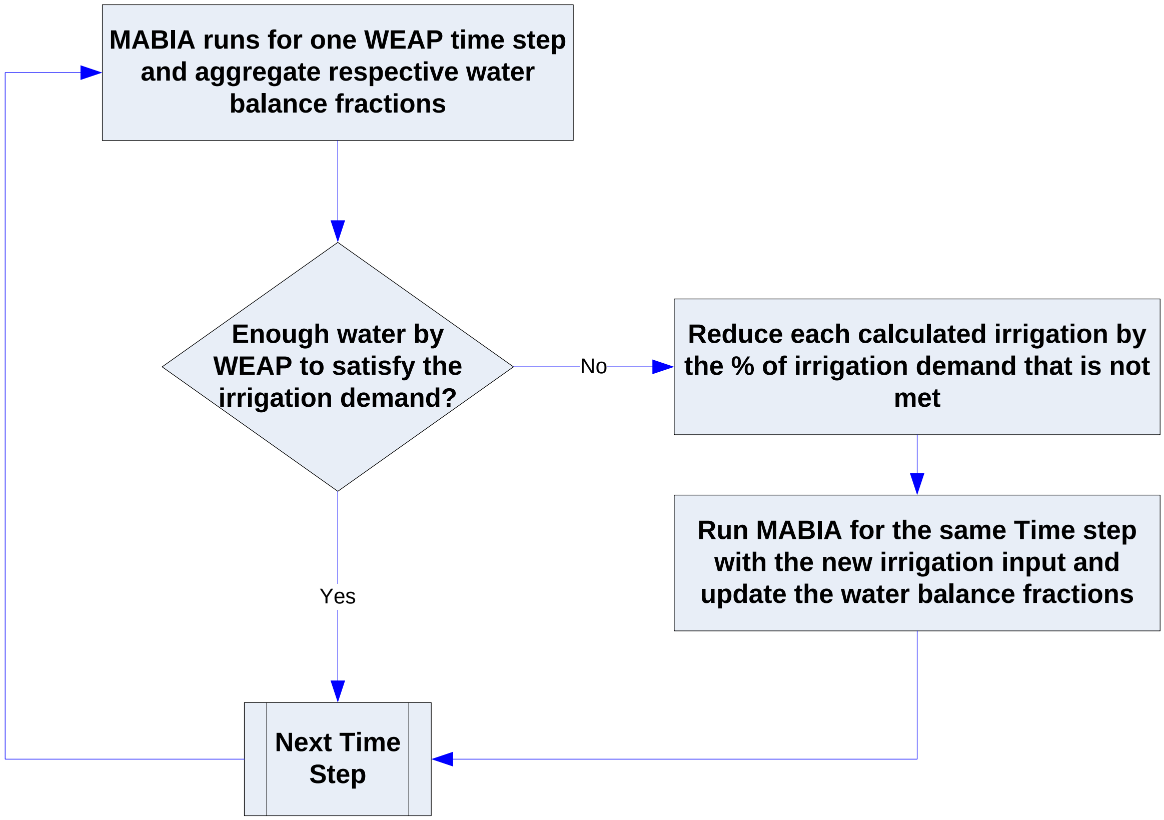


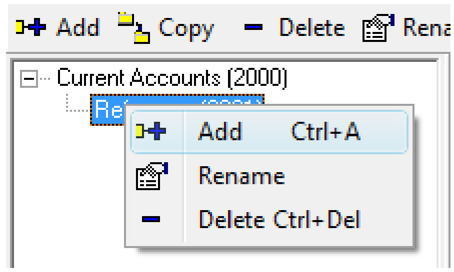
Figure: Flow chart illustrating the operating mode of the irrigation module

Creating and running Irrigation Scenarios

For this module you will need to have completed the previous module or have downloaded the file "WEAP-MABIA tutorial.zip" and have it opened into WEAP. To begin this module, go to the Main Menu, select "Revert to Version" and choose the version named "Starting point for all WEAP-MABIA modules".

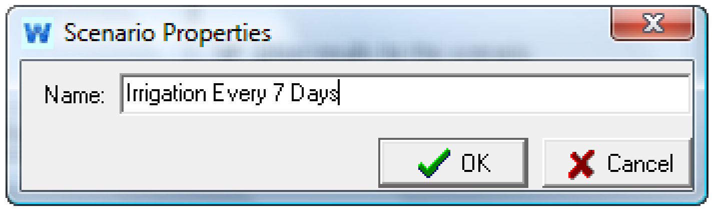
Create two New Scenarios to Model different Irrigation options

Create a new scenario to evaluate the impact of irrigating every 7 days on the water balance components.

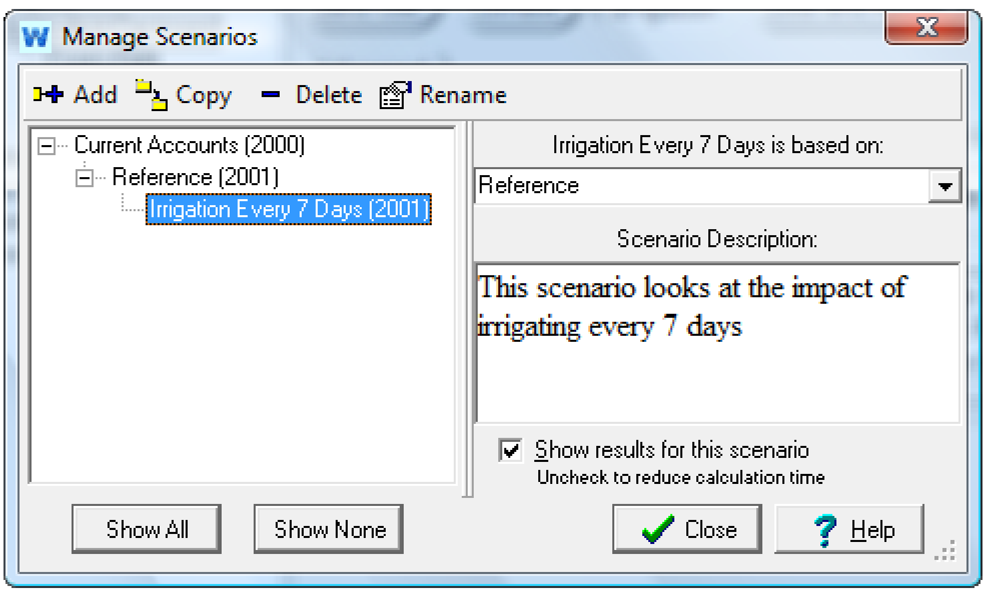


1. Choose the menu "Area", "Manage Scenario", right-click the "Reference" scenario and select "Add".

2. Name this scenario "Irrigation Every 7 Days".



3. Add the description "This scenario looks at the impact of irrigating every 7 days".



4. Repeat the same procedure to add another scenario to evaluate the impact of using deficit irrigations (that means to allow water shortage to occur) on the water balance components as well as its effect on the yield reduction. Name this scenario "Deficit Irrigation" and add the description "This scenario looks at the impact of using deficit irrigation".

Enter the Data for these Scenarios

Make the following changes in the Data view for the “Irrigation Every 7 Days” scenario:

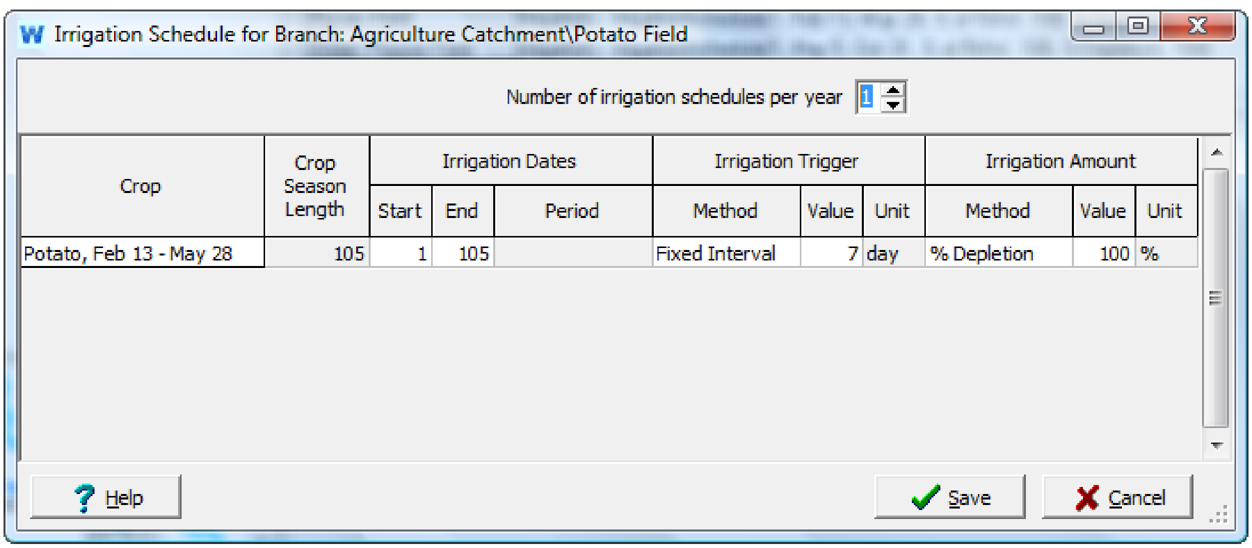
1. Select the “Irrigation Every 7 Days” scenario in the drop-down menu at the top of the screen.

2. Select the “Irrigation Schedule” tab under the “Irrigation” variable.

3. Change the irrigation schedule for the Potato Field:

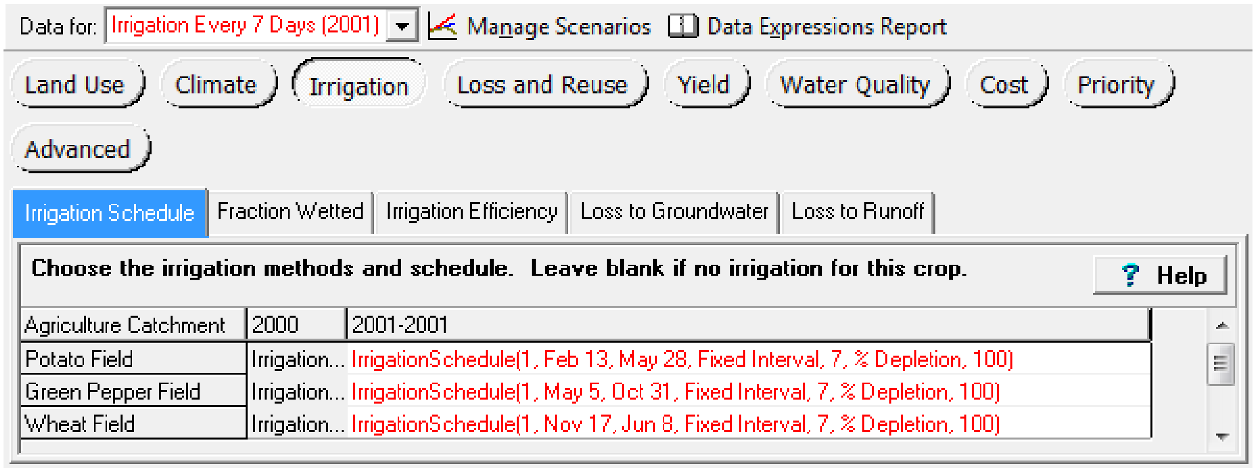
- Click the empty cell in front of “Potato Field” and select the “Irrigation Scheduling Wizard” from the drop down menu.
- Change the Irrigation Trigger Method from “% RAW” to “Fixed Interval” and change the Irrigation Trigger Value from 100 to 7 days.
- Click 

.



4. Repeat the same procedure to change the irrigation schedule for the “Green Pepper Field” and the “Wheat Field”.

After completing all the tasks described above, the “Irrigation Schedule” tab will look like this:



Note that the color of the data field changes to red after the change - this occurs for any values that are changed to deviate from the "Reference" scenario value.

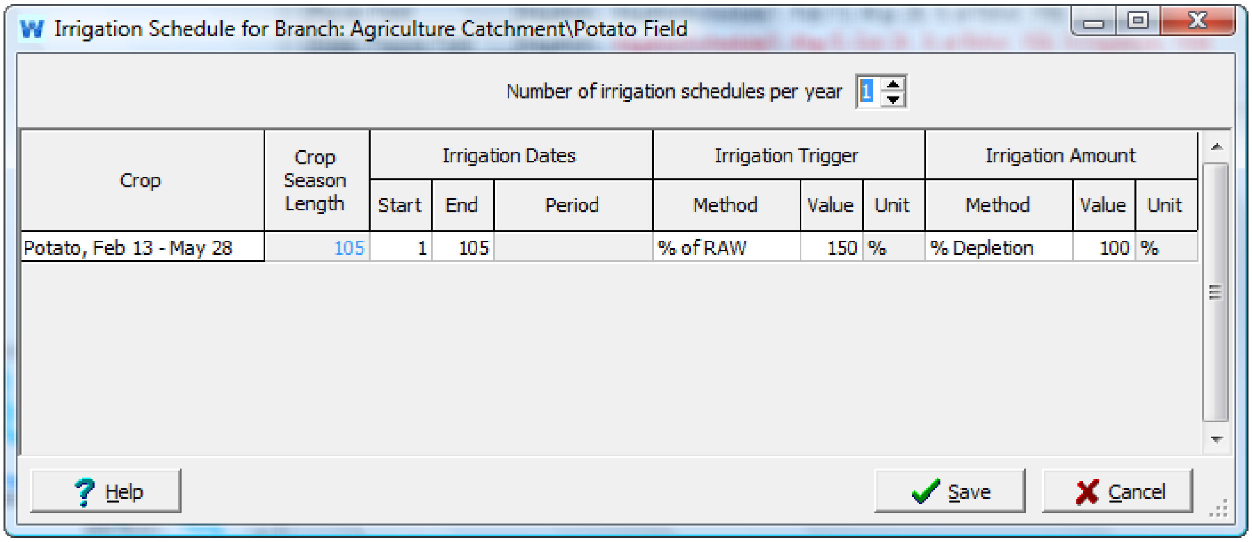
Make the following changes in the Data view for the "Deficit Irrigation" scenario:

1. Select the "Deficit Irrigation" scenario in the drop-down menu at the top of the screen.

2. Select the "Irrigation Schedule" tab under the "Irrigation" variable.

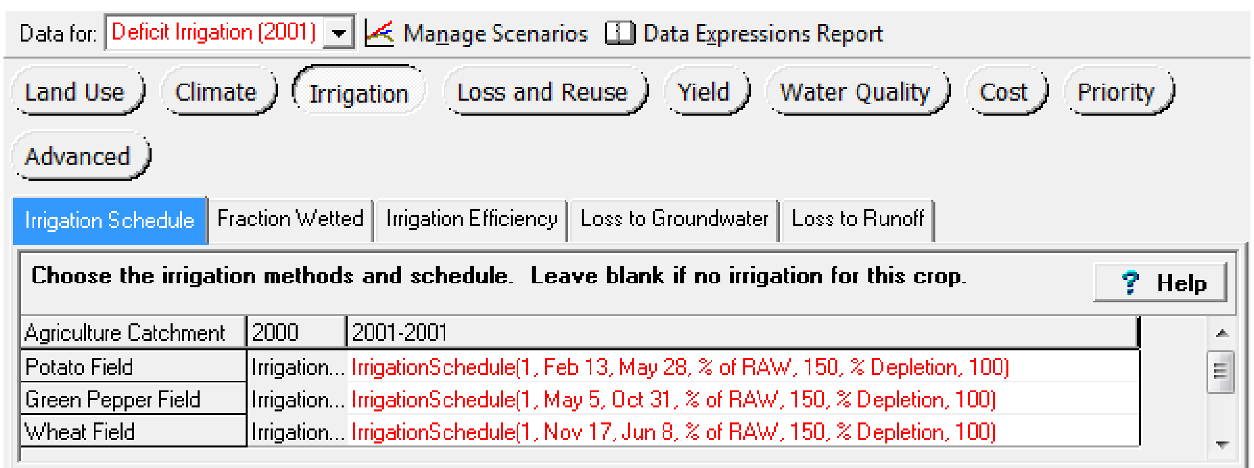
3. Change the irrigation schedule for the Potato Field. For that:

- Click the empty cell in front of "Potato Field" and select the "Irrigation Scheduling Wizard" from the drop down menu.
- Change the Irrigation Trigger Value from 100 to 150 %. That means we will allow for a water shortage of 50% of the RAW before irrigation is triggered off. For example, if RAW is 40 mm, then irrigation will be triggered off only if 60 mm have been depleted.
- Click 
.



4. Repeat the same procedure to change the irrigation schedule for the "Green Pepper Field" and the "Wheat Field".

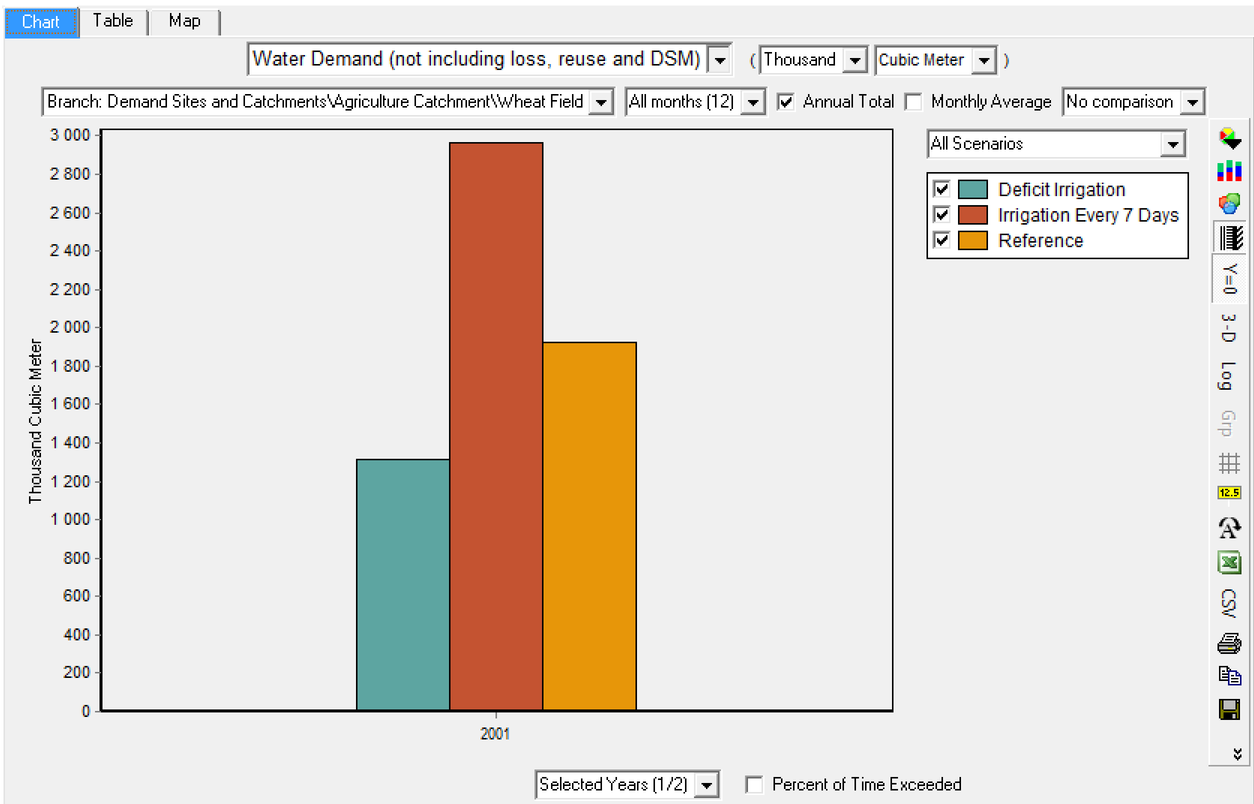
After completing all the tasks described above, the "Irrigation Schedule" tab will look like this:



Compare Results for the Reference and the Irrigation Scenarios

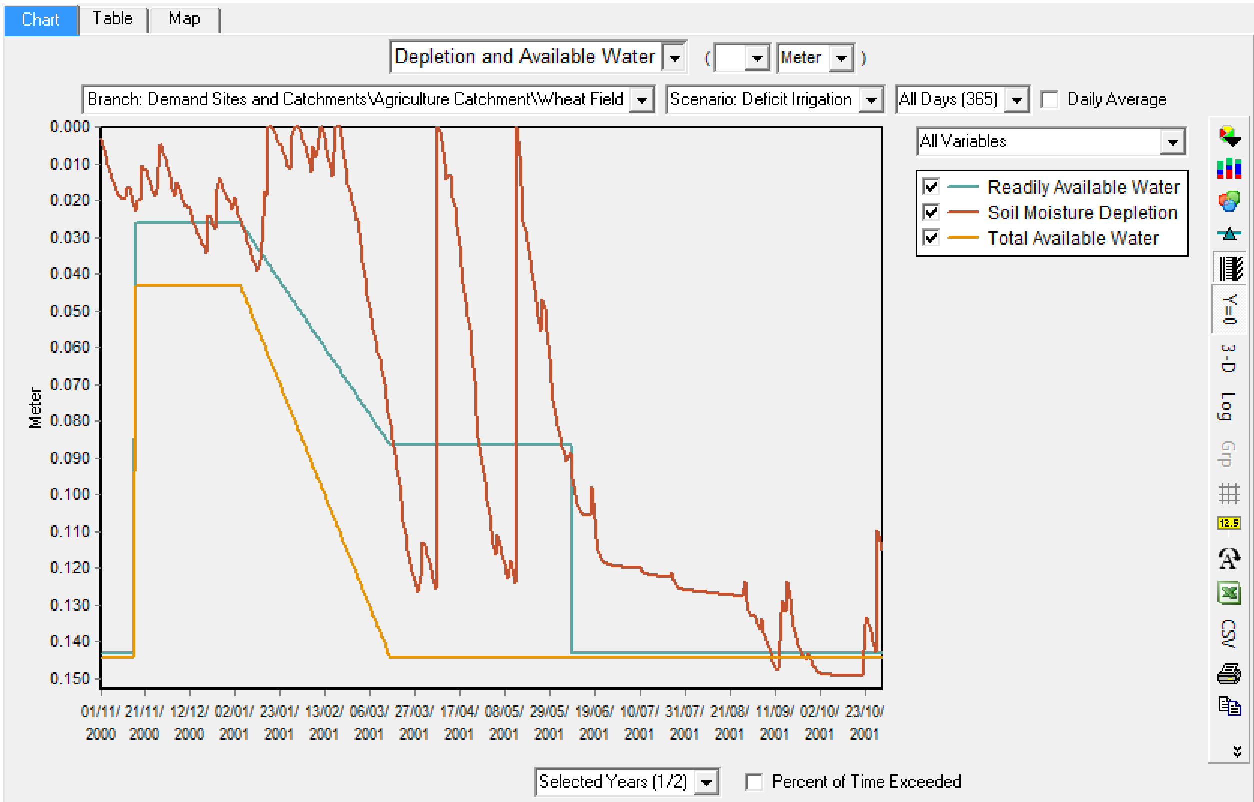
Compare, graphically, the results of the two scenarios we have established so far (Irrigation Every 7 Days and Deficit Irrigation) with the reference irrigation schedule (for which no water shortage has occurred).

For example, select "Demand/Water Demand" from the primary variable pull-down menu. Click in the drop-down menu to the right of the chart area, and select "All Scenarios". Choose to show only "Agriculture Catchment" demand by selecting it from the pull-down list in the upper left pull-down menu of the Results window and select the "Annual Total" box. Your graph should be similar to the one below.



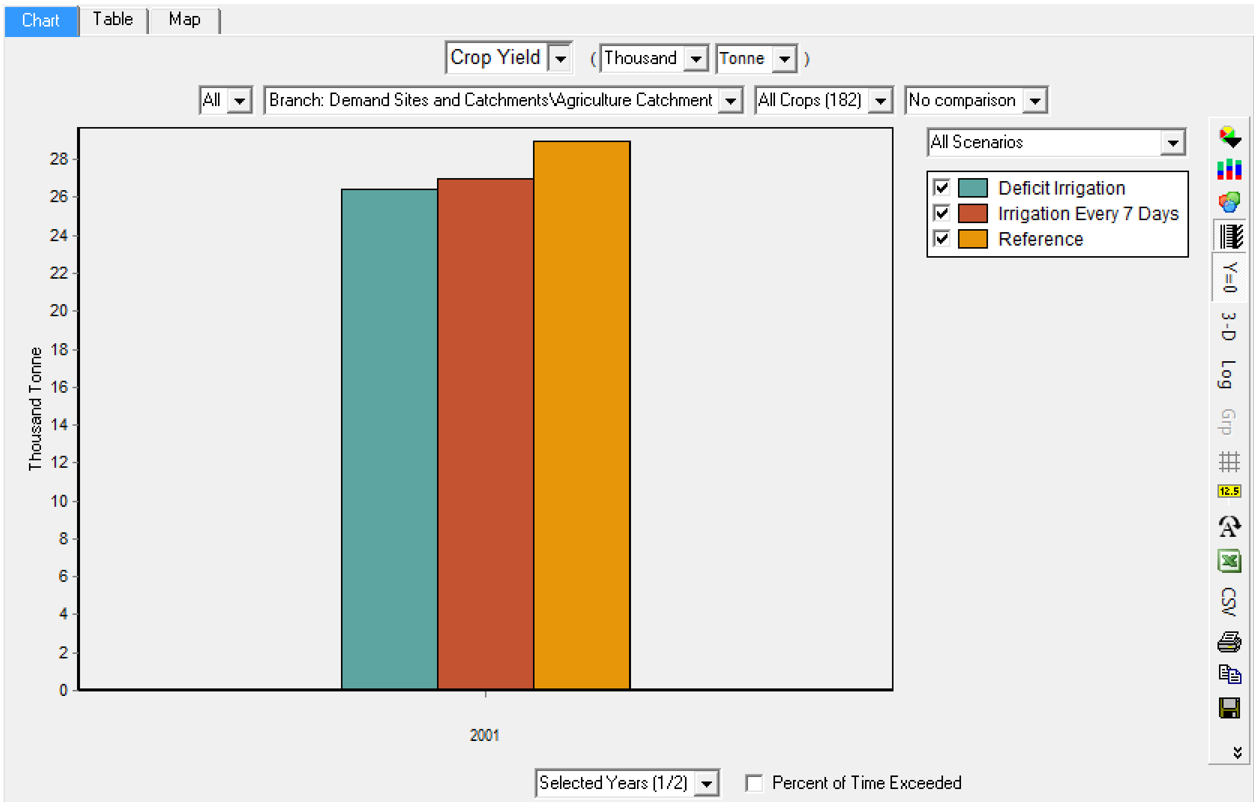
Note the lower Water Demand for Agriculture Catchment in the "Deficit Irrigation" scenario, as expected. The "Irrigation Every 7 days" scenario leads to the highest Water Demand for Agriculture Catchment.

Next, look at “Depletion and Available Water” of the “Deficit Irrigation” scenario for the Wheat Field. Use the primary variable pull-down menu to select “*Catchments/ Depletion and Available Water* “



Note that the available soil water goes below the readily available water during some periods of the cropping cycle of Wheat. This water shortage will reduce the actual crop evapotranspiration compared to ET Potential which means that the yield will be reduced as a response of the crop to water shortage.

Next, compare "Crop Yield" of the two scenarios with the reference. Use the primary variable pull-down menu to select "Catchments/Crop Yield"



Note that when using deficit irrigation, the yield was kept at an acceptable range for all Agriculture Catchment branches considered together. This could be explained by a better use of rainfall water and eventually by reduced water losses.

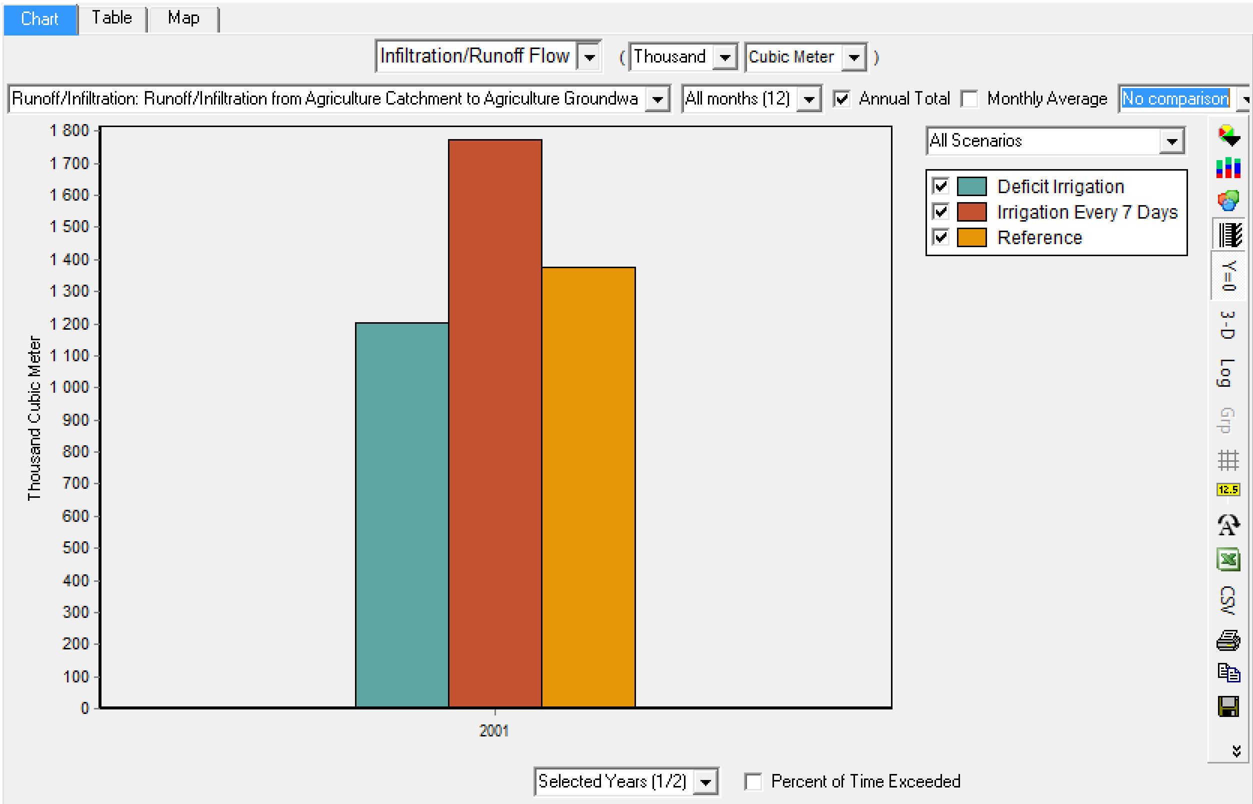


Chart
Table
Map
Infiltration/Runoff Flow
Thousand
Cubic Meter
Runoff/Infiltration: Runoff/Infiltration from Agriculture Catchment to Agriculture Groundwa
All months (12)
Annual Total
Monthly Average
No comparison
All Scenarios
Deficit Irrigation
Irrigation Every 7 Days
Reference
Thousand Cubic Meter
2001
Selected Years (1/2)
Percent of Time Exceeded

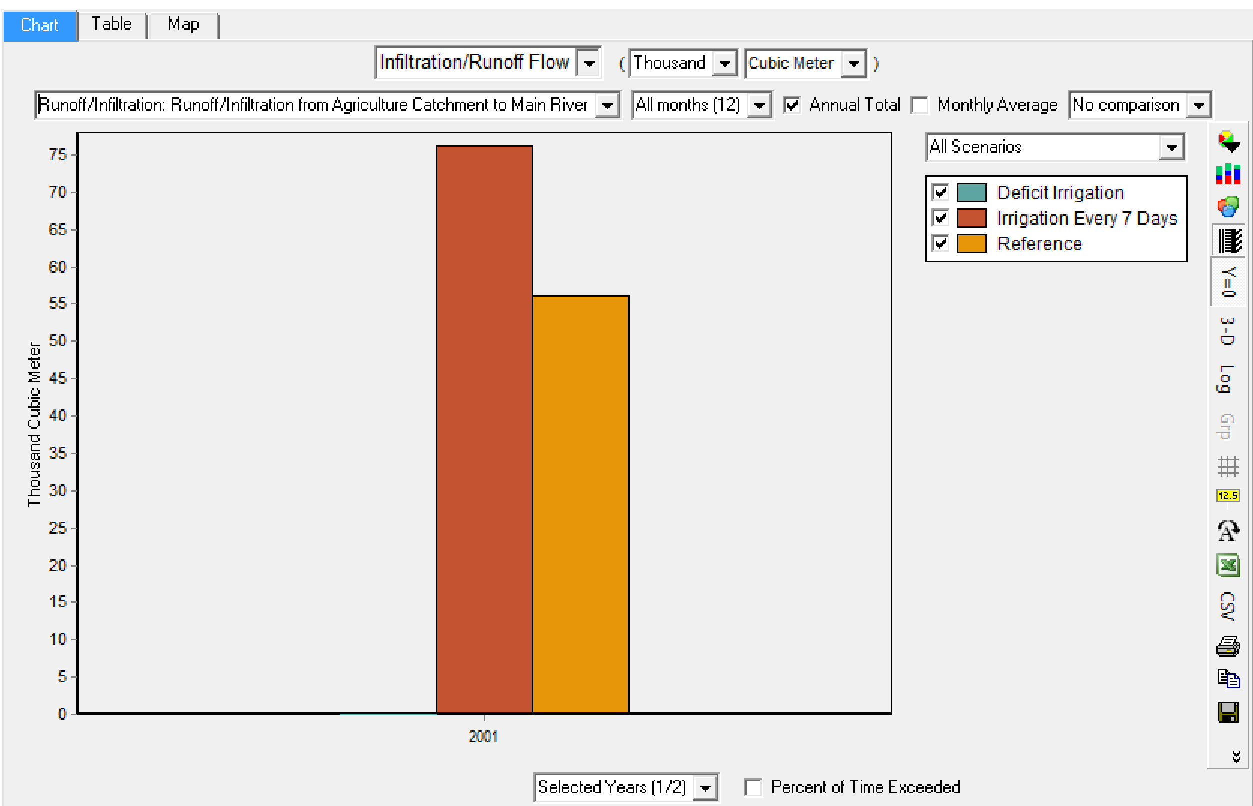


Chart
Table
Map
Infiltration/Runoff Flow
Thousand
Cubic Meter
Runoff/Infiltration: Runoff/Infiltration from Agriculture Catchment to Main River
All months (12)
Annual Total
Monthly Average
No comparison
All Scenarios
Deficit Irrigation
Irrigation Every 7 Days
Reference
Thousand Cubic Meter
2001
Selected Years (1/2)
Percent of Time Exceeded

The Climate Options and Calculation Module

Objectives: Present the steps required to input available climatic data and to calculate ETref.

Data files: - WEAP-MABIA, Tutorial.zip

- ETrefDailyClimate.csv
- MonthlyPrecipitation.csv

Description of the Climate input options

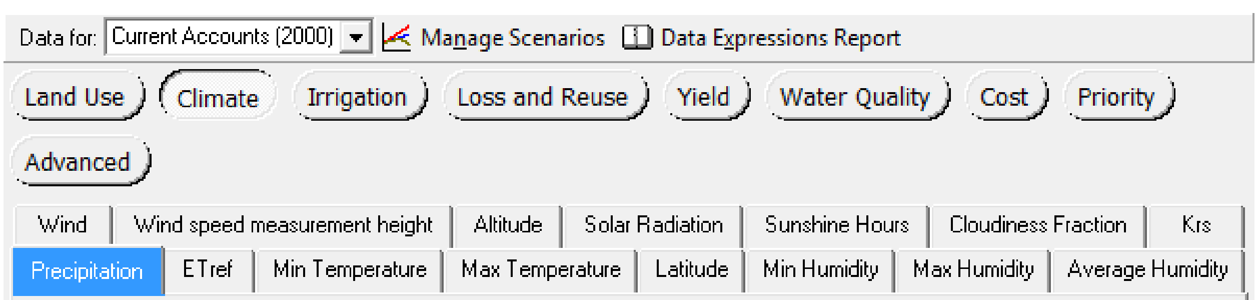
The MABIA method requires **daily** information concerning the weather conditions. The required daily climatic data for MABIA are:

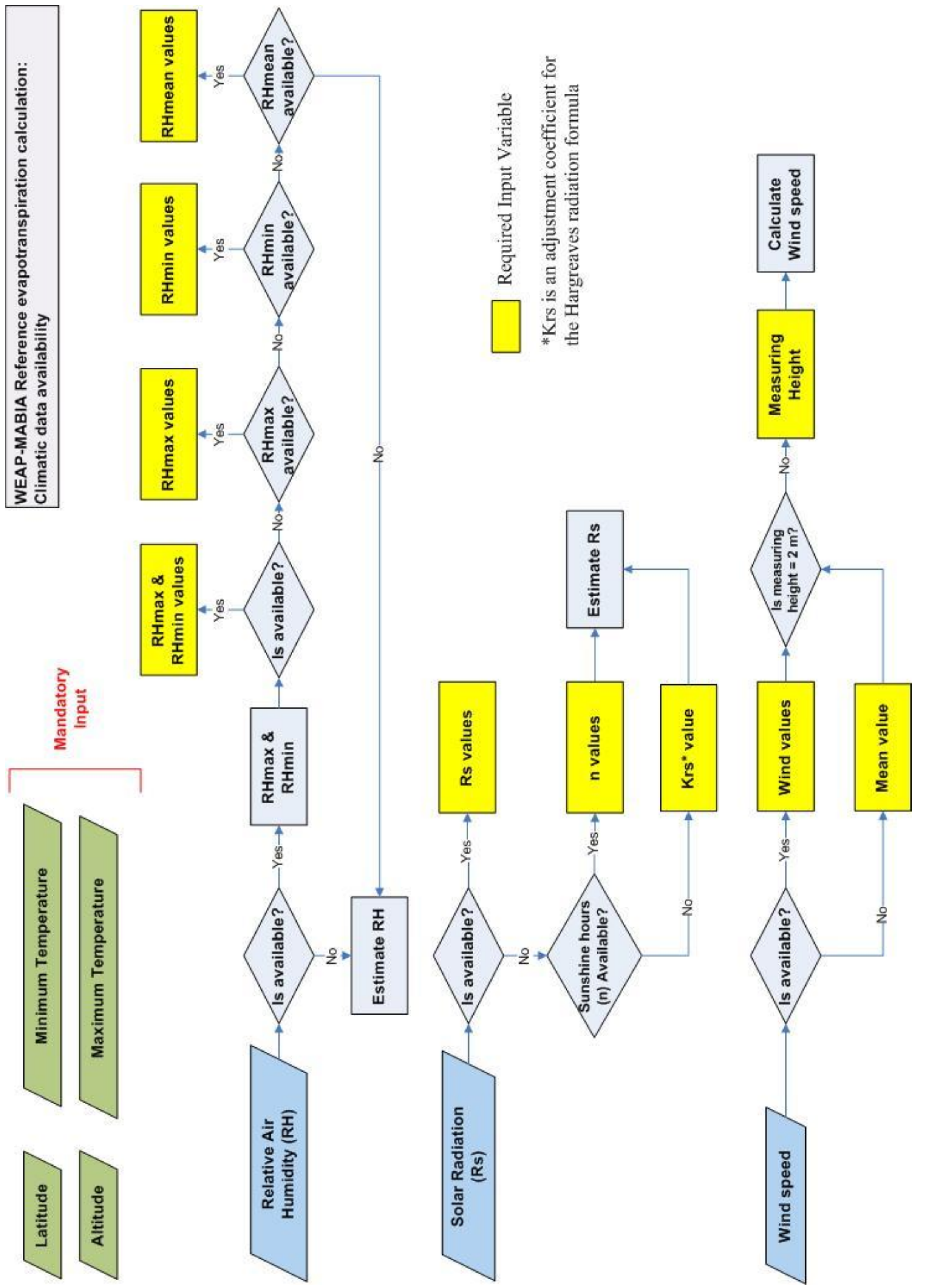
- Rainfall depth, which is the amount of water collected in rain gauges installed on the field or at a nearby weather station (mm);
- Evaporative demand of the atmosphere for the given weather conditions. It is given by the evapotranspiration of a reference surface, ETref (mm day^{-1}).

Additionally daily wind speed and daily minimum relative air humidity are required to correct the K_{cb} values during the mid-season and the late-season stage.

However, data on the reference evapotranspiration are most of the time unavailable. That's why the WEAP-MABIA model comes with different options to calculate ETref considering different scenarios of climatic data availability (see below) and using the Penman-Monteith equation as recommended by the FAO-56.

The climatic parameters that can be defined in WEAP-MABIA are:




WEAP-MABIA Reference evapotranspiration calculation:
Climatic data availability
Latitude
Altitude
Minimum Temperature
Maximum Temperature
Mandatory Input
Relative Air Humidity (RH)
Is available?
Yes
No
RHmax & RHmin
Is available?
RHmax & RHmin values
RHmax available?
RHmax values
RHmin available?
RHmin values
RHmean available?
RHmean values
Estimate RH
Solar Radiation (Rs)
Rs values
Sunshine hours (n) Available?
n values
Krs* value
Estimate Rs
Wind speed
Wind values
Mean value
Is measuring height = 2 m?
Measuring Height
Calculate Wind speed
Required Input Variable
*Krs is an adjustment coefficient for the Hargreaves radiation formula

- *Precipitation* Precipitation: This parameter is mandatory.

- Reference evapotranspiration ETref: ETref is the evapotranspiration from the reference surface, the so-called reference crop evapotranspiration or reference evapotranspiration, denoted as ETref. The reference surface is a hypothetical grass reference crop with an assumed crop height of 0.12 m, a fixed surface resistance of 70 s m-1 and an albedo of 0.23. The reference surface closely resembles an extensive surface of green, well-watered grass of uniform height, actively growing and completely shading the ground.

> Leave blank to calculate ETref using the Penman-Monteith equation.

- *Daily Minimum and maximum temperature* Min Temperature Max Temperature: These two parameters are mandatory to calculate ETref.
- *Latitude* Latitude: Latitude of the climate measurement station. This parameter is mandatory to calculate ETref.
- *Altitude* Altitude: Altitude of the climate measurement station. This parameter is mandatory to calculate ETref.
- *Daily Minimum Relative Air Humidity* Min Humidity: It is required to correct the $K_{cb\ mid}$ and $K_{cb\ end}$ values. If this parameter is left blank, then the default value (45%) will be used. It is also used along with the maximum relative humidity in the calculation procedure of ETref. When left blank, either maximum relative humidity or average humidity will be used.
- *Daily Maximum Relative Air Humidity* Max Humidity: It is used in the calculation procedure of ETref. If this parameter is left blank, the average humidity will be used instead.
- *Average Relative Air Humidity* Average Humidity: It is used in the calculation procedure of ETref. Only needed if data for maximum humidity are missing. If maximum and average humidity are left blank, then an estimate will be made by assuming that the dew point temperature is the same as the daily minimum temperature.

- *Daily Wind Speed* Wind: It is required to correct the $K_{cb\ mid}$.and $K_{cb\ end}$ values. If this parameter is left blank, then the default value (2 m s^{-1}) will be used. It is also used in the calculation procedure of ETref.
- *Wind Speed Measurement Height* Wind speed measurement height: For the calculation of evapotranspiration, the wind speed should be measured at 2 m above the surface. However, an adjustment has to be made if the wind speed measurement height is different from 2 m. If this parameter is left blank, then the default value (2 m) will be used. If another value is entered, an adjustment is made automatically.
- *Daily Solar Radiation* Solar Radiation: It is used in the calculation procedure of ETref. If it is kept blank, then an estimate of the daily solar radiation will be calculated using Sunshine Hours, Cloudiness Fraction or Hargreaves formula.
- *Daily Sunshine Hours* Sunshine Hours: This is the actual number of daytime hours with no clouds. It is used to estimate the Daily Solar Radiation if missing. If this parameter is kept blank, then the Cloudiness Fraction will be used. If both Sunshine Hours and Cloudiness Fraction are left blank, then the Hargreaves formula will be used.
- *Daily Cloudiness Fraction* Cloudiness Fraction: It is defined as the fraction of daytime hours with no clouds (0.0=completely overcast, 1.0=no clouds). If this parameter is kept blank, then the Sunshine Hours will be used. If both Sunshine Hours and Cloudiness Fraction are left blank, then the Hargreaves formula will be used.
- k_{Rs} Krs: k_{Rs} is an adjustment coefficient for the Hargreaves radiation formula. The Hargreaves formula is an empirical model to modify potential evapotranspiration in dependence of temperature and humidity when observed solar input is missing. Only needed if neither Solar Radiation nor Sunshine Hours nor Cloudiness Fraction are available. k_{Rs} can be set to 0.16 for interior regions and 0.19 for coastal regions.

More precisely k_{Rs} can be calculated using the formula developed by Allen (1997):

$$k_{Rs} = k_{Ro}\left(\frac{P}{P_0}\right)$$

where, P is mean atmospheric pressure of the site (kPa); P_0 is mean atmospheric pressure at sea level (101.3 kPa) and k_{Ro} is an empirical coefficient equal to 0.17 for interior regions and equal to 0.20 for coastal regions.

The daily climatic time series can either be read in WEAP from a file or entered in manually.

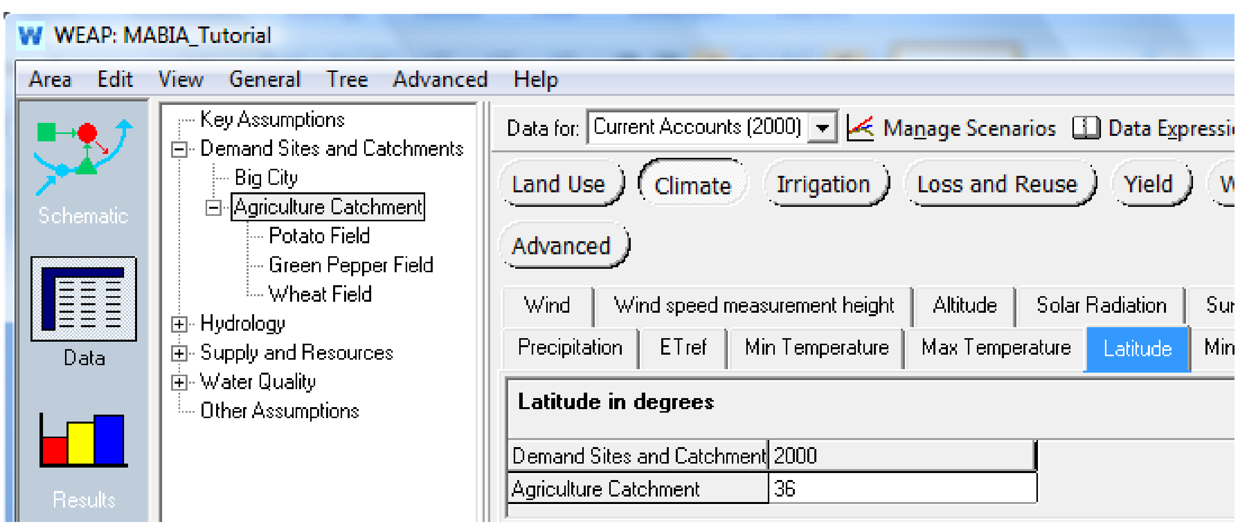
Creating and Running Climate Scenarios

For this module you will need to have downloaded the file “WEAP-MABIA tutorial.zip” and have it opened into WEAP. To begin this module, go to the Main Menu, select “Revert to Version” and choose the version named “Starting point for WEAP-MABIA, Climate modules”.

Preparing the Current Account

In this step we now want to see how different climatic data availability can be taken into account in WEAP through scenario analyses to estimate ETref. We will use the “ReadFromFile” function to read in from a CSV file (‘ETrefDailyClimate.csv’ in this case) the required daily climatic data.

With the “Current Account” selected, go into the data view and click on the “Agriculture Catchment” branch under “Demand Sites and Catchments” in the Data tree.



Select the "Climate" tab of the "Land Use" variable and enter the following data:

Latitude *36° 50' (enter the following expression 36+50/60)*

Altitude *6*

For the Precipitation and maximum and minimum temperature, we will use the "ReadFromFile" function to read daily data in. For that, we need to know for each climatic parameter the respective column number in the CSV file.

Open 'ETrefDailyClimate.csv' file into Excel and note that the column number for Precipitation, maximum temperature (Tmax) and minimum temperature (Tmin) are 1, 2 and 3, respectively.

	A	B	C	D	E	F	G	H	I
1	$DateFormat = d/m/y								
2	;Column Number	1	2	3	4	5	6	7	8
3	;Date	Precip. (mm)	Tmax (°C)	Tmin (°C)	HRmax (%)	HRmin (%)	Rs (MJ/m^2/d)	N (hour)	Wind (m/s)
4	01/11/2000	0	21.51	11.95	99	51	10.12	8	0.16
5	02/11/2000	1	25.08	8.28	99	38	13.29	8	0.57
6	03/11/2000	0	21.38	14.36	90	50	8.51	8	1.77
7	04/11/2000	0	25.61	14.7	75	30	10.51	8	1.03
8	05/11/2000	0	24.05	14.31	99	45	9.84	7	0.61

Enter the following data:

Precipitation *ReadFromFile(ETrefDailyClimate.csv,1)*

Min Temperature *ReadFromFile(ETrefDailyClimate.csv,3)*

Max Temperature *ReadFromFile(ETrefDailyClimate.csv,2)*

Krs 0.17 (This coefficient will be used if neither solar radiation nor sunshine hours nor cloudiness fraction are available.)

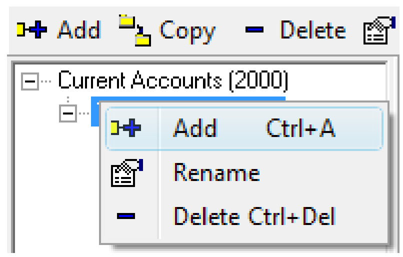
Leave the other parameters blank. Therefore, the default values will be used.

If the file 'ETrefClimate.csv' is not in the same directory of the WEAP area then you need to refer to the full path of your climate file.

Create Six New Scenarios to Model Different Climatic Data Availability

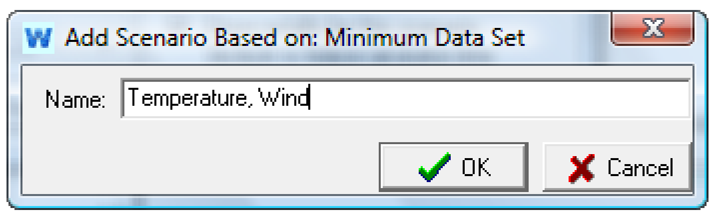
Rename the "Reference" Scenario in the Area\Manage Scenarios menu to "Minimum Data Set" which represents using only Temperature to estimate ETref. Note that you must be in the Data View or Schematic view to have access to the "Manage Scenarios" option in the Area menu. Change its description to "*Base Case Scenario with minimum climatic data set (only maximum and minimum temperature) to calculate ETref*". All the other scenarios will be based on the "Minimum Data Set" scenario.

Create a new scenario to evaluate the impact of using Maximum and Minimum Temperature and Wind Speed to estimate ETref on the water balance components.

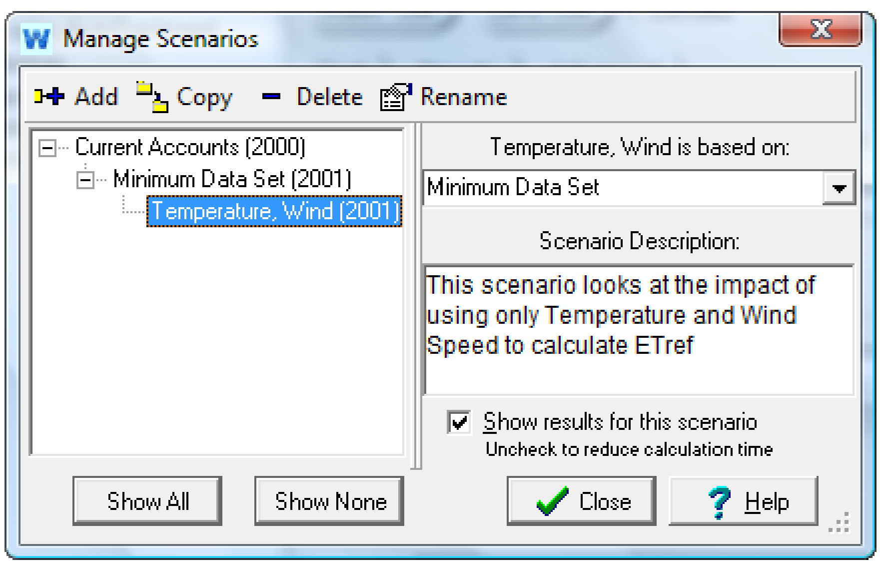


1. Choose the menu "Area", "Manage Scenario", right-click the "Reference" scenario and select "Add".

2. Name this scenario "*Temperature, Wind*".



3. Add the description "*This scenario looks at the impact of using only Temperature and Wind Speed to calculate ETref*".



4. Repeat the same procedure to add five additional scenarios to evaluate the impact of using different scenarios of climatic data availability (that means different options to calculate ETref) on the water balance components. Use the following data:

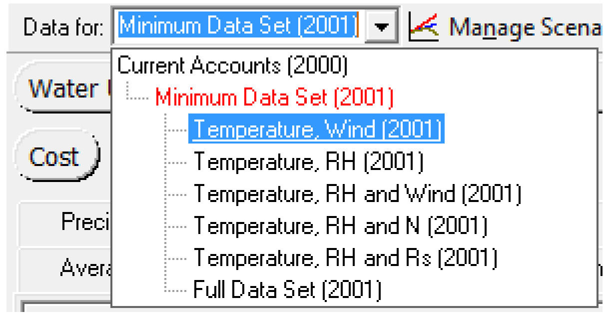
Scenario Name	*Scenario Description*
Temperature, RH	*This scenario looks at the impact of using only Temperature and maximum and minimum Relative Humidity (RH) to calculate ETref*
Temperature, RH and Wind	*This scenario looks at the impact of using Temperature, maximum and minimum Relative Humidity (RH) and Wind Speed to calculate ETref*
Temperature, RH and N	*This scenario looks at the impact of using Temperature, maximum and minimum Relative Humidity (RH) and Sunshine Duration (N) to calculate ETref*
Temperature, RH and Rs	*This scenario looks at the impact of using Temperature, maximum and minimum Relative Humidity (RH) and Solar Radiation (Rs) to calculate ETref*
Full Data Set	*This scenario looks at the impact of using a complete data set: Temperature, maximum and minimum Relative Humidity (RH), Solar Radiation (Rs) and Wind Speed to calculate ETref*

Enter Climatic Data

Each Climate scenario represents a different set of daily climatic data availability.

Make the following changes in the Data view for the "*Temperature, Wind*" scenario:

1. Select the "*Temperature, Wind*" scenario in the drop-down menu at the top of the screen.



2. Select the Wind tab and enter the following expression (make sure that you are in the "Data View", under the "Climate" variable):

Wind Speed *ReadFromFile(ETrefDailyClimate.csv,8)*

4. Repeat the same steps to enter the required climatic data for the remaining scenarios. For each climatic parameter, select the correspondent tab and enter the following data (make sure that you are in the "Data View", under the "Climate" variable):

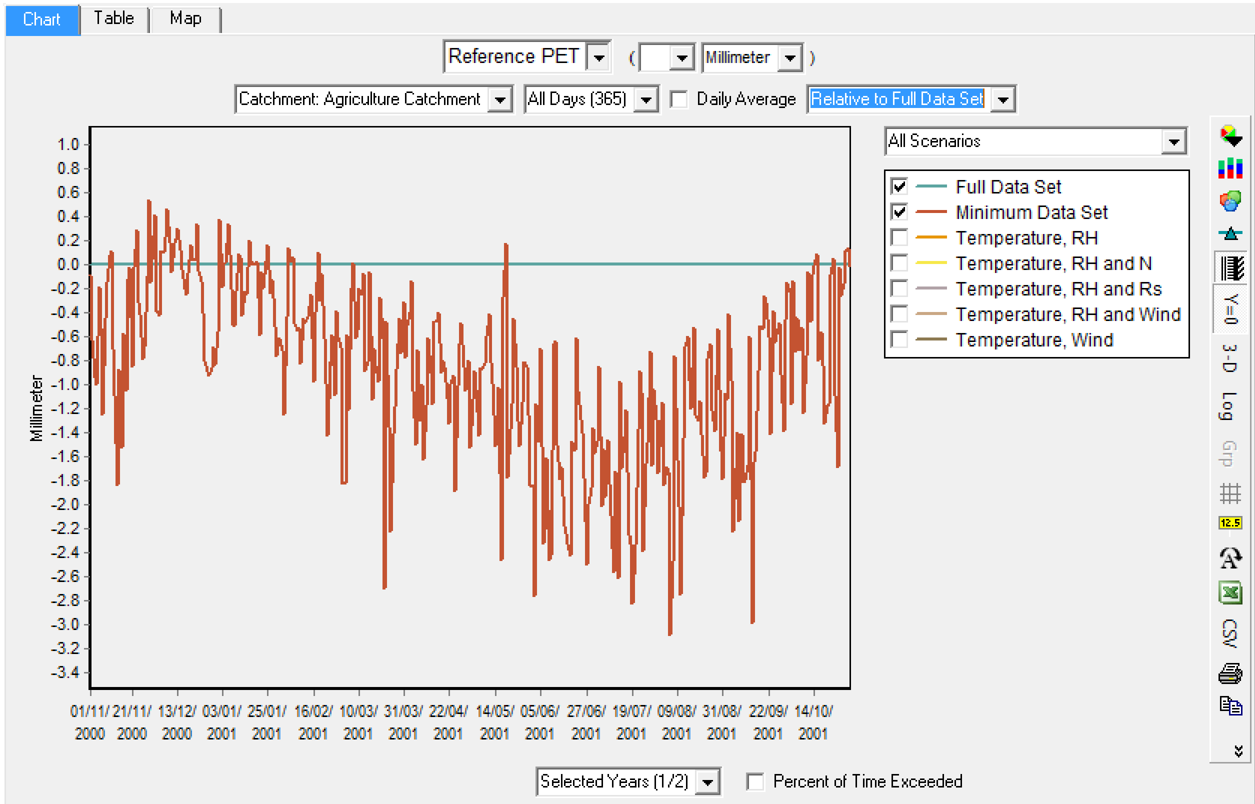
Scenario	*Climatic parameter*	*Expression*
Temperature, RH		
	Min Humidity	*ReadFromFile(ETrefDailyClimate.csv,5)*
	Max Humidity	*ReadFromFile(ETrefDailyClimate.csv,4)*
Temperature, RH and Wind		
	Min Humidity	*ReadFromFile(ETrefDailyClimate.csv,5)*
	Max Humidity	*ReadFromFile(ETrefDailyClimate.csv,4)*
	Wind	*ReadFromFile(ETrefDailyClimate.csv,8)*
Temperature, RH and N		
	Min Humidity	*ReadFromFile(ETrefDailyClimate.csv,5)*
	Max Humidity	*ReadFromFile(ETrefDailyClimate.csv,4)*
	Sunshine Hours	*ReadFromFile(ETrefDailyClimate.csv,7)*

Scenario	*Climatic parameter*	*Expression*
Temperature, RH and Rs		
	Min Humidity	*ReadFromFile(ETrefDailyClimate.csv,5)*
	Max Humidity	*ReadFromFile(ETrefDailyClimate.csv,4)*
	Solar Radiation	*ReadFromFile(ETrefDailyClimate.csv,6)*
Full Data Set		
	Min Humidity	*ReadFromFile(ETrefDailyClimate.csv,5)*
	Max Humidity	*ReadFromFile(ETrefDailyClimate.csv,4)*
	Solar Radiation	*ReadFromFile(ETrefDailyClimate.csv,6)*
	Wind	*ReadFromFile(ETrefDailyClimate.csv,8)*

Compare Results for the Reference and the Climate Scenarios

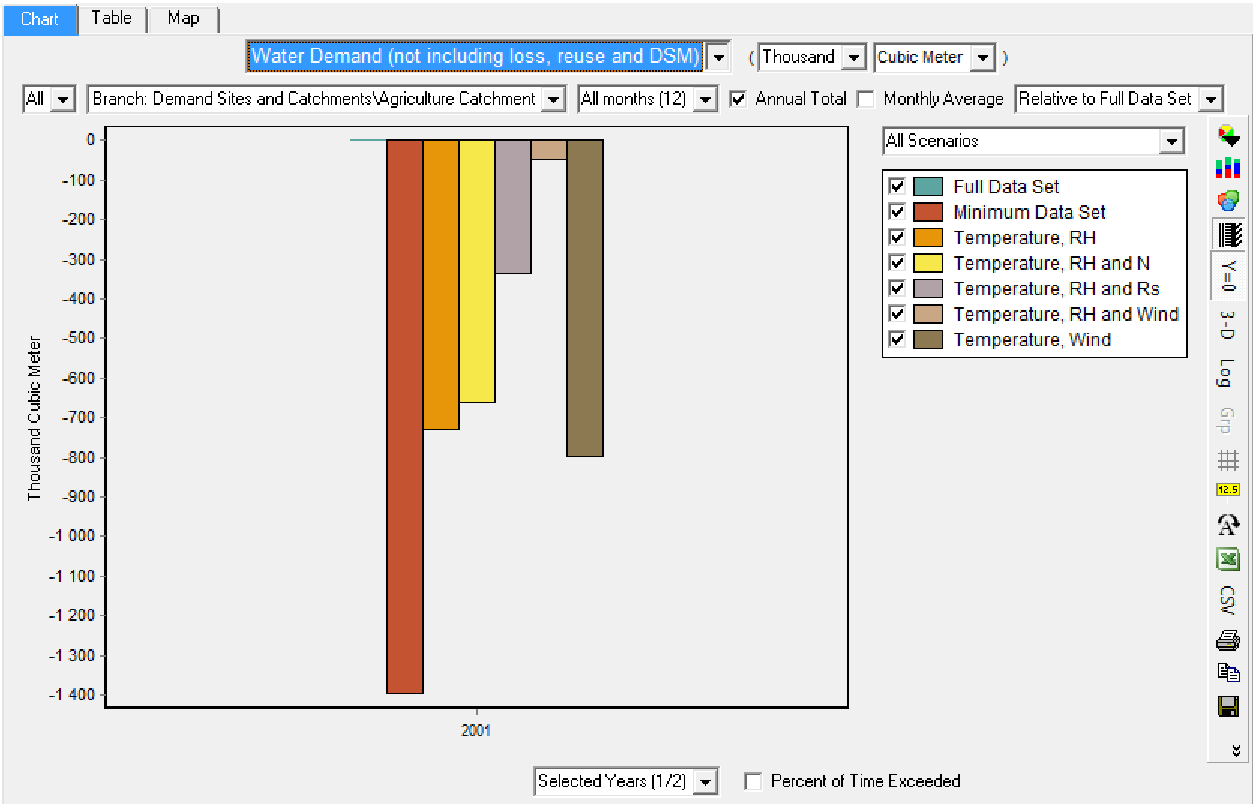
Compare, graphically, the results of the seven scenarios you have established so far with the *Full Data Set* scenario (for which Temperature, Relative Humidity, Solar Radiation and Wind are used to estimate ETref).

For example, select "Catchments/Reference PET" from the primary variable pull-down menu. Click in the drop-down menu to the right of the chart area, and select "All Scenarios". Choose to compare the scenarios to the full data set by selecting the option "*Relative to Full Data Set*" *from the* comparison combo-box *in the upper right corner of the Results window. Your graph should be similar to the one below.*



Note that the reference evapotranspiration (ETref) is underestimated when using only maximum and minimum temperature as available climatic parameters with higher differences especially during summer. The comparison of ETref estimates using limited data to those computed with full data set revealed that there are systematic errors that can impede the estimation of ETref with some discrepancies between the different scenarios. The difference between ETref obtained from full and limited data set could have noticeable effects on the water balance components.

Next, compare the "Water Demand" of the seven scenarios to illustrate the effect of the introduced errors on ETref on the water demand. Use the primary variable pull-down menu to select "Demand/Water Demand".



Again, note the higher water demand underestimation for the “Minimum Data Set” scenario.

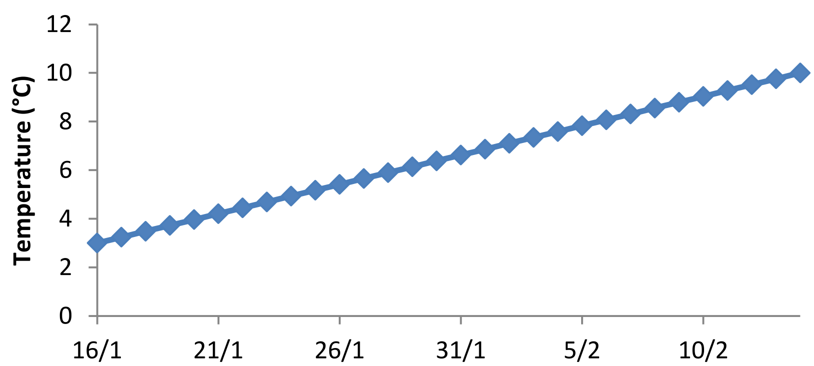
Disaggregating monthly to daily data

In cases where you have monthly data you may still be able to use them for the "MABIA catchment method", which requires daily data. For that you will need to specify a **Disaggregation Method** when using the ReadFromFile function to read data from a text, comma-separated value (CSV) file into any climatic variable.

Description of the Available Disaggregation Methods

Several different disaggregation methods are available: Interpolate, Repeat, Divide, and Divide with Gaps.

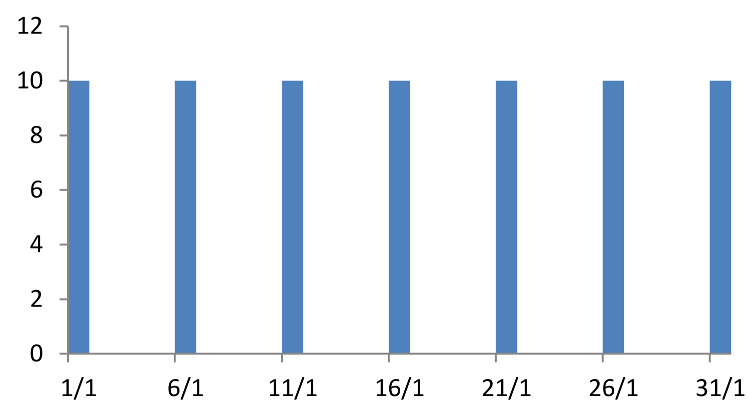
- *Interpolate*: Assume the monthly values are the values for mid-month; interpolate between them to derive daily values. Typical use would be to derive daily temperature or humidity or wind speed values from monthly averages. For example, if the temperature was 3°C and 10°C, in January and February, respectively, the "Interpolate" method would come up with the following daily values: January 16 = 3, January 17 = 3 + (1/29) * (10 - 3) = 3.24 (29 days between Jan 16 and Feb 14, so Jan 17 would be 1/29th of the way from the Jan 16 value to the Feb 14 value), January 18 = 3 + (2/29) * (10 - 3) = 3.48, ..., February 13 = 3 + (28/29) * (10 - 3) = 9.76, February 14 = 3 + (29/29) * (10 - 3) = 10.



- *Repeat*: Repeat the monthly value for each day.

- *Divide*: Divide the monthly value evenly across each day of the month, for example, to divide the monthly precipitation evenly onto every day. For example, if the January rainfall was 62 mm, each day in January would have 2 mm.
- *Divide with Gaps*: Divide the monthly value into a sequence of evenly spaced "events," such as rainstorms. The frequency of events is specified by the **Disaggregation Method Parameter**. For example, if the January rainfall was 70 mm and the Disaggregation Method Parameter was 5 (rainstorms every 5 days), there would be rainfall on these days: Jan 1, Jan 6, Jan 11, Jan 16, Jan 21, Jan 26 and Jan 31.

  The 70 mm of January rainfall would be evenly split across these seven events; therefore, each event would have 10 mm. Note that the last event was January 31, which means that the next event would occur on February 5 (5 days later). The first event will always occur on the first day of the Current Accounts year.



If the climate file to read was MonthlyClimate.csv, the Temperature and the precipitation parameters were in column 2 and 5, respectively, then the ReadFromFile function for the above disaggregation examples would be:

- Interpolate: ReadFromFile(MonthlyClimate.csv, 2, 0, Interpolate)
- Repeat: ReadFromFile(MonthlyClimate.csv, 2, 0, Repeat)
- Divide: ReadFromFile(MonthlyClimate.csv, 5, 0, Divide)
- Divide with Gaps: ReadFromFile(MonthlyClimate.csv, 5, 0, Divide with Gaps, 5)

The 0 used in the expression of ReadFromFile function is to tell WEAP that there is no shifting for years at all (offset = 0)

When one of the offered disaggregation methods is applied on rainfall data, a monthly sum is distributed over many single days. The algorithms described above result in uniform or almost uniform distributions: rain occurs on every day (“Divide”) or every three/five/eight days etc. (“Divide with Gaps”). These artificial temporal patterns do not correspond to temporal patterns observed in nature: because (advective) rainfall events are linked to fronts of low pressure systems, typically rainfall events are clustered, i.e. five or eight days with precipitation follow five or eight days without precipitation. At present there is no WEAP tool to create these clustered temporal patterns. When one of the offered disaggregation tools is applied, the model simulates too much water in the uppermost soil layer available for evaporation. As a consequence, evaporation rates are overestimated. The user should take into account these effects; whenever possible the user should come back to real rainfall data of daily resolution.

Creating and running Disaggregation Scenarios

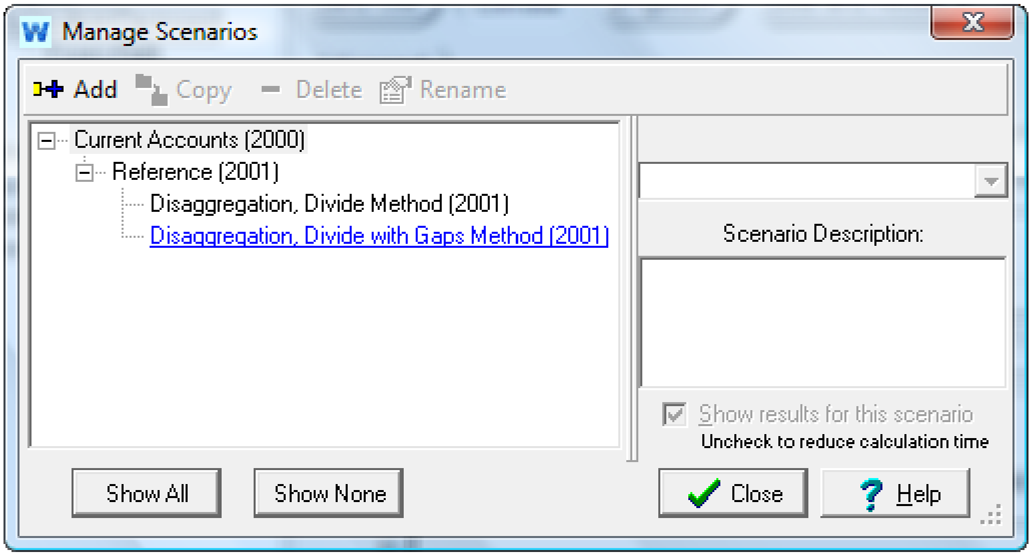
For this module you will need to have completed the first module or have downloaded the file “WEAP-MABIA tutorial.zip” and have it opened into WEAP. To begin this module, go to the Main Menu, select “Revert to Version” and choose the version named “Starting point for all WEAP-MABIA modules”. Only the disaggregation of monthly precipitation is considered in this example. You will need to download the file ‘*MonthlyPrecipitation.csv’.*

Create Two New Scenarios to Model Different Disaggregation Methods

Create a new scenario to evaluate the impact of disaggregating monthly precipitation to daily rainstorms using the divide method on the water balance components.

1. Choose the menu “Area”, “Manage Scenario”, right-click the “Reference” scenario and select “Add”.
2. Name this scenario “Disaggregation, Divide Method”.
3. Add the description “This scenario looks at the impact of using the ‘Divide’ method to disaggregate monthly precipitation”.
4. Repeat the same procedure to add another scenario to evaluate the impact of disaggregating monthly precipitation to daily rainstorms using the ‘divide with Gaps’ method on the water balance components. Name this scenario “Disaggregation, Divide with Gaps Method” and add

the description "This scenario looks at the impact of using the 'Divide with Gaps' method to disaggregate monthly precipitation".



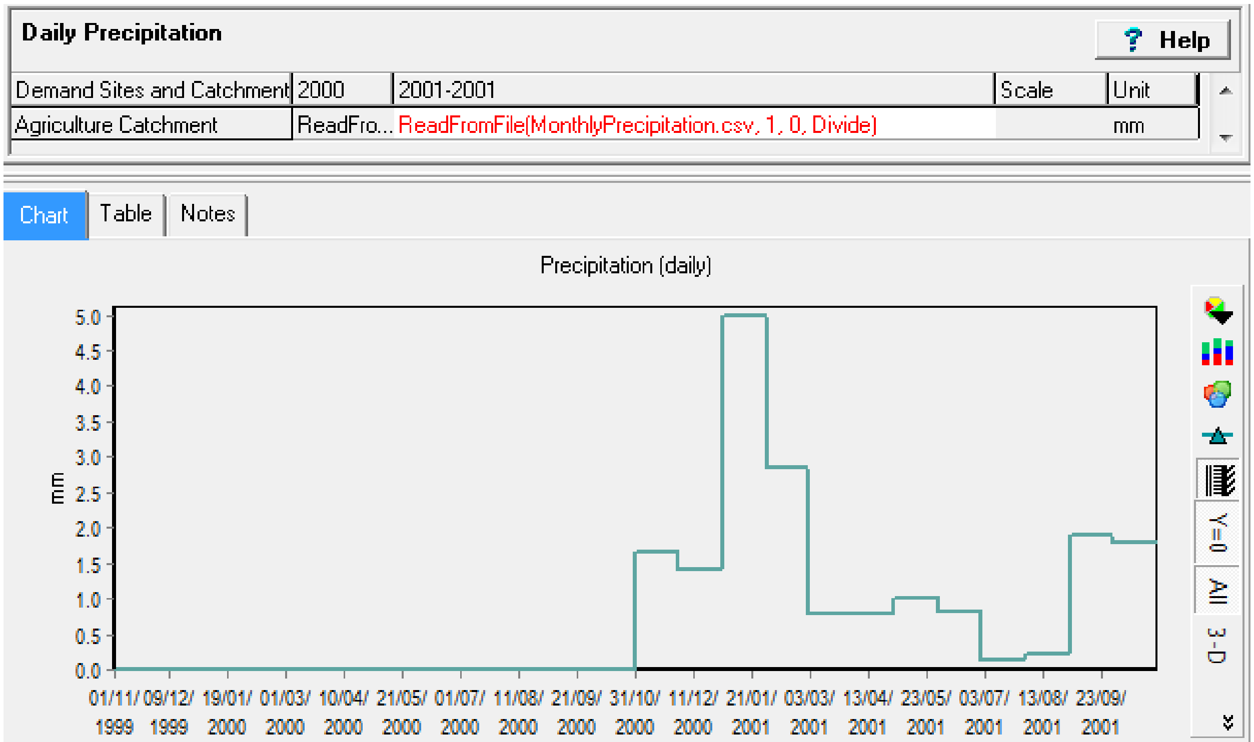
Enter the Data for these Scenarios

Make the following changes in the Data view for the "Disaggregation, Divide Method" scenario:

1. Select the "Disaggregation, Divide Method" scenario in the drop-down menu at the top of the screen.

2. Select the "Precipitation" tab under the "Climate" variable and enter the following expression:

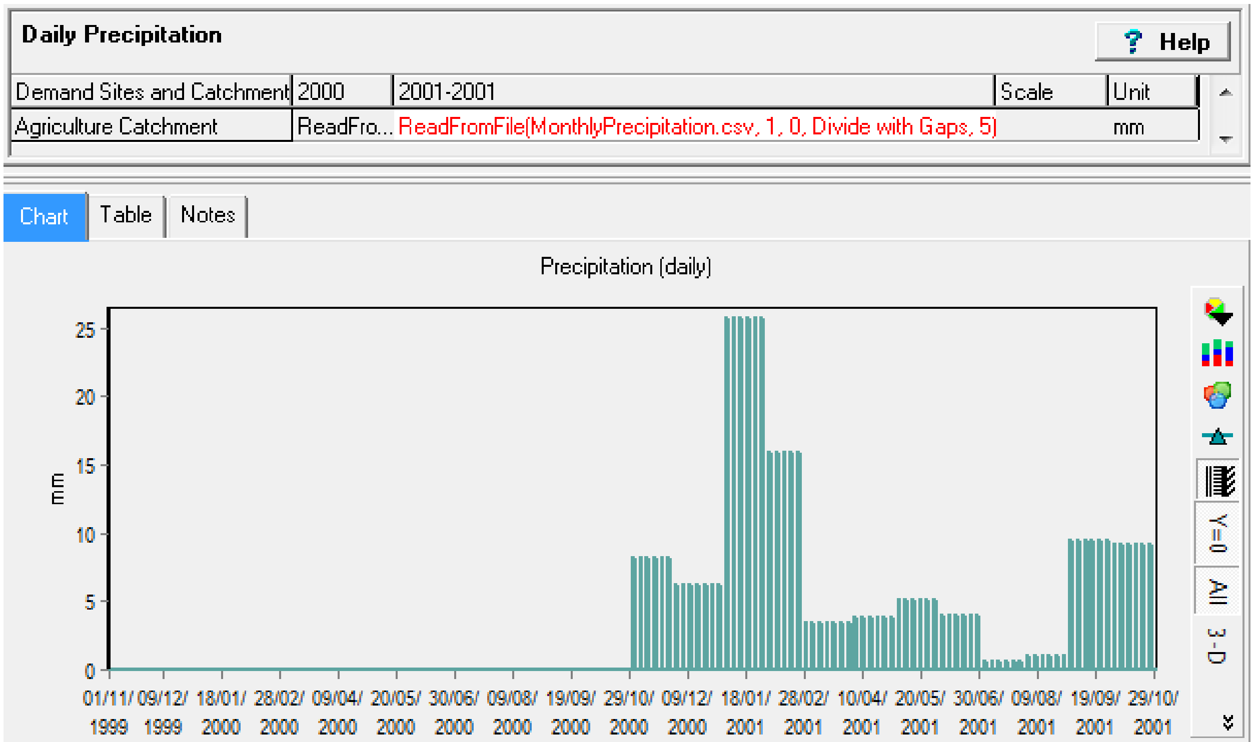
ReadFromFile(MonthlyPrecipitation.csv, 1, 0, Divide)



Make sure the MonthlyPrecipitation.csv file is under the Area folder; otherwise specify the full path of the file in the ReadFromFile function expression. The precipitation values being in the first column of the CSV file.

4. Repeat the same procedure to change the precipitation expression for the "Disaggregation, Divide with Gaps Method" scenario. Use this expression (rainstorm every 5 days):

ReadFromFile(MonthlyPrecipitation.csv, 1, 0, Divide with Gaps, 5)



Compare Results for the Reference and the Disaggregation Scenarios

Compare, graphically, the results of the two scenarios we have established so far (Disaggregation, Divide Method and Disaggregation, Divide with Gaps Method) with the reference (for which the real daily precipitations are used).

For example, select "Demand/Water Demand" from the primary variable pull-down menu. Click in the drop-down menu to the right of the chart area, and select "All Scenarios". Choose to show only "Agriculture Catchment" demand by selecting it from the pull-down list in the upper left pull-down menu of the Results window and select 'Relative to Reference' from the comparison box. Your graph should be similar to the one below.

Note the underestimation of water demands especially during winter for both disaggregation scenarios. As the disaggregation methods ensure uniform distribution of rainfall with a fixed pattern (every day for the "Disaggregation, Divide Method" scenario and every 5 days for the "Disaggregation, Divide with Gaps Method" scenario), therefore there is better use of precipitation by the different crops and hence, water losses are reduced. This could be verified by looking at the "Infiltration/Runoff Flow" results.

Select "Catchments/Infiltration/Runoff Flow" from the primary variable pull-down menu.

Using this chart, the reduction in water losses especially during winter can be seen.

The Soil Profiles Wizard Module

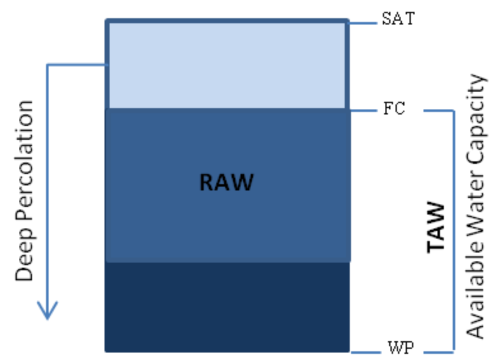
Objectives: Present the steps required to use the Soil Profiles Wizard.

Data files: - WEAP-MABIA, Tutorial.zip

- SoilData.csv

Soil Water Capacity Description

In the WEAP-MABIA model, the most relevant soil hydrological property determining the soil water balance is the available water capacity. It is assumed that the soil profile as a whole is vertically homogeneous and characterized by identical water retention properties. The available water capacity or the total available water (TAW) can then be calculated by water content at field capacity point (FC) minus water content at wilting point (WP).



Soil water contents at field capacity and wilting point are used to calculate the maximum water depth that can be applied by irrigation. If the area under investigation is relatively small or known to be quite homogeneous with respect to soil physical properties and topography, determinations of soil moisture contents at field capacity and wilting point at a reasonable number of sampling sites should provide accurate estimates. However, if the area being evaluated is large enough to exhibit substantial spatial variability of soil water availability, it is virtually impossible to perform enough measurements to provide good estimates within the temporal and financial constraints of the project. In such cases, inexpensive and rapid ways to estimate the parameters are needed.

Many indirect methods for estimation of water content at field capacity and wilting point have been proposed in the literature. Most of these methods are called Pedotransfer Functions (PTFs), because they translate existing surrogate data (e.g. particle size distribution, bulk density and organic matter content) into soil hydrological properties.

Pedotransfer Functions (PTFs)

Values of SAT, FC and WP are basic measurements determined experimentally in laboratory conditions. Direct measurement of water retention properties is expensive, time consuming, and labor intensive. Alternatively these properties can be derived from available soil data such as particle-size distribution, organic matter content, and bulk density. Estimation methods to obtain the required parameters from easy mappable input data are called Pedotransfer Functions according to Bouma & van Lanen (1987). They suggested a distinction between basic characteristics that can be measured in the laboratory or estimated in the field and other characteristics (called soil properties) that can be estimated from basic soil characteristics. Pedotransfer Functions relate different soil characteristics and properties with one another or to land qualities (Bouma 1989). They serve to translate, through empirical, regression or functional relationships, the basic information found in the soil survey into a form useful in broader applications, such as simulation modeling.

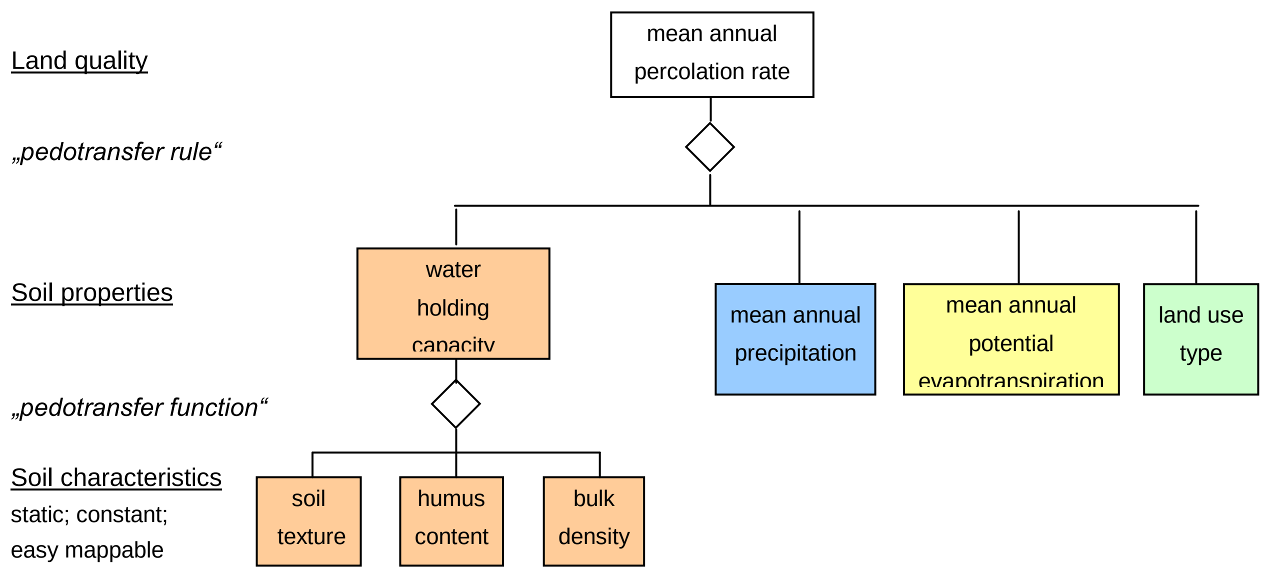


Figure: Flow chart illustrating the operating mode of Pedotransfer Functions

Another definition was given by Jones & Hollis (1996): Pedotransfer Functions (PTFs) are mathematical expressions relating basic soil properties, such as sand, silt and clay, to complex properties like water holding capacity. PTFs may be used to derive continuous functions, such as the parameters expressing the shape and form of the hydraulic conductivity / suction / water content relationships.

Pedotransfer Functions are categorized into "class" and "continuous" PTFs. Class PTFs predict certain soil properties based on the soil classes to which the soil sample belongs e.g. PTFs of Carsel and Parrish (1988) and Rawls et al. (1982). Continuous PTFs predict certain soil properties as a continuous function of one or more measured variables. This latter type of Pedotransfer Function can also be classified as single point and parametric regressions. Single point PTFs predict a soil property at a special point of the water retention curve or available water capacity e.g. the PTFs of Jabloun and Sahli (2006). The parametric PTFs aim to predict the parameters of a model, and the most widely used soil hydraulic model is the van Genuchten function (Van Genuchten, 1980) e.g. PTFs of Vereecken et al. (1989) and Wösten et al. (1999). Many competing algorithms were compared and evaluated on the basis of the laboratory database of a nationwide soil information system; the approaches from Vereecken and Wösten performed best because they yielded the least deviation between estimated and measured values. Therefore they act as WEAP's standard tools to estimate water retention parameters.

Vereechen: Vereecken et al. (1989) used multiple linear regression with sand and clay contents, organic carbon content, and bulk-density data from undisturbed samples of 182 horizons of 40 Belgian soil series to solve for the parameters of the van Genuchten equation to develop their PTF. The derived PTF is applicable to soils with the following ranges of Clay, Cl < 54.5 %, Silt, SI < 80.7 %, Sand, 5.6 < Sa < 97.8 %, Bulk Density, 1.04 < BD < 1.23 g cm^{-3} and Organic Matter Content, OM < 11.4 %.

Wösten: Wösten et al., (1999) used multiple linear regression with the soil particle size distribution, organic carbon content and bulk density from the HYPRES database to estimate the parameters of the van Genuchten (1980) water retention function. The HYPRES database consists of soil physical and hydraulic properties of 5521 soil horizons collected from 20 institutions from 12 European countries.

Jabloun and Sahli: Jabloun and Sahli (2006) used basic soil data from 109 soil horizons collected from different Tunisian soils to develop 4 point PTFs for different data availability. The derived PTFs are applicable to soils with the following ranges of Clay, 6.0 < Cl < 84.5 %, Silt, 4.3 < SI < 61.0 %, Sand, 0.7 < Sa < 87.5 %, Bulk Density, 1.2 < BD < 1.8 g cm^{-3} and Organic Matter Content, 0.2 < OM < 3.2 %.

The methodology used is outlined hereafter:

Step 1

Multiple linear regression techniques were used to relate the volumetric water content at SAT, CC and WP to particle soil distribution, bulk density and organic matter content. Linear, reciprocal, and logarithm of these basic soil properties were used in the regression analysis, and possible interactions were also investigated. The equation had the following form:

$$\theta_i = a_{i,1} + a_{i,2}Sa + a_{i,3}Si + a_{i,4}Cl + a_{i,5}OM + a_{i,6}BD + a_{i,7}\, {}^{1}\!/_{Sa} + ... + a_{i,8}\, {}^{1}\!/_{BD}$$
$$+ a_{i,9}SaSi + ... + a_{i,j}SiCl + a_{i,j+1}Sa^2 + ...a_{i,j+2}Cl^2 + a_{i,j+3}Ln(Sa) + ...a_{i,j+4}Ln(Cl)$$

where X_i is the value of the water content (i = 1 to 3 corresponding to SAT, CC and PWP, respectively); Sa, Si and Cl are, respectively, the percentages of sand (2-0.05 mm), silt (0.05-0.002 mm) and clay (< 0.002 mm); BD is the bulk density (g cm^{-3}); OM is the percentage of organic matter and $a_{i,j}$ (j = 1...n) are coefficients derived by multiple linear regression.

Step 2

For the sake of parsimony, the number of parameters of the latter equation was reduced using stepwise techniques leaving in the final equation only variables that explained a significant proportion of the parameter variability. However, most of the time users of PTFs are frequently confronted with situations where one or several input variables needed for a PTF are not available. Therefore, four equations were derived to estimate SAT, FC and WP, based on the available data: model JS_{PBO} included all basic information (sand, silt, clay, bulk density, and organic matter content); model JS_{PO} excluded bulk density; model JS_{PB} excluded organic matter content; and model JS_P, excluded both bulk density and organic matter content.

References:

- Jabloun, M. and Sahli, A., Development and comparative analysis of pedotransfer functions for predicting characteristic soil water content for Tunisian soil, Tunisia-Japan Symposium on Society,

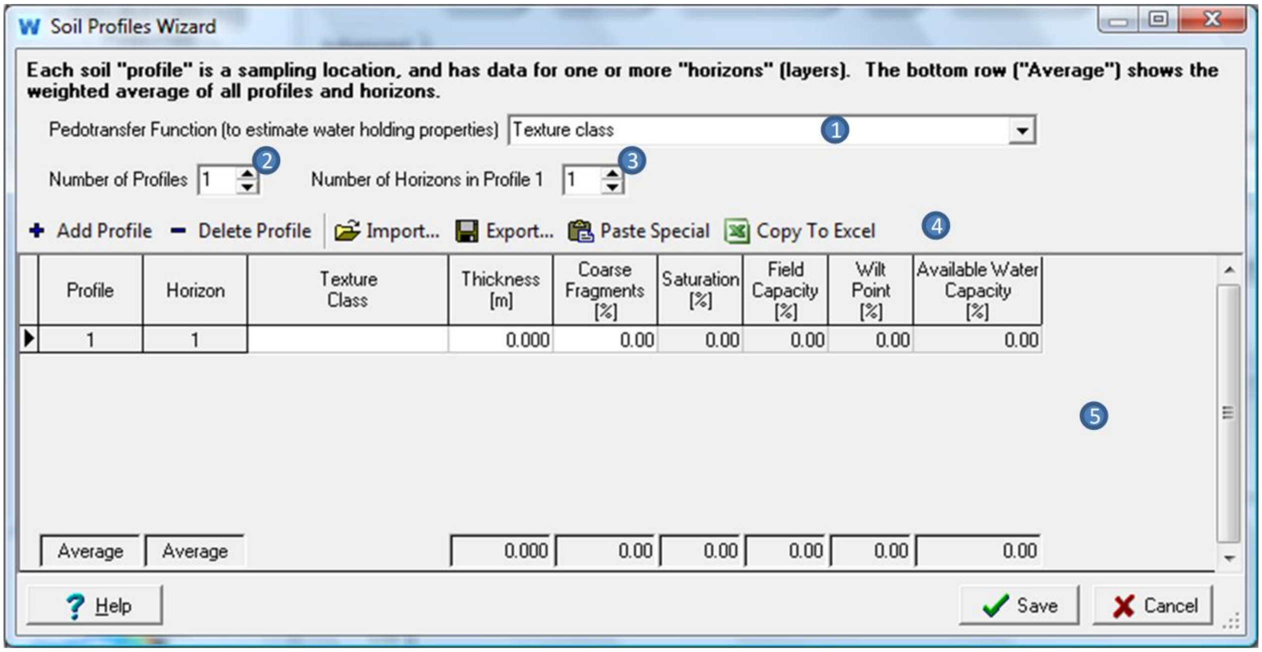
Science and Technology proceeding, 7th Edition, 2006, pp. 170-178.
- Vereecken, H., Maes, J., Feyen, J., Darius, P., Estimating the soil moisture retention characteristic from texture, bulk density and carbon content, Soil Science, 148 (1989), pp. 389–403.
- Wösten, J.H.M., Lilly, A., Nemes, A., Le Bas, C., 1999, Development and use of a database of hydraulic properties of European soils, Geoderma, 90, July 1999, pp. 169-185.

It should be noticed that PTFs are developed on the basis of databases of a limited number of soil samples. Consequently any PTF is likely to give less accurate or possibly even very poor predictions if used outside the range of soils from which they were derived. Thus, the predictive ability of PTFs is somewhat related to the similarity between the data set used in developing and testing the PTF.

Soil Profiles Wizard input options

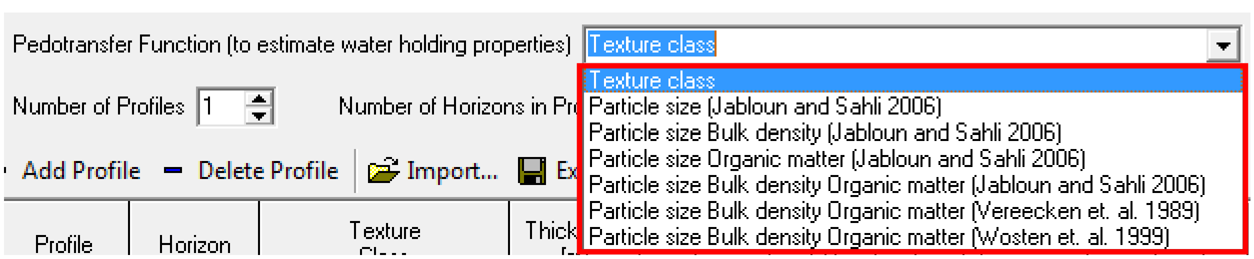
WEAP-MABIA comes with a built-in "**Soil Profiles Wizard**" which allows the estimation of the average soil water capacity (saturation, field capacity and wilting point) using one of the seven available Pedotransfer Functions (PTF), in order to determine the Soil Water Capacity for catchment land use branches in the "Data View", under "Land Use". Using this wizard, you can average water content values over several soil profiles (sampling sites) and soil horizons (layers). The seven available PTFs are chosen so they can be used with different scenarios of basic soil data availability.

This wizard is designed to average available water capacities from several soil and rock layers. Please notice that the "Soil Profiles Wizard" does not allow to allocate awc values from individual soil horizons to rooting depths of a specific crop of a specific growth stage; this functionality has not been realized yet. For example, when the upper meter of the soil profile consists of 50 cm silt loam above 50 cm consolidated rock, a moderate available water capacity (≈ 11 % volume) is calculated (average of 21 and 0 % volume) and this average is used for all growth stages of the crop under consideration. When a rooting depth of 50 cm is assumed, the program does not work with water retention properties of the silt loam layer, but all calculations are based on an averaged soil water capacity of the entire soil profile.



- 1 Combo box from which to choose one of the seven available Pedotransfer Functions to use in estimating soil water capacity. The decision which approach is the most appropriate one depends on data availability of local soils.

  Of the seven available Pedotransfer Functions, one is based on texture class and the other six use particle size (PSD: %Sand, %Silt and %Clay), optionally with data on bulk density (BD) or organic matter content (OM). The PTF names (which include references to the original author and date) that can be used, along with the parameters required by these functions, are:



1. "Texture class": Texture class, from the Soil Library
2. "Particle size (Jabloun and Sahli, 2006)": PSD.
3. "Particle size Bulk density (Jabloun and Sahli, 2006)": PSD and BD.
4. "Particle size Organic matter (Jabloun and Sahli, 2006)": PSD and %OM.

5. "Particle size Bulk density Organic matter (Jabloun and Sahli, 2006)": PSD, %BD and %OM.
6. "Particle size Bulk density Organic matter (Vereecken et al., 1989)": PSD, %BD and %OM.
7. "Particle size Bulk density Organic matter (Wösten et al., 1999)": PSD, %BD and %OM.

- (2) Text field to specify how many profiles (sampling sites) you have.
- (3) Text field to specify for each profile, how many horizons (layers) you have data for.
- (4) Toolbar to Add/Delete profiles and to Import/Export and to copy and retrieve soil data from Excel.
- (5) Data table used to enter soil data. The required data variables are defined each time you choose a different Pedotransfer Function.

In general, PTFs that are based on detailed knowledge of soil physical properties perform better than PTFs that use soil texture as the only input variable. Available water capacities per FAO texture class, taken from the internal Soil Library, should be regarded as rough estimates.

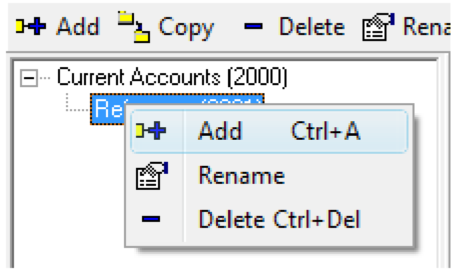
> It should be stated out that it can be very difficult to select what is the more appropriate method to use for a specific application in a specific environment and under a specific scenario of available data, considering that the different PTFs can produce very different results. Therefore, assuming that some laboratory or field measurements of the desired hydrological parameters are available for local soils, hence the PTFs estimates can be evaluated against such data, allowing the selection of the best performing method that can be used afterwards for similar sites.

Creating and running Soil Scenarios

For this module you will need to have completed the first module or have downloaded the file "WEAP-MABIA tutorial.zip" and have it opened into WEAP. To begin this module, go to the Main Menu, select "Revert to Version" and choose the version named "Starting point for all WEAP-MABIA modules".

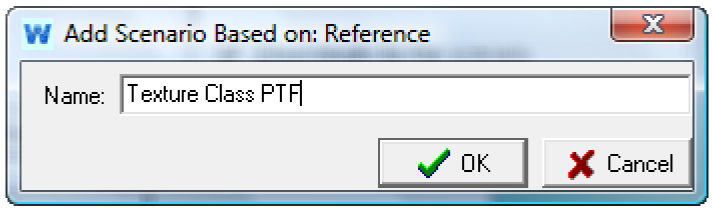
Create Seven New Scenarios to Model The Use Of Different PTFs

Create a new scenario to evaluate the impact of using the "Texture class" model to estimate the Soil Water Capacity on the water balance components.

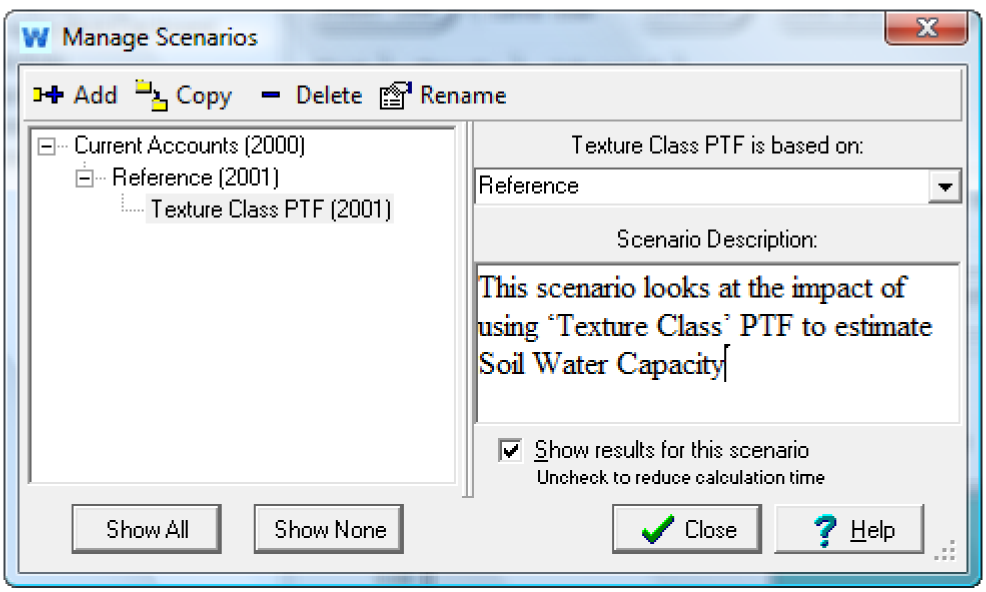


1. Choose the menu "Area", "Manage Scenario", right-click the "Reference" scenario and select "Add".

2. Name this scenario "Texture Class PTF".



3. Add the description "This scenario looks at the impact of using 'Texture Class' PTF to estimate Soil Water Capacity".



4. Repeat the same procedure to add six additional scenarios to evaluate the impact of using different scenarios of soil data availability (that means different PTFs) on the water balance components. Use the following data:

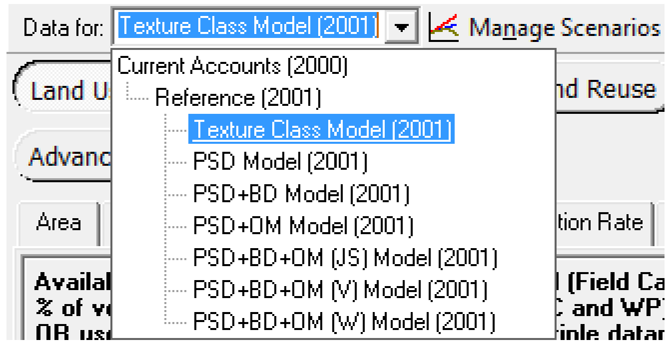
Scenario Name	*Scenario Description*
PSD Model	*This scenario looks at the impact of using 'Particle size (Jabloun and Sahli, 2006)' PTF to estimate Soil Water Capacity*
PSD+BD Model	*This scenario looks at the impact of using 'Particle size Bulk density (Jabloun and Sahli, 2006)' PTF to estimate Soil Water Capacity*
PSD+OM Model	*This scenario looks at the impact of using 'Particle size Organic matter (Jabloun and Sahli, 2006)' PTF to estimate Soil Water Capacity*
PSD+BD+OM (JS) Model	*This scenario looks at the impact of using 'Particle size Bulk density Organic matter (Jabloun and Sahli, 2006)' PTF to estimate Soil Water Capacity*
PSD+BD+OM (V) Model	*This scenario looks at the impact of using 'Particle size Bulk density Organic matter (Vereecken et al., 1989)' PTF to estimate Soil Water Capacity*
PSD+BD+OM (W) Model	*This scenario looks at the impact of using 'Particle size Bulk density Organic matter (Wösten et al., 1999)' PTF to estimate Soil Water Capacity*

Enter the Data for these Scenarios

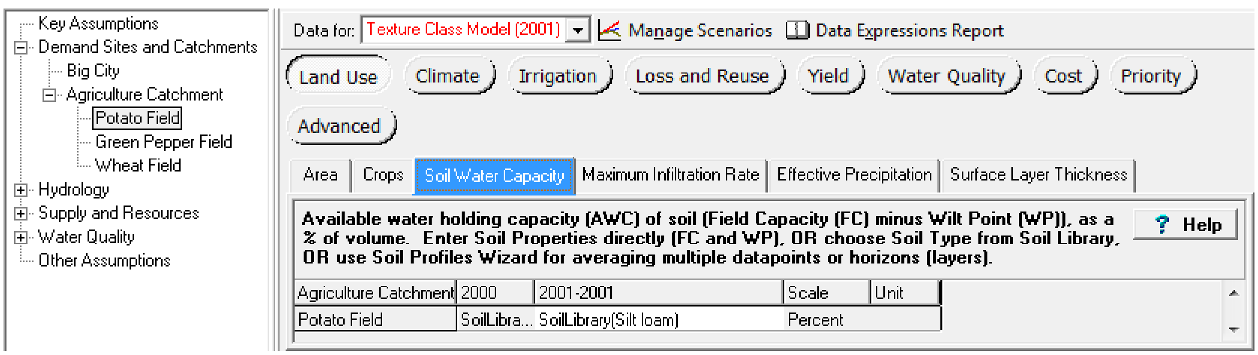
For these scenarios, only the soil data of the "Potato Field" branch will be considered. Data on particle size distribution, bulk density and organic matter are given for only 1 profile at 3 soil horizons.

Make the following changes in the Data view for the "Texture Class Model" scenario:

1. Select the "Texture Class Model" scenario in the drop-down menu at the top of the screen.

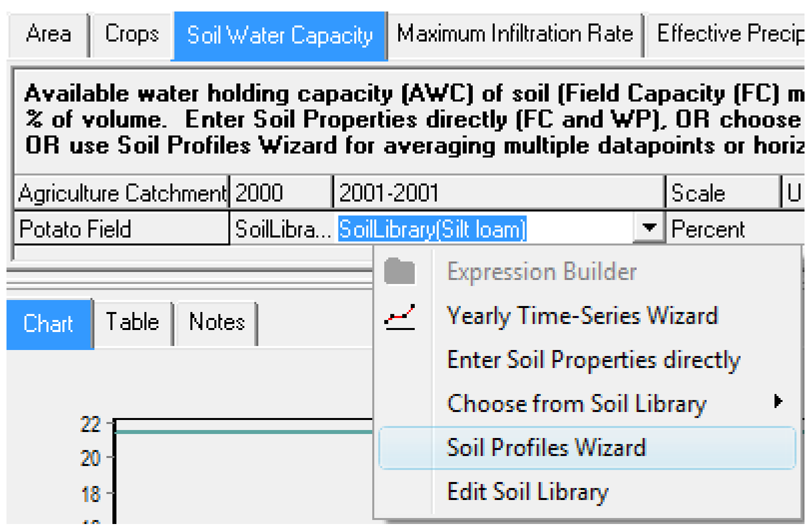


2. Select the "Potato Field" branch under the "Agriculture Catchment" then select the "Soil Water Capacity" tab under the "Land Use" variable.



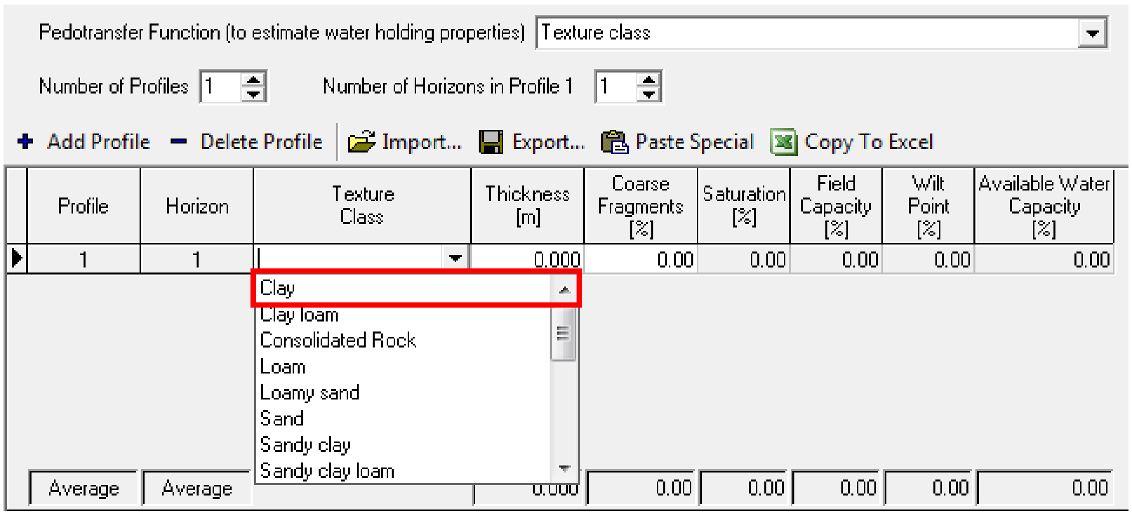
3. Change the Soil Water Capacity for the Potato Field:

- Click the empty cell in front of "Potato Field" and select the "Soil Profiles Wizard" from the drop down menu.



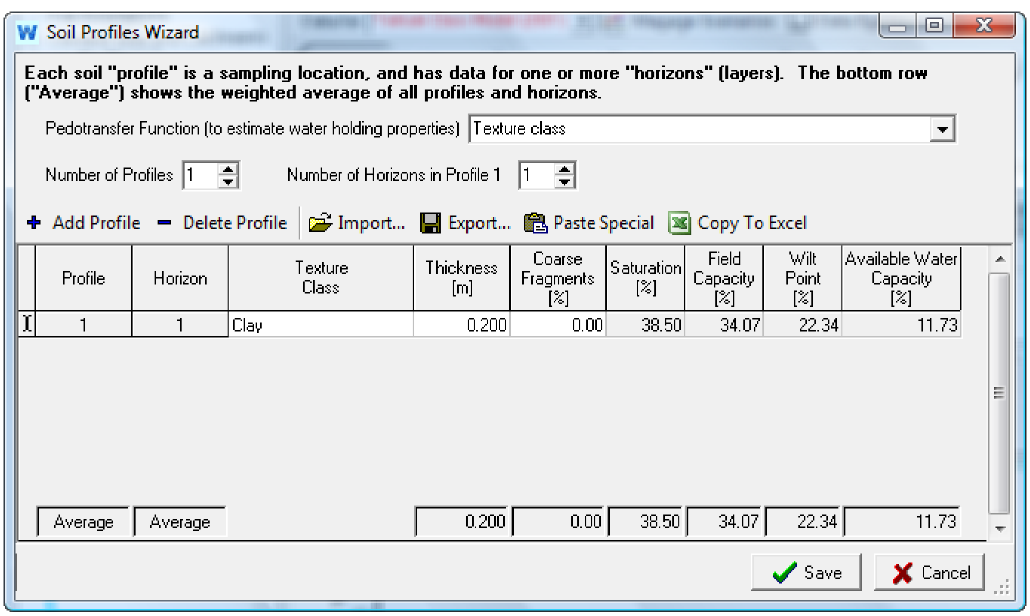
By default, the "Texture class" model is selected. For this experimental site the three soil horizons were homogenous and the soil was Clay. Therefore, you can keep the number of profiles and the number of horizons per profile to their default values (1).

- In the Data View, click the empty cell under "Texture Class" and select from the drop down menu the soil texture. For this example, select Clay.



4. Set the "Soil Thickness" to 0.2 m.

After completing all the tasks described above, the "Soil Profiles Wizard" will look like this:



5. Click 

.

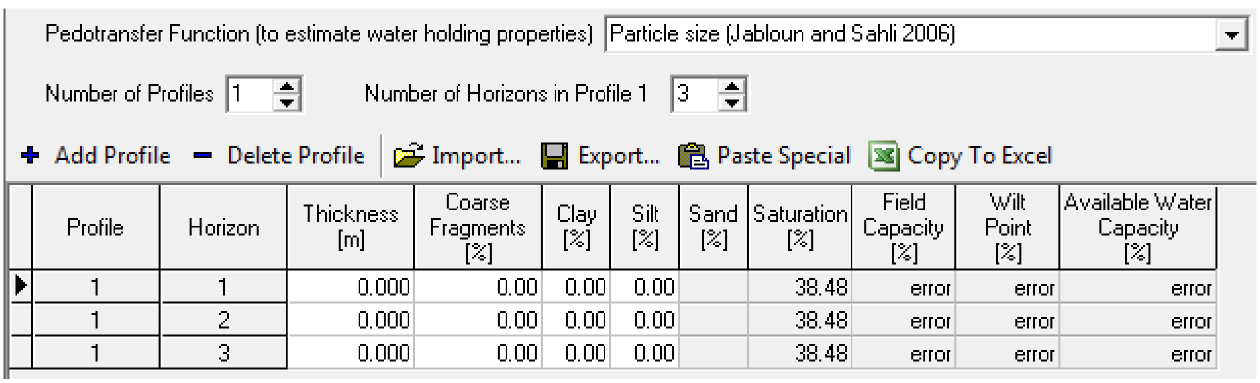
> - The soil thickness is used by WEAP to calculate the weighted average of the water content values over the specified soil profiles (sampling sites) and soil horizons (layers).
> - The presence of coarse fragments (e.g., rocks) will reduce the water holding capacity of the soil. Keep its value to 0% for all soil scenarios.

Make the following changes in the Data view for the "*PSD Model*" scenario:

1. Select the "*PSD Model*" scenario in the drop-down menu at the top of the screen.

2. Change the Soil Water Capacity for the Potato Field:

- Click the empty cell in front of "Potato Field" and select the "Soil Profiles Wizard" from the drop down menu.
- Select the model "*Particle size (Jabloun and Sahli, 2006)*" from the PTF drop down menu. The data table is changed automatically by WEAP and shows the data required for the chosen PTF.
- Set the number of horizons per profile to 3. Three rows are in the data table.

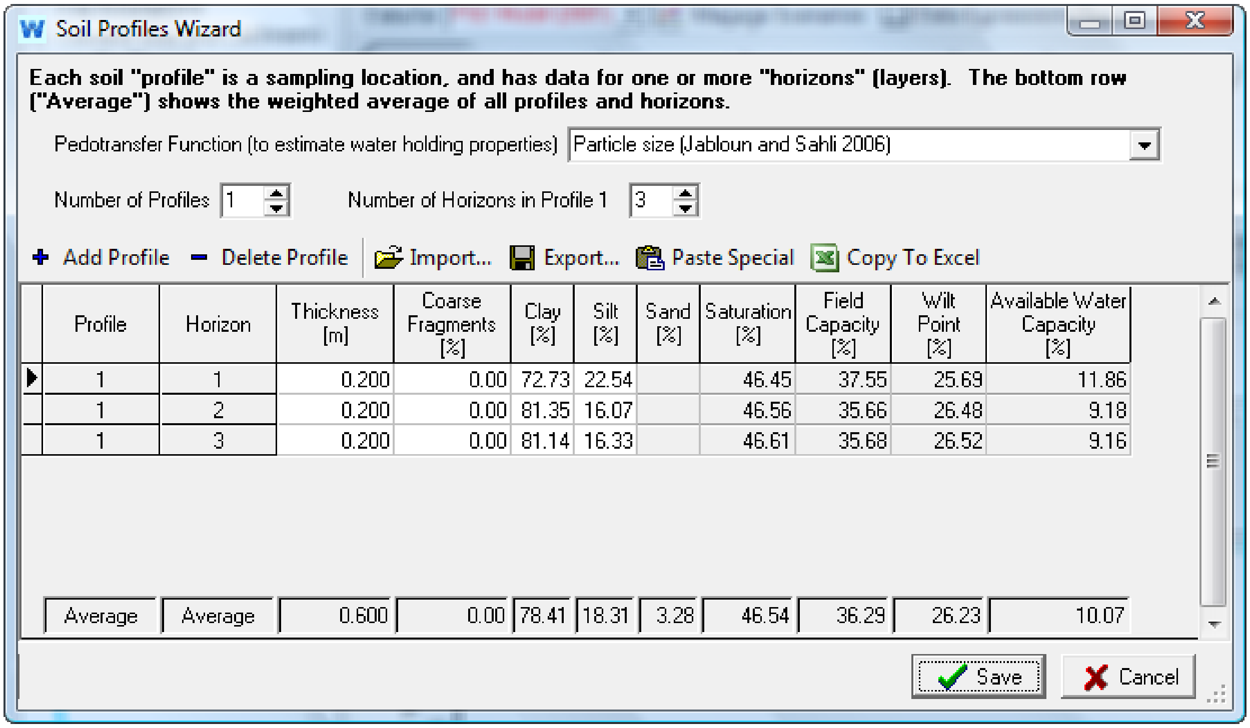


> The sand fraction is calculated as 100 - %Clay - %Silt, so does not need to be entered.

- Enter data for the 3 horizons as follows:

Profile	*Horizon*	*Thickness*	*Coarse fragments*	*Clay*	*Silt*
1	*1*	*0.2*	*0*	*72.73*	*22.54*
1	*2*	*0.2*	*0*	*81.35*	*16.07*
1	*3*	*0.2*	*0*	*81.14*	*16.33*

Each time you enter the data for one horizon, WEAP will calculate for you the water content at SAT, FC and WP and well as the value of the Water Available Capacity.



- After you enter all data, click **Save**.

Note that the weighted average values are calculated using the 3 horizons. These average values are what will be used for calculating soil moisture by the MABIA Method.

If you have the soil profile data in a CSV file or Excel spreadsheet, you can read those in the "Soil Profiles Wizard" without having to retype the data:

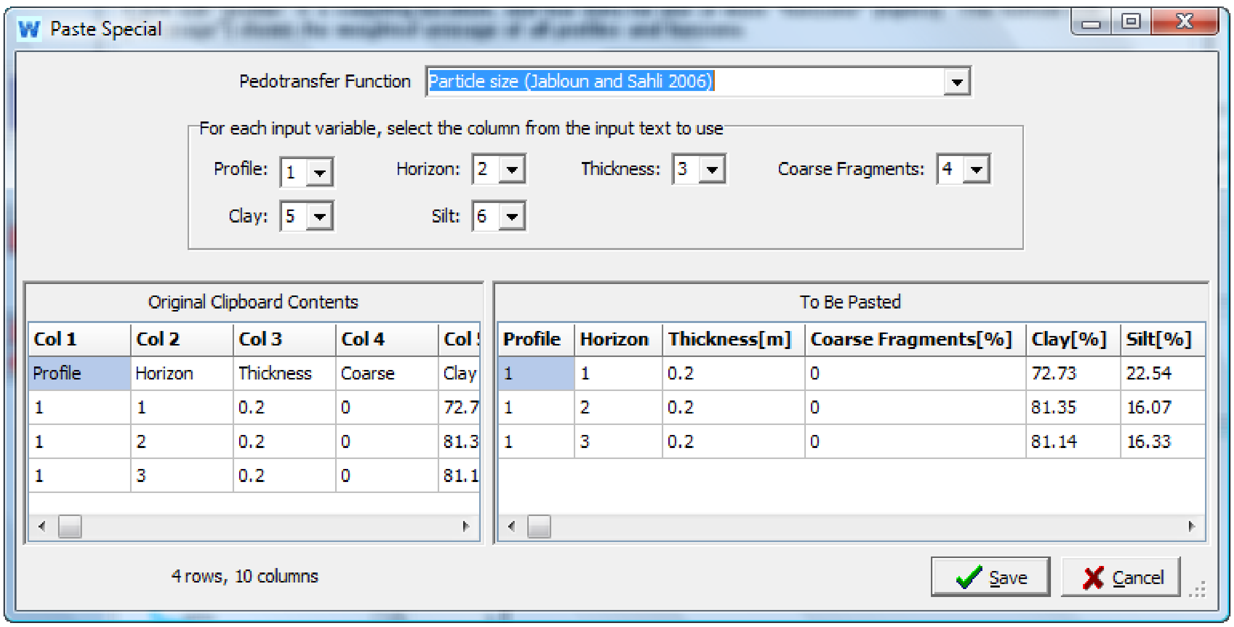
- For a CSV file, click the **Import...** button and browse to find the CSV file.
- To bring in the data from the Excel spreadsheet, copy the data from Excel onto the Windows clipboard and click the **Paste Special** button.

In both of these cases, WEAP will read in the rows and columns of data (from CSV file or Windows clipboard), and display it in a new window, along with its best guess as to which variable each column header represents. The data should be arranged so that each horizon of each layer is on its own row, and each column represents a different variable.

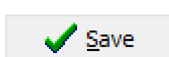
To test this functionality, you need to have the "SoilData.csv" file. You can download this file from http://www.bgr.bund.de/IWRM-DSS .

1. In the "Soil Profiles Wizard" click 

 and browse to find the "SoilData.csv" file. Click "Open".
2. A "Special Copy" window appears. Select the model "*Particle size (Jabloun and Sahli, 2006)*" from the PTF drop down menu.



Note that WEAP will read the column headers of the CSV file and perform for you the best guess as to which variable each column header represents. Besides, you can define for each input variable the column number from the input text to use.

3. Click 

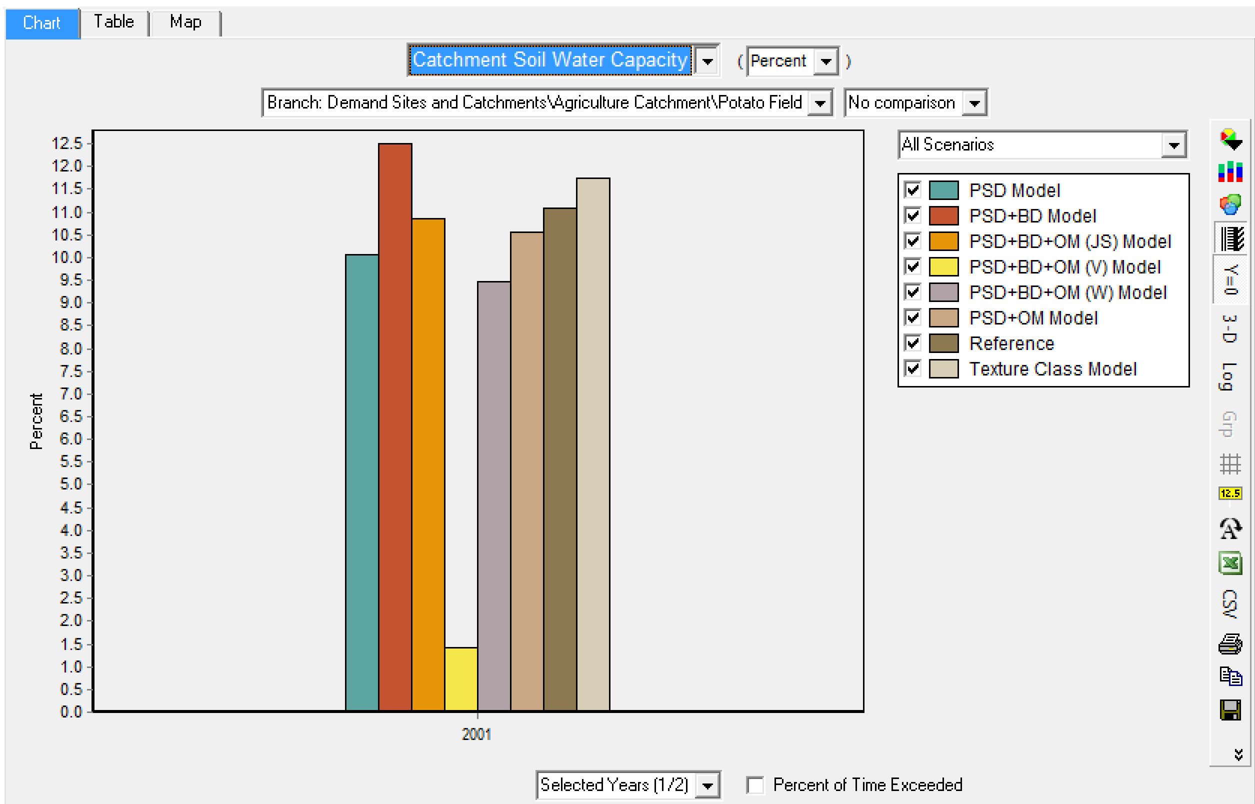
 to import soil data into the "Soil Profiles Wizard". The number of profiles as well as the number of horizons per profile are also imported from the CSV file.

Use the Import from CSV file to define the Soil Water Capacity for the remaining soil scenarios.

Compare Results for the Reference and the Soil Scenarios

Compare, graphically, the results of the seven scenarios you have established so far with the reference scenario (for which the experimental values of SAT, FC and WP are used).

For example, select "Input Data/Demand Sites and Catchments/Land Use/Soil Water Capacity" from the primary variable pull-down menu. Click in the drop-down menu to the right of the chart area, and select "All Scenarios". Choose to show only "Agriculture Catchment\Potato Field" Soil Water Capacity by selecting it from the pull-down list in the upper left pull-down menu of the Results window. Your graph should be similar to the one below.

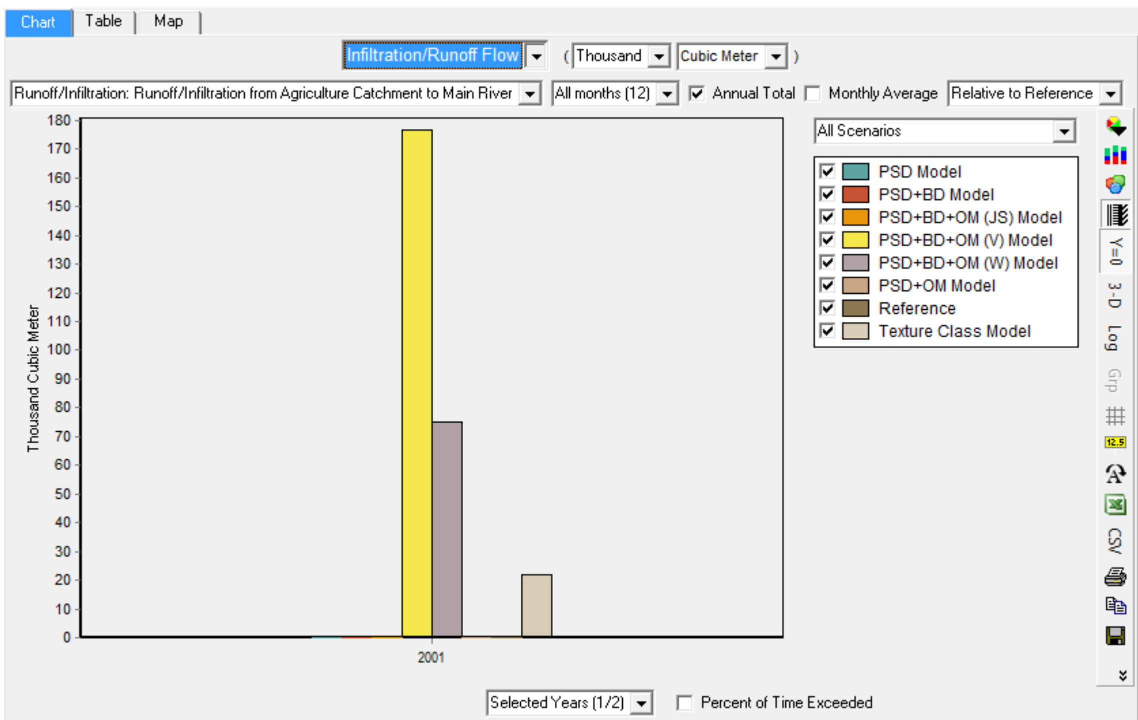


Note that the estimation of the Soil Water Capacity depends on the Pedotransfer Function used. The *'Particle size Bulk density Organic matter (Jabloun and Sahli, 2006)'* PTF gives the best estimation 10.9% against 11.1% for the experimental value. However, the *'Particle size Bulk density Organic matter (Vereecken et al., 1989)'* PTF gives the lowest Soil Water Capacity compared to the experimental values (Reference scenario). This underestimation of the Soil

Water Capacity could be due to the fact that the characteristics of the particle size distribution of the soil sample used in this example were outside the range of validity of the '*Vereecken'* model (see page 79).

Next, compare "water losses" of the seven scenarios with the reference. Use the primary variable pull-down menu to select "Catchments/Infiltration/Runoff flow". In the comparison combo-box select "Relative to Reference".

Please notice that surface runoff in WEAP is not determined by applying a process-based rainfall-runoff model. For three influencing effects see page 33.



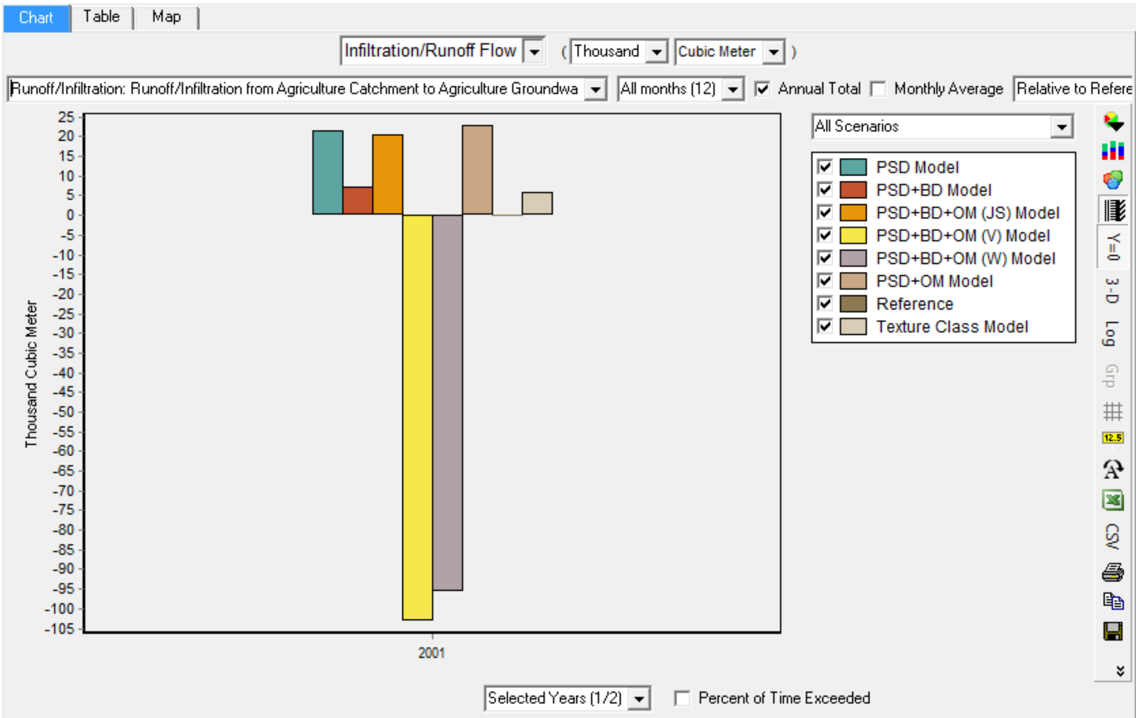


Chart
Table
Map
Infiltration/Runoff Flow
Thousand
Cubic Meter
Runoff/Infiltration: Runoff/Infiltration from Agriculture Catchment to Agriculture Groundwa
All months (12)
Annual Total
Monthly Average
Relative to Refere
All Scenarios
PSD Model
PSD+BD Model
PSD+BD+OM (JS) Model
PSD+BD+OM (V) Model
PSD+BD+OM (W) Model
PSD+OM Model
Reference
Texture Class Model
Thousand Cubic Meter
2001
Selected Years (1/2)
Percent of Time Exceeded